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Individual Risk and Innovative Behavior –
A Neo-Schumpeterian Agent-Based Analysis

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Abbreviations

ABM	Agent-Based Modeling
ACE	Agent-based Computational Economics
cf.	Confer
CNSE	Comprehensive Neo-Schumpeterian Economics
df	Degrees of freedom
ed.	Editor
eds.	Editors
e.g.	Exemplum gratia, for example
GEM	Global Entrepreneurship Monitor
IHCP	Individual Health Coverage Plan
innos	innovations
KIDS	Keep it descriptive, stupid!
KISS	Keep it simple, stupid!
OECD	Organization for Economic and Commercial Development
p.	Page
pp.	Pages
PSID	Panel Study of Income Dynamics
UK	United Kingdom of Great Britain and Northern Ireland
UNESCO	United Nations Educational, Scientific and Cultural Organization
US	United States of America
vs.	Versus

1 Introduction

"[T]he main inducement for the development of innovation studies, particularly in Europe, appears to have been the recognition of its wider social and economic impact and the perceived need for increased knowledge about what role policy may play."[1] This is exactly the focus of this work. On the one hand, we will concentrate on the wider social and economic impact of innovation and will consider the implications on the dynamics of a society. On the other hand, we aim at finding hints on a proper role and strategy for the public sector and its policies to successfully support a prosperous development of its society, specifically with respect to social insurance.

We cannot simply derive a justification for governmental action from the fact that markets are imperfect.[2] This may be true and reasonable in the neoclassical school, but in evolutionary economics the most important factor of an economy is its ability to positively shape the future. In that sense, a market imperfection is very different from a situation of market failure.

In cases where market failure is the cause for a loss of wealth, governmental action is beneficial by limiting the negative consequences. On the other hand, if we speak of market imperfections, which could for example result from the situation which we will present below, the government does not necessarily have to take action. For, in most cases, governmental action is not as perfect and impartial as it is supposed to be and it is not always foreseeable which consequences the public action will have in other fields. An example for a market imperfection can be an innovation in a sector where the diversity of similar products offered is very high or where we find a high speed of innovation. Customers may not be willing to pay the due cost of information to find the product best suited to them and might therefore not adopt innovations that would - from the point of view of an unrelated observer - be beneficial to them. Those cases cannot be qualified as market failure, but are rather market imperfections because the market *could* provide the wealth maximizing option.

The reason why governmental action is relevant and important lies in the social justification. There are emergent phenomena in a society that will lead to a distribution of wealth and happiness that may disadvantage those who are less apt at realizing their potential. As an exemplary case, we can think of the combination of aging and poverty. In regions where a substantial amount of the elder population is facing the

[1] [FaVe09], p. 229
[2] cf. [Wegn09]

risk of poverty, many services designed for senior citizens may not be realistically available. Health care services and medical support appliances are often very costly. Not every person has had the opportunity to save enough money during their active life to provide for those risks at a later stage in life or some people may have chosen not to save enough money. In both cases, the society is in a difficult situation. Helping those people may be very costly and not helping them is not acceptable from a moral point of view.

Private insurance companies could be set up to cover those risks. Especially health insurance is in many countries provided by private companies. This can be organized in a very efficient way. Nevertheless, there is still an advantage related to public intervention. For example, help for senior citizens in need could be achieved by establishing a public transport system that explicitly takes into account the needs and specialties of the elder. This includes busses with curb-level access, traffic light intervals adjusted to slower pedestrians or even the installation of important public services in spatial proximity to the people who need the particular service.

Those measures are certainly designed to be implemented on a medium- to long-term scale. Besides, they are realistically only achievable by a public organization since they involve decisions that influence the society as a whole and since many such projects involve very large amounts of money to be invested. A third reason is that private insurance companies mostly care about the insured risk and would therefore only support measures reducing this risk. A public body, however, aims at optimizing the happiness of the people and their welfare. By consequence, its scope and portfolio of adequate measures is unequally larger and can be better targeted at the needs of the particular focus group, e.g. senior citizens.

In that sense, the social insurance is a direct support for social peace and can assist the individual in a very efficient way on his pursuit of happiness. No private system could offer a comparably comprehensive approach due to the limited target group of only those insured, the limited financial possibilities only provided by the members and the limited regulatory and practical possibilities. A private company can achieve the same result as a public system almost exclusively with respect to spending and distributing money, but it has to fall short against the societal counterpart in all other domains where money may not be the only component to a successful and efficient provision of services designed at helping people in need.

From this discussion, we can easily derive the justification for a system of social insurance. Since not everybody will be struck by fate in the same way and some will experience better luck than others, we could argue that social insurance should be instituted following the mandate of justice and fairness, as well as social peace.

Nevertheless, these are rather political arguments and it is interesting for an economist to approach this question with a different mindset. This study will try to gain insight on the economic effects of such a social insurance offering when looking explicitly at the future orientation of an economy. This means that we will explore the effect which the integration of the public sector has on the innovativeness of the members in the society. We will establish an agent-based model based on the Comprehensive Neo-Schumpeterian Economics-approach. This model will be used to analyze the impact of social insurance in order to answer the research question, if social insurance can spur innovation in a society.

Our work is structured as follows: in chapter 2, we will focus on innovation and discuss why it plays such a central role in today's economic discussion. Chapter 3 is devoted to the Comprehensive Neo-Schumpeterian Economics-approach and explains its theoretical concept as well as the qualities which make this the best suited framework for the ensuing discussion. The subsequent chapter 4 deals with the question how innovation can be spurred and which measures can be used to actually increase innovativeness in the society. It also looks at the specificities of the most relevant actors in the process of generating novelty. Chapter 5 will focus on the other side of our research question and deals with social insurance by introducing the concept and discussing the important aspects. Furthermore, we will present other studies which have dealt with comparable issues. Their results will later be compared to the outcome of the simulation. In chapter 6, we concentrate on agent-based modeling and explain and discuss this form of reasoning as well as its use in economics. It will serve as a theoretical prelude for chapter 7, which is devoted to the description of the model. In agent-based modeling, it is important to make sure that the model is thoroughly explained so that all assumptions, hypotheses and integrated influences are visible. This will allow us to interpret the results in chapter 8 where we find that social insurance seems to be able to foster innovativeness and generate a positive effect on the mean income in a society. Chapter 9 will conclude.

2 Innovation

2.1 Definition of Innovation

It is crucial to first define the key terms used in this paper before starting to discuss their influences. When trying to pin down the term "innovation" we find mainly two slightly different approaches. The first is somewhat broader and can be illustrated by the following quote: "Innovations result in qualitatively new products or methods, which are considerably – however this could be defined – different to the original state." [3] This definition stems from the practical view of the business world and takes into account what counts for managers. Nevertheless, it leaves out an important distinction and therefore, this paper will deal with the term "innovation" following the second definition, which states that there is a difference between invention and innovation: "Invention is the first occurrence of an idea for a new product or process, while innovation is the first attempt to carry it out into practice." [4] So, the intention to use it commercially is a crucial fact that turns an invention into an innovation. The differentiation between the two ideas can sometimes be hard or impossible, but there are many cases in which the inventor is not using his invention commercially and thus he cannot be described as an innovator.

One of the most famous cases in this context is the invention of the Apple-PC. Steve Wozniak developed in 1975 both the Apple I and the Apple II which can be considered as the first personal computers of the world. It was then Steve Jobs, who is still CEO of Apple Inc. today, and the investor Mike Markkula who commercialized these inventions, while Wozniak only became a simple developer at Apple's.[5]

This example can also illustrate, that there are different prerequisites for an invention and for an innovation. In order to come up with an invention, people need a certain amount of creativity or a willingness to explore new paths and in most cases some specific technical knowhow. For an innovation, on the other hand, it is important to have a thorough knowledge concerning the integration of an invention into the production or the production process as well as its commercialization and diffusion. Steve Wozniak definitely had the technical knowhow and the creativity to build a PC, but he lacked the capabilities to market it successfully. Thus, the *innovation* was made by Apple.

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[3] cf. [Pösc00]
[4] cf. e.g. [Fage05], p. 4
[5] cf. [VPet06]

A precursor in the economics of innovation was Joseph Alois Schumpeter. His scientific approach was based on the assumption, that economic growth can only be generated by new combinations.[6] Those can be accomplished in five different ways:

i) introducing a new product, which also includes the improvement of an existing good;

ii) introducing a new production technique;

iii) entering a new market;

iv) finding a new source of resources or preliminary products;

v) implementing a new form of organization.

For Schumpeter, it is not important if those techniques, markets, sources of resources or preliminary products or forms of organization have existed before. What matters is that they have never been used in this industry or this context.

Others prefer a stricter and narrower definition. For example, the OECD states in its Oslo Manual that in order to speak of an innovation there needs to be commercialized technical novelty in terms of products or the production process. Basically, this definition is limited to the forms i) and ii) of Schumpeter's list.[7]

This paper will refer to all five of Schumpeter's forms, since the decisive point is to make sure that there is a dynamic force in the market and the society. As long as there is novelty in one of those fields and this novelty is used commercially, then we will consider it an innovation.

Besides, we find the distinction between radical and marginal innovation.[8] Radical innovation, on the one hand, is the consequence of a technological revolution, marginal innovation, on the other, stems from a process of incremental improvement. While it is true, that the radical form has a much better visibility in the public, it is important not to underestimate the marginal innovations. In many cases, marginal innovation is needed to adapt a good or service to adequately serving its purpose or to increase the utility for the consumers. As an example, one can think of the first cars (a radical innovation). Those first ones were hardly faster than horse carriages and both difficult to navigate as well as hardly reliable, especially on longer journeys. Thanks to incremental innovations, those first cars turned into the highly complex machines, which grant our societies an important part of our mobility. This is a common process

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[6] cf. [Schu34a], S. 188

[7] cf. [OECD01]

[8] cf. [Fage05]

in almost every industry: marginal innovations improve a radical innovation and increase the value and utility for the consumers.

2.2 Why innovate?

The Canadian Dairy Commission quotes a study of 800 Canadian companies in the food processing and manufacturing industries, which showed that 64% of the firms that had introduced product innovations achieved higher margins on the new products in comparison with their regular product lines.[9] This data would likely be sufficient to convince a great deal of people of the importance of innovation. Nevertheless, it falls short of some points.

An innovative entrepreneur does not only face many valuable opportunities, but also some considerable risks. Trying to innovate is expensive and there is no guaranteed return. Is it worth innovating, if my older products will lose part of their market share? How much will I have to invest, until the innovation will be ready to be sold on the market? How can the risk of a failing innovation be measured and how high are the sunk costs of an unsuccessful innovative endeavor? All those concerns are valid remarks which make it important to answer one combining question: why should an entrepreneur try to innovate?

The main criterion for a manager to be willing to be innovative is that the innovation will lead to higher benefits compared to the *status quo* or the predicted developments of the industry when keeping the current strategy. This could, for example, be the result of an increase in the sales of the product provided that the margin on the product does not diminish.

The increase in sales and thus in profits can result from a change in the consumer's behavior influenced by an innovation. The utility of such an innovation can also stem from a decrease of production cost. You can also think of avoiding a predicted decrease in profits by introducing a new product or strategy. This chapter will treat all those cases and tries to find answers to the question why it is reasonable for an entrepreneur to innovate.

Some sources quote the need to innovate fairly drastically by stating: "But not to innovate leads to an even stronger and particularly fatal danger. It's choosing one's own decay."[10] This statement shifts the focus completely since the risk of an innovation loses importance. The choice that is left for an entrepreneur is sure failure

[9] cf. [CDC05]
[10] [CECII02]: "Mais ne pas innover conduit à un péril encore plus grave et particulièrement fatal. C'est se condamner à terme"

or having the chance to survive and even grow thanks to innovation. If you know that your competitors will take over your market share – even though this may happen slowly – then not innovating will definitely be your ruin in the long run. This is, of course, not true in all sectors or industries, but every manager has to understand that choosing to remain on old paths increases the chance for the competitors to get ahead. So, securing the market position and competitiveness is a first incentive to innovate.

Only focusing on the fear of losing market share, though, will not entirely grasp the problem. Innovation can also serve the purpose to broaden one's own position in the market, strengthen its environment and increase own profits. In that case, the innovation has to provide the entrepreneur with a comparative advantage. This can mainly be achieved by one of four strategies: (1) a better performance, (2) lower costs, (3) a clear differentiation in the own product line compared to the competitors or (4) a better focus on customer needs and other demands like governmental regulations.

The first argument, a better performance, follows the thought that this will increase the value for the customers. It fits into category i) and iii) of Schumpeter's list. For each product, there are potential customers who decide not to buy a product. Some of them, may have been tempted or almost indifferent, but finally chose not to consume or buy it. Those customers can be attracted by an improved performance, since there are now even more arguments for purchasing this particular good or service. Besides, this strategy of improving your goods will only rarely lead to major losses of existing customers since the increase in sales is achieved by an improvement and not a repositioning of the product. It is probably even more convincing when thinking about this strategy in terms of entering a new market. The old customers will keep buying the product as well as at least some of the customers in the new market. This will raise sales for the entrepreneur.

A very vivid example of such a strategy can be found in the market for video games. For years, Microsoft, Sony and Nintendo have been struggling for the predominance in this sector. The smallest of the three, Nintendo, has introduced a new concept in the video game experience for players and tried to regain customers through this shift into a new market: "In order for the video industry to continue growing, it has to win back those who oppose games and conquer the entirely absent groups of women and senior citizens. In order to reach this goal, – above all – game consoles have to be easy to handle and offer new gaming possibilities." [11] The innovation is thus used to reactivate former customers, win new ones and tie existing ones to their own product line. The success of this endeavor didn't take long to show: the Nintendo Wii won the 2007 Customer's Choice Award by the review publisher Reevoo[12].

The second strategy we had been talking about was to reduce costs, which means that a company focuses on innovations coming from the points ii), iv) and v) of Schumpeter's list. An innovation in the field ii) refers to those cases, where a new production technique is used, which makes it possible to produce the good or the service at lower costs than before. The textbook example of such an innovation is the introduction of the conveyor belt and the assembly line by Henry Ford which helped increase efficiency in car manufacturing. This optimization of the production process gave the Ford Motor Company the ability to produce considerably more cars in the same time and at lower cost per car than their competitors and gave them a clear cost advantage.[13] The next point, iv), deals with new sources of resources or of preliminary products, where a company can be innovative by finding new ways of getting the inputs they need in the production process. A German entrepreneur has, for example, come up with the idea to stop mining gravel from gravel pits, but to lift it from the ground of the ocean. This enables him to avoid the rising prices due to the growing scarcity of gravel on land and helps him secure his market position in the long term.[14] The third point is a cost reduction in the way the company is organized. For example, for some companies a change in the legal form or a move of their headquarters into a different country can lead to a lower tax burden or improved conditions for loans.[15]

The third strategy, to win a competitive advantage by differentiating the product or service, applies to the category iii) of the list. In this case, it's not necessarily the novelty of the product, but more importantly its distinction from other offers on the market, that make it successful. If an entrepreneur feels that a certain part of the market is not targeted by the existing products and services, he may see an opportunity in tailoring his offer specifically to this segment. This change in his product line does not necessarily have to be a change in the product, but could just be a new image of the brand or a new channel of distribution. Airlines for example offer a fairly

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[11] [Köll06]: „Damit die Videoindustrie weiter wachsen kann, muss sie die Spieleverweigerer zurückgewinnen und die gänzlich abstinenten Frauen und älteren Semester erobern. Dafür müssen die Konsolen vor allem einfach zu bedienen sein und neue Spielmöglichkeiten bieten.“

[12] [Wood08]

[13] [PrVo07]

[14] [ZDF07]

[15] [Goahead10]

homogenous service, which is the transportation from point A to point B. Still, some companies focused on trying to add to this service many accessories like free food and beverages during the flight. This opened the doors for other companies to tailor their service of transportation to those people who cared more about the price than the additional services offered on other airlines. The innovation in the differentiation and the entering into this new market segment – customers who only want the flight but are not keen on paying extra for food and drinks on board or large leg room – made it possible for those no-frills airlines to get a hold in the market of aviation.[16]

The fourth option, adapting better to customer's needs and wants and other rules, can basically apply to each of the five points on Schumpeter's list. It is crucial for a company to make sure the customer understands how the product will serve his needs and wants and how it will adjust to his demands. Besides, sometimes a small regulatory change for example because of governmental prerequisites can give companies a lead in their market. The car manufacturer Peugeot had been using filters for particulate matter in its cars when in 2005 the European Union passed a directive on the pollution with this particulate matter[17]. Thanks to the new directive and the customer's shift in perception, the French company could market their cars differently and had a considerable competitive advantage over its competitors.

Those were some examples, why it is reasonable for a profit-maximizing manager to be innovative. By applying one of the mentioned strategies, he can improve his company's position in the market and increase its profits. Only innovation offers the possibility to enter new markets. Other strategies can only bring shifts in the structure in the existing ones.

Apart from the pure profit maximizing strategies, other factors can also lead entrepreneurs to attempt to be innovative. Fame and social recognition can also explain the motivation to take such risks. In this respect, the personality of the entrepreneur is crucial since it is his devotion that will make him pursue his goals. He has to keep working on his inventions and innovations even when projects seem to be difficult. At times when there may be no or little motivation from his environment, he will have to assure that intrinsic motivation is maintained until the innovation will be introduced into a market. In some cases, it seems that those non-monetary motivations gain importance in the sector of innovation. Movements like the open-source software industry or open-innovation approaches of companies have shown that projects where

[16] cf. [Bram10]
[17] cf. [EUComm05]

inventors and innovators actually finalize their inventions to establish innovations can be successful and lasting without monetary recompense for the creators.

We also have to ask from an economic point of view if and why innovation is important for an economy and its members. So while we have shown the interest for the individual entrepreneur to venture an innovation, we can ask why a public body or the so-called "social planner" would have an interest in creating an innovation welcoming environment.

The main objective of most economic models is to explain and predict the allocation of limited resources amongst individual actors.[18] Out of the great number of different approaches and models, the neoclassic and the neo-Keynesian are the most popular. A third theoretical school, evolutionary economics, however, is catching up in popularity amongst researchers. It has been established well into the 19th century and has grown ever since with famous economists contributing to the growing theory. "The heterodox orientation of this economic current shows in representatives such as Nicholas Georgescu-Roegen, Friedrich August von Hayek, Thorstein Veblen and, last but not least, Joseph A. Schumpeter, all of them being substantial precursors to this school of thought."[19] A combining critique of those economists concerning the neo-classic theory lies in the assumption of homogeneity of the economic agents. We will further elaborate on this critique in section 6.1.3.4 when we justify our choice of agent-based modeling as the methodology used in this paper. In this context, Joseph Alois Schumpeter uses innovation as the crucial parameter for economic development.

Schumpeter reasons that describing an economic system by its tendency towards equilibrium is not satisfactory.[20] Neoclassic and neo-Keynesian theories can explain how prices and quantities are set on a market and can model the process of adapting to a given set of data. They can also map situations in which there exists more than one equilibrium because a change in the data can lead to different equilibriums and therefore different situations. Schumpeter lists explicitly changes in "non-social data (natural conditions) or in non-economic social data (here belong the effects of war, changes in commercial, social, or economic policy) or in consumer's tastes"[21] as examples for which those two theories can find adequate answers.

[18] see for example [HaKC02]
[19] [HaWa09], p. 10
[20] the following argumentation is based on [Schu34a], pp. 184
[21] [Schu34a], p. 185

He starts his critique at the point where economic life in itself is changing. Static analysis may be able to deal in some ways with continuous change such as for example, the evolution from a small retailer to a large chain of supermarkets. When it comes to discontinuous change, though, they fail because they can neither explain the emergence of such "productive revolutions"[22] nor the phenomena linked to them or their effects on the way of living in a society. Schumpeter mentions as an example the construction of a railroad, which can fundamentally change the way of doing business and have a considerable impact on the people's everyday lives. Economic development is change, which is produced endogenously – so from within the system – and not caused by exterior influences. Therefore, the mere growth of an economy can not necessarily be described as economic development, since it might only stem from a change in the environmental variables (for example, the growth in the population).

Axiomatically, economic theory often argues that it depends on the producers to create economic development. This is in conflict with the theory of product or life cycles, where the needs and wants of consumers play an important role. Schumpeter advocates a different mindset and follows that "[d]evelopment in our sense is then defined by the carrying out of new combinations."[23] Nowadays, this relation is closely linked to his name: "Generally, one may say that novelty, i.e. innovation, is the core principle underlying the Neo-Schumpeterian approach."[24]

A second important aspect in Schumpeter's theory is linked to uncertainty, which is inseparably linked to the discontinuous process of developing innovations. It is the ignorance about when innovations will come up and what effects they will have. There is a considerable difference between the concept of risk and uncertainty. Risk in this context is defined as the chance that a certain event may or may not occur and that its probability can be estimated.

Uncertainty, on the other hand, is an aspect that is different to risk in its most important characteristic. We speak of "true uncertainty"[25] when the probability of certain events cannot be estimated with any heuristic or when we cannot even predict what consequences an event will have. In that sense, innovations are always linked to uncertainty since they are something new. The new aspect in the product or service is

[22] [Schu34a], p. 185
[23] [Schu34a], p. 188
[24] [HaPy06], p. 5
[25] [Knig21], III.VII.48

responsible that – even if we knew every other single coordinate in the system – we could not be certain about the implications of the introduction of the novelty.[26] "For when it comes to the unknown novelty, the danger of the emergence of uncontrollable situations can never be completely ruled out."[27] Consequently, using an approach dealing with expected values and outcome matrices will not help an innovative entrepreneur in his decision about the implementation of the innovation and accordingly, a social planner who tries to support innovation in order to maintain or improve the standard of living should also think about how people can best cope with this uncertainty.

The next chapter will use the Comprehensive Neo-Schumpeterian Economics (CNSE) approach to try to explain where innovation comes from.

[26] cf. [GrPH01], pp. 8

[27] [Witt87], p. 162: "Denn für das unbekannte Neue läßt sich die Gefahr, daß unkontrollierbare Situationen entstehen, nicht völlig ausschließen."

3 Innovation and the CNSE-Approach

This chapter will deal with the question how innovation can be measured and will link the results to the CNSE approach, which is suited to analyze the innovative activity in a region and will serve as a basis for the following discussions.

The CNSE-approach which we will present in the second part of this chapter is rooted within the school of evolutionary economics which we have introduced above. Similarly, we will place our model in an evolutionary economics context. This binds us to respect three fundamental criteria which distinguish evolutionary theories from other economic approaches.[28]

An evolutionary theory has to be dynamic and focus on a development in time. This implies that we should not limit ourselves to static situations and try to improve or optimize those, but that it is important to find theories which can deal with change and evolution which is inherent in each system. Even though adding development and time into models makes those more complex and might even create further difficulties, ignoring the influence of change over time may lead to fundamentally wrong implications. Therefore, economic models in an evolutionary perspective have to be dynamic.

Additionally, an evolutionary concept has to follow a historic time approach which is irrevocable. This means that if the system could ever face the same decision matrix again, it does not have to follow the same development path. Even though there are proverbs in many languages stating that “history repeats itself”[29], we cannot consider that a situation will always lead to the same end, because this would not only imply that we can reproduce the exact same situation – which may be possible though extremely unlikely – but it would also necessitate a world without memory meaning that there are no experiences which can lead to a different decision behavior of the involved actors. Yet, every human being has a certain history of events which will influence his behavior and where it is impossible to entirely ignore it in any decision process. “History is important, partly because every complex organism, every human being and every society carries the baggage of its past.”[30] This leads to a situation where every decision – as similar as it may seem – is unique in its historic context and each theory will have to respect the impossibility of creating general theories which

[28] This presentation of characteristics is based on the explanations in [Witt87], pp. 9f

[29] An easy search through Google for “History repeats itself” and its French and German counterparts “l’histoire se répète” and “Geschichte wiederholt sich” leads to more than 5 million pages (search conducted on 01st March, 2010).

[30] [Hodg01], p. 3

will hold universally. "Those changes can neither form a circular flow, which could always repeat, nor can they be considered to be pendulum movements around a center."[31]

Furthermore, the third criterion which is necessary before we can speak of an evolutionary theory is that the subject of research is innovation and the impact of novelty on systems and entities. The critical part in this point is that "the generation of *new* situations and possibilities are explained *endogenously*."[32] Non-evolutionary theories can very well include change and novelty, but they treat it as an exogenous shock to the system and subsequently explain the reactions and adaption processes within the system. In order to qualify as an evolutionary theory, the generation of novelty and the introduction of new combinations have to be interior to the model and part of the explanatory power of the theory.

Considering those three aspects, we will develop an agent-based model which is supposed to shed light on the correlation between the welfare state and its social insurance promise, and the innovative behavior of its citizens. The model is dynamic since it simulates a certain period of time, it is irreversible and situated in historic time since each run will generate different 'histories' which the agents will use as decision bases for their behavior and it focuses on the generation of novelty and innovation in a society comparing the different concepts of social insurance and their effects on the innovativeness of the people in the economy. Therefore, we will use evolutionary economics approaches in the setup and interpretation of the model.

3.1 Measuring innovation

Before trying to figure out how innovations are created and how the model should be designed, we first have to find a way to measure innovations. Some economists even feel it could be worth dedicating their whole career to this goal: "The dream of getting hold of an output indicator of inventive activity is one of the strong motivating forces for economic research in this area."[33] A first approach could lie in the assumption that an entrepreneur who wants to commercialize an invention will try to protect it. So the number of patents could be a measure for innovation.

Two arguments are in favor of this idea: (1) patent protection is not for free and can be linked to high costs. Therefore, the expected profit from the patent has to be at least as high as its costs. The consideration of those factors can serve as a first filter to identify

[31] [Schu34b], p. 89
[32] [Witt87], p. 11: "das Entstehen *neuer* Situationen und Möglichkeiten *endogen* erklärt wird."
[33] [Gril90], p. 14

real innovations. Besides, (2) there is a selection within the patent offices. Not every patent application is granted and therefore it is assured, that patents meet certain standards.[34]

Nevertheless, patent protection as a measurement for innovation has several shortcomings. One of them is that many innovations will never be patented.[35] The ongoing discussion on the patentability of computer software and the new trend in this sector, where many programmers and companies offer their software for free as so called open-source software, are linked to this issue. Patents are therefore not in all sectors a valid proxy for innovations. A second shortcoming refers to the varying relevance of innovations and their different impacts on economic development. Some patents may protect an invention that fundamentally influences its market and another one might merely serve as protection for a different product from the same inventor. In comparison, patents can serve as a blur estimator for innovation if one bears in mind the difficulties inherent in this approach.

A different approach[36] focuses on the legal disputes and litigations concerning patent issues. The idea behind it is that a company will only go to court for patent infringement if the value of the claim is sufficiently high. This measure could therefore help distinguish valuable from not so valuable patents.

Other methods trying to measure the innovative activity of a society focus on the success of an innovation. This may be legitimate in sectors, which are highly innovative and where lots of innovations appear. Nevertheless, this approach does not only share the disadvantages of a very indirect measurement and a vague cause-effect-linkage, but it also might fight the wrong battle, since "[i]nnovation is not always measured by success. (...) Learning from failure can be a big part of innovation."[37] The discussion on the correct ways of measuring innovation is still not settled. In 2006, the government of the US has established a new commission that is charged to work exactly on that question.[38]

In this paper, we will consider each novelty, which is successfully introduced into a market, an innovation. As shown above, this is empirically hard or even impossible to measure, but for the theoretical analysis, this definition is sufficiently accurate.

[34] cf. [Gril90]
[35] cf. [Lern02]
[36] cf.[KoLe98]
[37] The author [Wing07] quotes John Menzer, Vice Chairman of Wal-Mart Stores, Inc.
[38] cf. [USADoC06]

3.2 The CNSE approach

The Comprehensive Neo-Schumpeterian Economics (CNSE)-approach[39] has been developed in the Neo-Schumpeterian spirit as described above and tries to enlarge this concept. Its starting argument is that technological innovations may be a major source of economic development, but they are not the only one and they need a fitting environment. Therefore, the influences and interactions with the financial and the public sector have to be taken into account as well.

"In order to understand the crucial co-evolutionary relationship, one must explore the bracket accompanying all three pillars, namely their orientation towards the future which introduces uncertainty into the analysis. The fundamental importance of true uncertainty (cf. Knight 1921) has to be seen as a characteristic concerning the single pillars as well as a phenomenon shaping the relationships between the three pillars causing a high degree of complexity."[40]

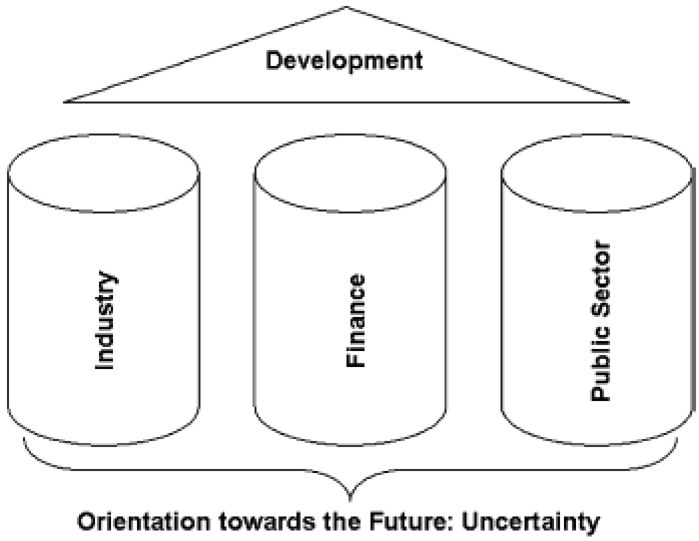

Fig. 1. *The three pillars of comprehensive Neo-Schumpeterian Economics.*

Figure 3-1: The three pillar model in the CNSE[41]

For an integral analysis of economic development the co-evolutionary interrelations between the three sectors have to be included, since they can be complementary or rivaling and therefore either spur or hinder economic growth. In either case, the influence of those interdependencies on the system will be non-deterministic, which

[39] The CNSE-approach has been developed by Horst Hanusch and Andreas Pyka and this chapter is following in large parts their works [HaPy06], [HaPy07a] and [HaPy07b]
[40] [Hanu10], p. 93
[41] taken from [HaPy07a], p. 280

means that uncertainty will increase. The system's development will consequently be shaped by the interaction of the different functions and mechanisms of the three pillars. The following paragraphs will present these pillars in detail.

3.2.1 Industry sector

Unlike the neoclassic or neo-Keynesian theories, the Neo-Schumpeterian approach separates the industrial sector in three levels: micro, macro and meso. It follows that "entrepreneurs carry out innovations (the micro level), that swarms of followers imitate them (meso) and that, as a consequence, 'creative destruction' leads to economic development 'from within' (macro)"[42].

The micro-level is where all actors are individually active and behave on a certain set of rules. It is the most elementary level and the single elements of a system are treated and analyzed on an individual basis. The meso-level allows for an analysis of structures and smaller organizations which result from the interaction of some individual agents who share certain characteristics, while the macro-level offers a perspective of the whole system. As an example, we could think of all the companies as the micro-level. They can be combined to industries on the meso-level and then the macro-level would look at the whole system of all companies.

In all those models, there are many different dynamics such as catch-up-processes or sudden, discontinuous changes which result from developments in the sectors or in the institutional conditions of the markets. Those changes may have implications for the competitiveness of nations or regions (the macro-level) as well as for companies and their environment (the micro-level). The consequence of those qualitative changes is that the price will not be the only criterion on which competition plays, but that innovation and responding to change plays a crucial role. This leads to the fact, that "[i]n knowledge-intensive industries, we often observe the coexistence of small entrepreneurial firms, shaping technological development and contributing strongly to technological progress, and large established companies carrying on their business in routinised ways"[43].

[42] [Dopf06], p. 2
[43] [HaPy07a], p. 282

3.2.2 Finance sector

For Schumpeter, the creative entrepreneur was the most important actor for economic development, but the banker followed right afterwards. According to him, the two need each other in order to work efficiently: the entrepreneur offers investment opportunities for the banker and the banker provides the entrepreneur with the capital he may need.

Today, the financial sector is much broader than only banking, since it also includes stock markets, private equity companies as well as venture capital provider. All the actors in this sector face the same two exogenous constraints: the uncertainty, if innovations will be developed and will prevail, and the time-frame of an innovation. Knowledge creation and innovation are developments which cannot be planned and which need time. This fact underlines the future-oriented design of the Neo-Schumpeterian approach. Furthermore, it leads to two opposing behavioral patterns: on the one hand, an investor will try to limit the time horizon of his investment as much as possible in order to minimize uncertainty and to be able to react faster to new developments. On the other, this short-term approach increases the risk of barking up the wrong tree and can lead to dangerous bubbles in certain markets.

Those bubbles underline furthermore the role of the banker in a Schumpeterian system: for central banks in the CNSE, it is crucial to watch both the price level stability *and* the pace of the market. In order to have the right balance for the market, they have to find the optimal configuration between two directions: the first one is to limit money supply in order to manage inflation and the second one – quite opposite – is a sufficient money supply that fosters innovation and the Neo-Schumpeterian dynamics. Schumpeter argues that the regular flow of money is bound in the production process that is already in place. In order to receive the financing to develop and implement an innovation, the innovator needs money that is currently not used.[44] Here, the role of the banker is crucial in allocating those funds to the most promising entrepreneurs.

[44] [Schu34b], pp. 107

3.2.3 Public sector

True uncertainty in the Neo-Schumpeterian model makes a governmental agent necessary. Following each innovation there will be – as already expressed in the term "creative destruction"[45] – winners and losers. Since no individual knows *ex ante* if he will be a winner or a loser, it can be beneficial for him to agree to a social contract.[46] Depending on their risk behavior, a group of individuals could set up a social contract which can minimize uncertainty. In this contract, every individual agrees that if he will be a winner, he will help the losers. *Ex post*, every individual will have an outcome that will allow him to live decently even if he was not a winner. This idea of a willingness to accept a contract that might prove to have been too cautious is commonly described as humans acting under the veil of ignorance, since uncertainty makes it impossible to estimate the risk an individual is facing.

We will discuss in chapter five, why a government is structurally better suited to offer such a contract than a privately organized system. For the government, it is important, that all the measures taken to establish such a contract have been weighted on how they influence the future orientation of the society and its economy. It is obvious that the potential for economic development is not supposed to be drastically limited, but rather to be promoted. Important fields where governmental action can be beneficial are all goods and services with external effects, such as merit goods.[47] We speak of external effects when the consumption of a good or service impacts other people without them being involved in the consumption decision. This can be a positive effect such as education or environmental protection. The added value that a year of schooling gives to an individual may be lower than the benefit better qualified citizens bring for the entire society and the extent to which a highly educated citizen can contribute to an improved standard of living in a country. The same is true for an insurance against poverty in the old age. Here, the dilemma grows out of the high time preference of humans. Many will not save a sufficient amount in order to finance their retirement. A future-oriented government might choose to implement measures that will incite people to prefer future consumption over the present one and thus secure their lifestyle at a later point in life.

This can also be illustrated when looking at unemployment insurance and its external effects on the future-orientation of a society. There is evidence, that this form of

[45] [Schu43], p. 81
[46] [HaPW09], p. 6
[47] cf. [Musg57], [Musg59]

insurance as well as its dimension influence the match quality of workers compared to their jobs and their employers.[48] The coverage people receive and feel in a situation where they lose their job or are unable to work will take the pressure from them to accept the first somewhat decent job offer, and will allow them to take the time to search for an adequate position. Since people will be more motivated, more creative and more productive when working in positions they feel more comfortable in, offering unemployment insurance should have an innovation enhancing effect.

This is true irrespective of disincentives linked to unemployment insurance related to the increase in opportunity cost of work which will lead to a reduced supply of work from some workers. This negative effect can be due to two reasons: some job searchers may not find a job which pays more than the funds they receive from the unemployment insurance scheme and others might value the combined utility of unemployment compensation and of free time higher than the additional income a job would provide them with. In any case, unemployment insurance can offer an advantage to the inventiveness and the creativity in a society thanks to its catalyst function in the search process for a new job.

Furthermore, creative destruction leads to a shift in required competencies for workers. When moving from the horse carriage to the car, there were many qualified coachmen and too little chauffeurs. In a Neo-Schumpeterian context, the government has the obligation to take such developments into account when designing a labor market policy that deserves to be called future-oriented. A mere focus on full employment in potentially obsolete fields of activity is far too short-sighted and will destroy the development opportunities of the concerned country in the future. It is important that the government acts to reduce the consequences of drawbacks both for society and the individual while enabling the system to react fast and successful to new opportunities that will arise. "In this way, public dynamics are closely connected to Neo-Schumpeterian dynamics, which demand higher qualities of public goods such as infrastructure, education, basic research etc. as a condition *sine qua non* for economic development."[49]

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[48] cf. [CeNo06]

[49] [HaPy07a], p. 286

4 How to foster innovation?

Now that we have established that innovation is necessary to ensure a productive and prosperous development of an economy and that it is crucial for every economic actor to take into account all three sectors and their interplay, the next question relates then to how it is achievable that innovative activity and technological progress can be stimulated from a policy perspective.

This chapter will discuss current approaches that are supposed to serve as a guideline for political actors to support innovation in a sustainable way without risking a breakdown of the system due to exaggerated dynamics in some sectors. We will introduce the Neo-Schumpeterian Corridor as a framework in which we can further demonstrate the different roles and fields of action a social planer has to respect.

Following this discussion, we will look at the personality of the innovator with a special focus on his risk aversion, for the risk aversion plays a critical role in the decision to realize and implement an innovation and it is therefore in the interest of the actor who is trying to stimulate innovation to respect the different interdependencies between the individual risk aversion, the innovative activity in an economy and the political measures he has at hand. Finally, we will point to important features which a Schumpeterian banker needs and which should be respected when designing a policy approach aimed at fostering innovation.

4.1 Current approaches

In order to stay within the Neo-Schumpeterian framework and especially to follow along the CNSE-approach, we will consider first the state of an economy by introducing a concept called the Neo-Schumpeterian Corridor.

4.1.1 The Neo-Schumpeterian Corridor[50]

In the past, the different economies in the world have always evolved in waves where expansion and boom phases have been followed by times of contraction, recession and even depression. Besides, we have seen many bubbles form and eventually burst leaving behind surprised economic actors who were unwilling or unable to foresee that a dynamic development in a certain sector had left a healthy and sustainable development path and had started to grow too fast for other, interrelated sectors to keep up with it. The idea of the Neo-Schumpeterian Corridor is based on exactly this observation that while an economy which grows too slow cannot be a goal of political

[50] cf. [HaPy07a]

intervention, there also exists a development path which goes too fast for the system to support. The optimal situation of an economy is when both dynamics – those stimulating growth and development and those slowing down the system – jointly keep an economy within a certain zone of development found to be sustainable.

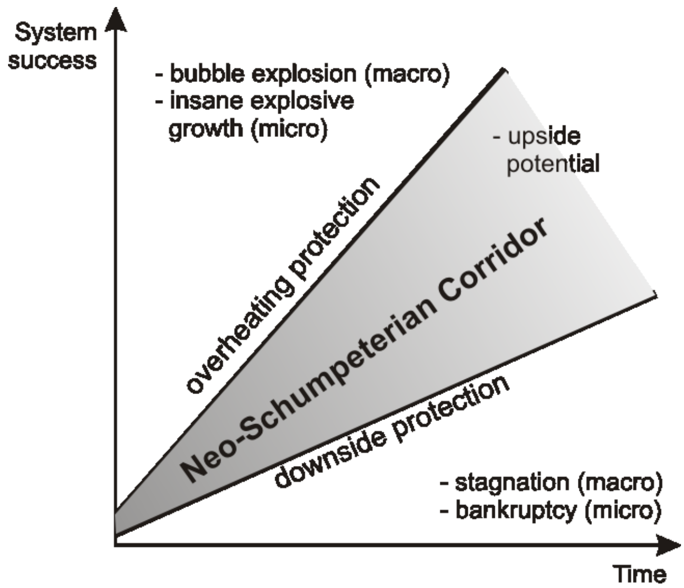

Figure 4-1: The Neo-Schumpeterian Corridor[51]

The goal of a political actor is then to keep the economy within this corridor and to secure its staying in that position. That means that he will have to watch for slowing tendencies and support new innovative fields, but also that he will have to keep in mind that an exaggerated growth might endanger the whole system. This future-orientation is the most prominent feature of the Neo-Schumpeterian Corridor. A system can only pursue a stable growth path for a longer period of time if it stays within this corridor.

Every economy that is growing too little will face difficulties of creating the necessary dynamics in order to advance the standard of living. The functional chain evolves according to the following logic: due to the low growth, there is no need for companies to invest any further than the mere replacement of investments. So, there will be a lack of new, especially risk-taking investments, which would be needed to reinstall a positive momentum. This is true in many dimensions since the lack of investment can be found "with respect to physical, human, intellectual and social capital"[52]. Therefore, all those industries producing investment goods and services will

[51] taken from [HaPy07a], p. 287
[52] [HaWa09], p. 15

suffer due to a lack of demand. As a consequence, private consumption will decrease since households will experience a loss of income or wealth when companies lose profits (lower dividends or capital gains distributions) when they will have to reduce their workforce (loss of work income), or when they are evaluated at a lower price due to deteriorated future growth perspectives (falling stock prices). Even the fear of an income reduction in the households can have strong effects on the consumption behavior.[53] At this point, the crisis spreads to the market for consumption goods and the economy falls even deeper below the corridor.

In a society, not only the amount of innovations will decrease but also the support for risk-bearing entrepreneurs and as a consequence the standard of living will drop – if not on an absolute scale then at least on a relative scale compared to economies which have been able to keep a dynamic and growing system.

On the other hand, if the economy is growing at an accelerated rate, then the environment will soon be supportive and spur an even faster process of change within the concerned sector. The interrelatedness of the economy, however and the interdependence of the different sectors require the fast growing domains to watch out for their less dynamic partners. There exists a state where the inert sectors slow down the fast growing and innovative fields to a sustainable but dynamic growth path. This situation, where the less dynamic sectors serve as a "natural brake for an exuberant economic dynamics"[54], is from a theoretical point of view the most successful situation even though it is not necessarily very stable or frequently found.

Much more common, however, is the case, where the dynamic sectors expand at an insupportably high rate. If the differences between the fast changing fields and the more sluggish domains are growing too big, then the tension within the system increases ever more. Bottlenecks, capacity shortages or an insufficient speed of adaptation in low growth sectors can then endanger the system that it might break and fall into pieces due to the excessive pressure and stress the economy is faced with. In such a situation, the economy has fallen prey to its own success.[55] Such a highly dangerous development may unfold out of several constellations.

One possible scenario is that the dynamics within a successful sector speed up considerably. Then an increasing number of actors will try to participate in this lucrative field and invest their time and money with a fading consideration of the risks

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[53] cf. [Knol08], especially pp. 69f
[54] cf. [HaWa09], p. 13
[55] cf. [Schu43], pp.156ff

involved. This is comparable to a crowd starting to populate a frozen lake. The first skaters will access it very cautiously and carefully test if the ice is strong enough to hold them. The more people are already on the ice, the less newly arriving skaters will doubt the sufficient load bearing strength. Eventually, some people will arrive who are absolutely inexperienced with judging if an ice sheet is strong enough and they will trust in the fact that they see as many people already on the ice. Even though their first steps may still be a little hesitantly, all skaters will grow ever more confident in the strength of the ice. If either the load bearing capacity is exceeded or the weather starts melting part of the ice, then the ice field will break and experts and beginners alike will find themselves in the water. The analogy holds for the unfolding of an economic bubble and its bursting.[56] Whenever clever entrepreneurs find a new field, they will carefully assess their risks and opportunities and will be fairly aware of their odds. The better an economic sector performs, the more people will see their chances in this domain and will risk their own entrepreneurial endeavor. Just as most skaters may have left the ice before it breaks and therefore leaving it intact for experts to use and enjoy it, it is possible that the market forces work good enough to ensure that the system will not overheat. In the case of overheating, however, the ice may break in a sense that demand withdraws or investors pull out leaving both the successful companies and the imitators in critical distress to recreate their business environment. This is comparable to the crash in the dot-com-industries in 2000. The additional danger stems from the interaction of the different sectors in economic life. The financial investors will push forward an emergent boom in an industry and will be ready to sponsor ever more projects. In this situation of greed and over-confidence in the system, dangerous bubbles may form that bear destructive power if they burst.[57]

The other possible and dangerous development of such an overheating of the system is based on the interrelatedness of different sectors and the varying speeds of change bearable in each of these sectors. Even though a nascent field may be able to support high dynamics and an accelerating development process, the connected sectors may be overstretched and their failing to keep up with the changing environment will make the whole industry tumble. This follows the common example of an athlete who works out too hard in the beginning in order to strengthen his muscles, but who does not watch at an accompanying training for the adjacent ligaments. In a situation of stress, the muscle may be able to withstand the forces, but the ligaments and joints may not

[56] see also [Ogle07b], pp. 121

[57] This process has been very convincingly described by [Mins90]

be able to support the tension and tear. The consequence may be that the corresponding body part will suffer important limitations because of the failing of a crucial link.[58] We can observe such a development in many fast growing domains, for example in emerging countries where capacities in many domains of public life have to be enlarged while the investment boom neglects crucial but less visible linkages. The financial crisis in Asia in the mid-1990s has come about from exactly such a phenomenon. While the investors who came mainly from abroad saw great new opportunities, the economies in the countries were not yet ready for this enormous boom. "As the Asian economies grew, infrastructure bottlenecks became apparent."[59] In the end, the crisis in the financial markets tore down many aspiring projects and crushed dreams of a too rosy future. The economic growth path had not only come to a halt, but it was important for society and the economy in those countries to redefine their rules of the game in order to avoid a next crisis. Even though the failing has eventually only occurred in the financial market, the entire economies had been brought close to a breakdown. This overstressing of systems which cannot or not yet support high growth dynamics is the second reason why a growth path above the Neo-Schumpeterian Corridor is not sustainable.

Often, such a situation of exaggerated speed of change is accompanied by a hype on certain, selected industries and the following high dependence on the performance of those sectors. Those industries may consequently become of systemic importance and a negative development for those sectors may prove to be disastrous for the economy and the society. It is of utmost importance for a regulatory body to watch over an increased specialization and the resulting dependencies. As we have seen in the recent crisis, some companies had to be saved by the government because their systemic relevance made the risks following a potential failing of the company unpredictable and likely devastating.[60]

A situation which we might consider to be best apt at securing a positive future development turns out to be in itself catastrophic. The Sugarscape model, a landmark in agent-based modeling, simulates one case that shows such a development.[61] In general, the individuals have to live on this "sugarscape" – which can be thought of as a simulated country or region – where they provide for their needs by harvesting sugar

[58] cf. for example [Weid08]
[59] [Wong99], p. 393
[60] [Hanu10], p.100
[61] [EpAx96], p. 63

in a landscape. The sugar is the only good they need to survive and the more they have the wealthier they are. They behave according to the metabolisms needed and the vision they have. The lower the metabolism the less sugar they need to survive, and the higher the vision the better they can find fields with plenty of sugar. In this setting, a simulation with individuals that have low metabolism and high vision – which can be considered as showing the highest amount of fitness possible – led to a complete extinction of the specie while a less good equipped society managed to survive virtually forever.

Briefly sketched, this situation is comparable to a free and unregulated development path in the individual model we will develop hereafter. Even though it may be very dynamic and productive, this system could also prove to be less good suited to secure a sustainable growth path. It is also a question of fitness and how this parameter could be defined in specific terms. A system which we might qualify as very "fit" in the sense of being very productive may not at all be "fit" to cope with structures it caused by itself. Consequently, it is difficult to define a fitness parameter which should be directed at evaluating the efficiency of a system. What it comes down to can be best described by the following quote from Schumpeter: "A system – any system, economic or other – that at *every* given point of time fully utilizes its possibilities to the best advantage may yet in the long run be inferior to a system that does so at *no* given point of time, because the latter's failure to do so may be a condition for the level or speed of long-run performance."[62]

Only when an economy is following a development path which is within the corridor it can develop in a sound, future-oriented way best designed at generating future success. It is this speed of change where the more sluggish sectors will not be over stretched and where the dynamic sectors still have the possibility to tap into their full potential. Thus, watching for a healthy and joint development of all different economic actors and sectors will generate the highest long-term success opportunities for an economy and a society. Realistically, this can only be achieved if the different sectors interact on a basis of mutual understanding of every sector's role as discussed above. This explicitly includes an active role for the government. "*Modern* capitalism needs an active and both sensitive and authoritative support and control. Without continued promotion by entrepreneurs and without thorough monitoring by governmental agencies (a necessity which is strongly underestimated by many supporters of the free

[62] [Schu43], p. 83

market and even by Schumpeter) it can neither reach its full potential nor capitalize on it on a sustained basis."[63] It is of crucial importance that an active public sector watches over the development in the economy, for only through its intervention a system can be kept within the corridor for a longer period of time.

4.1.2 Innovation enhancing regulation

When a public body is trying to support the innovative activity in the society, it can start at different points. The most general is linked to using financial means to set incentives in certain fields for innovation. This can include funding for research institutions, subsidies for innovating companies or the shift in public consumption to products which show some kind of innovating activity. In each of these cases, the government uses money directly to support some kind of innovation. The difficulty, however, lies in the justification for the subsidy. No government can simply spend money without explaining the purpose of the expenditure. Innovation itself can be such a goal, but then it is hard to target the money, because innovation can happen in every field and sector which is conceivable.

Still, we can point to some regulatory measures which will certainly increase the potential for innovation in the society just because they facilitate the access to information or make it easier to realize the innovation.[64] This includes decisions in the regulation of intellectual property rights and the possibility to trade those. An example is the availability of public data which can increase the usability for third parties and may lead to new utilizations and benefits which can be derived from it.[65] In this case, the regulatory aspect focuses on the framework which accompanies innovative activity in a given society and therefore creates a better potential for innovation. Since this approach is not linked to large budgetary consequences, it can be fairly easily implemented.

If, however, the government links the goal of innovation fostering to a different goal, then it will have to specify the purpose which the novelty is supposed to serve. Consequently, the state will have to regulate either its spending procedure or the

[63] [Mccr08], p. 22: "Der *moderne* Kapitalismus bedarf einer aktiven, ebenso feinfühligen wie entschiedenen Förderung und Kontrolle. Ohne beständige Förderung durch Unternehmer und ohne sorgfältige Überwachung durch staatliche Behörden (eine Notwendigkeit, die von vielen Befürwortern des freien Marktes, auch von Schumpeter, stark unterschätzt wird) kann er sein volles Potenzial weder erreichen noch dauerhaft ausschöpfen."

[64] cf. [Eife09]

[65] see for example [YuCa10].

criteria for companies to receive subsidies. This means that we have to ask if it is possible to actually enhance innovation through regulation.

Innovation always refers to something new and unknown which implies that it is impossible to predict or foresee where and when inventions will be made or novelty will surface and how this will affect the market. Regulation, on the contrary, always has to have a justification and therefore a purpose which it is meant to promote. Unless innovation *per se* is the goal of the regulatory act, which seems very unlikely because there is hardly a clear way how to promote innovativeness itself, then the problem arises that the regulation will have to be directed at some kind of purpose or goal in the future.[66] "If we cannot approximately foresee what may happen, then we cannot implement laws or supportive measures for it."[67] Consequently, regulation and innovation cannot be easily brought together.

Nevertheless, it may be favorable to try to link the goal of future orientation to some other goals. Looking at the actual implementation in the field of environmental protection in Europe, we find that it has grown more and more important over the last years, among others because the state created incentives to invest and innovate in this field. In an exemplary way, we can take a look at the law for renewable energies[68] in Germany, where the government pursued its goals of environmental protection and provided substantial subsidies for innovative forms of harvesting energy such as solar power, wind power or biomass energy. The public money gave a large incentive to researchers across the country to focus their knowledge and creativity in exactly this domain. The result was that "now the Germans are suddenly in the limelight for being a forerunner of promising technologies for the future."[69]

So, is public regulation which follows precise goals a good way to foster innovation? The answer can certainly not be too easy since we can hardly estimate the effects which would have resulted if the regulation had not taken place. There could have been some substantial research in the field of renewable energies because either the main actors would have focused on those domains anyway or because some landmark invention could have been found even without the increased incentive. Furthermore,

[66] cf. [Eife09], pp. 11
[67] [Herz10]: "Wenn man nicht ungefähr voraussehen kann, was passieren kann, kann man doch auch keine Gesetze oder Förderungen dafür erlassen."
[68] cf. [Juri03]
[69] [Weig07], p. 42: "Jetzt stehen die Deutschen plötzlich als Vorreiter zukunftsträchtiger Technologien im internationalen Rampenlicht."

we do not have a measure how much of the research incentive is going to labs which do not create a benefit.

Additionally, a very difficult argument points to the fact that we do not know if the researchers who now focused on projects within the scope of the subsidies could have contributed to a more substantial progress in a different field. This means that a research and innovation incentive in a certain sector may divert the inventive capacity and effort from other fields and create a shortage of innovation there. Since it is impossible to foresee the future and innovation itself, it is even less possible to estimate the size of this redirection effect.

Furthermore, in a world where innovation follows a linear chain of events starting with basic research and leading to a marketable new product or service, such regulatory support may help in a way that the government can find the bottlenecks in the chain and try to open those up. But, once we understand innovation as a recursive and interactive process which takes place among different actors, we can no longer consider it a linear process. This implies that any regulation will affect one or more components of this system and a change will have repercussions which are difficult to estimate.[70] From this we can follow that regulation which is meant to foster innovation is not suited for situations in which market imperfections should be cured since the government is in no way a perfect player but is likely to introduce new imperfections at other stages.[71] Accordingly, in this work we ask which – if any – effect the measures in place have on the innovativeness. This analysis may help in the future when assessing the potential of governmental methods to foster innovation and to help sharpen the view for the interactions which may result between different sectors and measures. In the next two sections, we will focus on the two most prominent actors in the innovation process: the innovator and the financier.

[70] cf. [Bora09], pp. 28
[71] cf. [Wegn09], pp. 88

4.2 Personality of the innovator

The most important actor when talking about innovation is the person who will implement it. This is the one Schumpeter refers to when talking about an 'entrepreneur' or the person who is willing to carry out new combinations. The innovator is the one who will recognize new opportunities and goes on to grasp them, he is the one who "is seeing what everyone else has seen, and thinking what no one else has thought"[72].

There is an important distinction for Schumpeter between the entrepreneur and the manager. While the English definition of entrepreneur today is closely connected to the idea Schumpeter had in mind[73], the German term 'Unternehmer' is still used in a much broader way.[74] For Schumpeter, the entrepreneur is the driving force within a capitalistic economy, for he is the one who can disturb a static equilibrium process, bring about change, and make the society exit the circular flow it is otherwise doomed to follow. His view is therefore one of an "equilibrium-disturbing [...] entrepreneur"[75]. Without a Schumpeterian entrepreneur, we would find ourselves in a static economy where the life cycle is repeated over and over. Consequently, in such an economy the Walrasian entrepreneur making neither profit nor loss would appear.[76]

We have to make sure that the entrepreneur is not confounded with a manager who is merely the one leading an enterprise. An innovator does not have to be the manager of a company and not every manager is an entrepreneur in the sense that he is an innovator. Only if the manager is innovative and grasps and tries new ways or things, then we can consider him an entrepreneur. Furthermore, an individual who may not be in an executive position at a company can still be an entrepreneur if he dares to try the introduction of a novelty or of an innovation. "Therefore, the true importance of the function of the entrepreneur consists, not in the mere *running*, but only in the *creation* of an enterprise"[77]. Accordingly, we will use the term 'entrepreneur' in the understanding that he is the one who will implement innovations and carry out new combinations.

[72] [Swan09], p. 122
[73] for an overview of definitions, see http://dictionary.reference.com/browse/entrepreneur [Dictionary.com10]
[74] The German Civil Code (BGB) defines in §14 entrepreneur ("Unternehmer") as "a natural person, legal body or an association vested with legal capacity who acts as part of her commercial or self-employed activity while contracting an act of legal significance". ("eine natürliche oder juristische Person oder eine rechtsfähige Personengesellschaft, die bei Abschluss eines Rechtsgeschäftes in Ausübung ihrer gewerblichen oder selbständigen beruflichen Tätigkeit handelt.") [BMJ10b]
[75] [GrPH01], p. 7
[76] [Schu28], p. 247
[77] [Schu28], p. 247

A second distinction is important because Schumpeter himself takes great care to distinguish the two: entrepreneur and capitalist. An entrepreneur can create new combinations and by consequence be innovative without using any capital of his own. Schumpeter separates very clearly between the person who has and employs capital in the production process and the one who brings in new ideas with which he can change the structure of the economy. In order to be entrepreneurially active, it is not necessary to possess large amounts of money.

Since the model which we will develop is based on the micro-entities in an economy, we have to focus more closely on the personality of this innovator and discuss the personal traits, his "entrepreneurial spirit"[78], which lead him to the implementation of innovations as well as his incentives to search for novelty.

Whenever a person is trying to create something new, he will run into difficulties, barriers and opposition. There are people who fear the change and there are rules and regulations which may inhibit the execution or trial of new things. In order to overcome such obstacles, an entrepreneurially disposed individual needs to have the will and the passion to keep pursuing his goal.[79]

Furthermore, there are certain facets in the personality of each person which can make him likely to try to achieve greatly.[80] Schumpeter points to two aspects which are not easily brought in line with traditional economics[81]: there are people, who have managed to acquire great wealth and who could use it to satisfy their wants and needs, but who will continue to work hard and accept challenges and enormous difficulties. Even though it can hardly be the desire to gain more consumption possibilities, they keep pursuing ambitious goals. Consequently, they seem to see a utility in working and forgoing their leisure time.

The second aspect we find in the Schumpeterian analysis is that many innovators and entrepreneurs do not aim for the monetary rent linked to an innovation or the implementation of a new idea. There are very different motives underlying the inspiration to create something new, such as "the dream and wish to found a private empire, [...] the will to win. The will to fight on the one hand, the will to be successful

[78] cf. [GrPH01], p. 12
[79] cf. [Mccr08], p. 93
[80] cf. for example [Witt87] or [Dono10]
[81] [Schu34b], pp. 135f

solely for the sake of the success on the other hand. [...] Joy of creating finally is a third kind of family of motives."[82]

While this intrinsic characteristic which motivates the individual to become an entrepreneur is clearly important, it is not sufficient when we aim at explaining the innovative behavior.[83] There are more personal traits which play a role such as the educational level and the experience which the individual has acquired in a certain field of interest.[84] We will define those additional traits in more detail in section 7.3.3.6 when we explain the precise implementation of the inventive and innovative behavior in the model.

Nevertheless, we will briefly discuss the risk attitudes of an innovator and the implications for the innovative process. We could argue with Schumpeter that "the entrepreneur is never the one who bears the risk. [...] For, even though the entrepreneur is liable with his potential wealth, the possession of such wealth is not something substantial, albeit something facilitating."[85] He goes on to find that the entrepreneur might even risk his reputation, but that he never bears the economic responsibility. When following Schumpeter, then the innovator only has to worry about his innovation turning out to be a success, but in any case he has nothing to lose. Yet, this is only true for the innovator who will not simultaneously assume the role of the capitalist or of the banker providing the means to finance the innovation. Besides, he may not be worried about the perception of failure in his social environment. This leads us to the point that "[w]ithout a general willingness to innovate, i.e. a willingness to deal with the ex-ante non predictable possibility of failure and economic losses, any innovative behaviour becomes impossible."[86] Furthermore, it may be hard in some theoretical cases to separate between the functions of entrepreneur, capitalist, manager and financier, but it is virtually impossible in real world cases, especially if the entrepreneur is also the manager or the one providing the financial means. Consequently, the risk related to an innovation or an entrepreneurial activity may be twofold for the innovator[87]: first, he has the opportunity cost of pursuing other

[82] [Schu34b], p. 138: "der Traum und Wille, ein privates Reich zu gründen, [...] der Siegerwille. Kämpfenwollen einerseits, Erfolghabenwollen des Erfolgs als solchen wegen andrerseits. [...] Freude am Gestalten endlich ist eine dritte solche Motivfamilie"
[83] [Witt87], p. 166
[84] cf. [Witt87], p. 167 or [Dono10], pp. 112
[85] [Schu34b], p. 217: "Niemals ist der Unternehmer der Risikoträger. [...] Denn obgleich eventuelles Vermögen des Unternehmers haftet, so ist doch ein solcher Vermögensbesitz nichts Wesentliches, wenngleich etwas Förderndes."
[86] [HaPW09], p. 4
[87] [BoLe10], p. 15

activities which could for example consist of earning money in a conventional industry or simply being employed. Second, he may not see the reward related to carrying out the innovation substantial enough considering the risk related to it. The financial risk is only one aspect among several others, such as for example "[o]lder people might include [...] the specifics of the health care system in the risk-reward assessment"[88]. Accordingly, once we consider an individual who is trying to implement his innovation, we should also take into consideration the risk he might face within this process. In the simulation, we will implement those ideas in such a way that an inventor who will use the financial support of a financier to implement the innovation will not calculate his risk. An innovator who will realize the innovation using his own means, however, will judge the risk and decide according to his risk assessment if he will carry it out.

4.3 Personality of the financier

From Schumpeter's argument that the entrepreneur is not the one who has to assume the risk of an innovation and shoulder the uncertainty, we have to ask who will – in this theoretical framework, and then applied to practical terms – bear the risk connected to the realization of an innovation. Schumpeter is very clear on that: "The risk is always exclusively borne by the capitalist"[89] and defines earlier that "the banker [...] himself became the capitalist."[90] To Schumpeter, the entrepreneur will gain the entrepreneurial profit for having the idea of trying a new combination. It is thinkable that he does not possess any funds, but that he will receive the financial means from a future-oriented banker.

While the banker can therefore contribute the financial resources to the innovative endeavor, his role will not stop there. There are some important non-pecuniary contributions he can offer to increase the probability of a success of the innovation.[91] This means that the banker should be familiar with some aspects of the industry where he is investing and that he can assist the founder with his expertise from earlier investment projects or with his insight into the financial promotion of the innovative project.

The financier can offer the innovator a network of experiences and contacts which may be very valuable but not at all a financial contribution. Establishing a close

[88] [BoLe10], p.15
[89] [Schu34b], p. 112, footnote 12: "Das Risiko trägt immer nur der Kapitalist"
[90] [Schu34b], p. 110: "Der Bankier [...] ist [...] selbst der Kapitalist geworden."
[91] cf. [Chri05]

contact between the entrepreneur and the financier will help both because the financier will get to know better the entrepreneur which might reduce the risk of asymmetrical information and moral hazard, and the innovator will be able to profit from the insight and the network of the financier.

From a practical view[92], venture capitalists focus more and more on the personality of the entrepreneur and his skills and personal traits. High quality education becomes a factor which is highly relevant in the decision on funding. Nevertheless, there are many elements which an investor will look at – and there is no clear sign what characteristics are the most important. While some financiers focus on the proximity to the investor, others may concentrate on their knowledge in the particular field of interest.

There are different strategies, how a business angel can reduce his risk connected to the investment. More experienced investors tend to group together with other angels when financing a project, whereas less experienced business angels prefer those fields of investment where they have a sound knowledge of the market structure and the business environment.[93]

When it comes to the strategy and the approach of the financier towards the innovative endeavor, we may look at the perspective which venture capital firms use when assessing start-up projects. It seems that the quality and the academic qualification of the venture capital seeker grow in importance with the amount of money and of insight sought for. The inventor, who is not willing to make the effort to get a venture capital partner and the business insight linked to it, is "starving on the wrong foot"[94]. The business angel needs to see the effort of the inventor which makes it crucial to constantly convince the stakeholders of the project.

Furthermore, we can ask how a financier will react towards an inventor who is looking for an investor, but who has already failed in earlier comparable projects. According to the five panelists from the venture capital discussion quoted above, the unsuccessful trial of implementing an innovation and starting a business is in no way a drop-out criterion for potential venture capitalists. What is important to the investors is to see the reasons for the failure as well as the reaction of the individual to this experience. Yet, failure is something which is not entirely avoidable or "you don't have to worry

[92] Much of the insight in this discussion is from the "Venture Capital Panel on Differences between USA and Germany", [CDTM09].
[93] cf. [PaWB05]
[94] [Bich09], at 63 min:07 sec

about failure. [...] Failure will find you."[95] This implies that an unsuccessful innovation endeavor does not necessarily lead to the impossibility of finding an investor for the next innovative project.

Overall, the inventor who is unable to finance the implementation of his own invention will need to resort to an investor who will provide him with the financial means. If this financier can also add some non-pecuniary contributions such as a promising network and valuable insight, then the innovator-banker couple will assume the predominant role, Schumpeter assigns to them in an economy.

[95] [Gold09], at 49 min:45 sec

5 Social insurance

Every human being on this planet needs – at a minimum – food and shelter in order to survive. Most healthy adults are capable of procuring for their own needs, while it may be difficult for the young and the old, for the sick or the handicapped, for the less witty or the less skilled people to secure a sufficient income. Many of the features that limit us in taking care of our own life are changing over the course of a lifetime. While the infant will eventually grow to be an adolescent and learn to look out for himself and while the adult knows that with increasing age, the risk of being unable to satisfy his needs and wants grows larger and larger, there are some factors which not every human being will be concerned with. Illness, unemployment, accidents are all strokes of bad luck that a person may or may not encounter and that influence his life to different degrees. Since often enough, those people struck by negative incidents face major difficulties of continuing their life and their predicament may not even be anyone's or at least not their own fault, people have always tried to secure themselves against such risks.

In this work, we will understand social insurance as all measures by the public authorities to secure a certain standard of living for everyone in the society. This means that it can go beyond mere monetary measures and payments to people in need and that it can include the provision of public services designed to alleviate the distress individuals may face in the situation of a realized risk. Furthermore, social insurance in our situation will require the recipient to be in need. This implies that he does not have the means to secure his own standard of living.[96] Most countries have installed some system of social insurance in order to make sure that no person will be in existential distress.

In the next sections, we will first discuss social security in its historical context and look at the concrete implementations especially in Germany, France and the US today. Furthermore, we will look at models which have tried to answer the question on how social insurance influences the welfare in a society, we will present empirical data on the issue and we will link the discussion to the political domain of the median voter.

[96] We will relax this requirement somewhat in the concrete implementation of the model and will discuss the reason for it in section 7.3.3.3.

5.1 Social security

The terms 'social insurance' and 'social security' are not unambiguously used.[97] In this work, we will use them almost synonymously. We will refer to 'social insurance' as the theoretical concept of providing a safety net for the citizens governed by the public authority in question and we will use the term 'social security' when speaking about concrete implementations.

5.1.1 History of Social Security

The ancient Greeks would store olive oil thanks to its two features of high nutritional value and longevity, so that they would be able to overcome difficult periods and avoid any risk of starvation.[98] Furthermore, people would look out for each other as a kind of social contract, where those who were fortunate enough to escape from major dismays would help those who had to suffer damages. This could be accomplished in an informal way in a family or clan setting or more formal in guilds or principalities and is a behavior that can be observed in most groups of human beings.

When those groups grow too big, it becomes more and more difficult to secure the lifestyle of every member of the group and the social contract as well as the moral pressure on the fortunate ones to share degrades. On the other hand, if the behavior of the individual in need is not observable at a reasonable cost, then the free-rider problem arises with people trying to shirk their duties and thus living from the welfare of others. Soon enough, societies realized that they had to formally organize the support for people living in abject poverty so that they would secure their survival without putting social harmony at risk.

In the middle of the 16th century, Elizabeth I., queen of England, passed some acts that were supposed to alleviate the life of the poor.[99] Especially the Elizabethan Poor Law of 1601 would consolidate all previously passed measures, so that poor people who wanted to work but could not, would receive help from the society. The same accounted for those who were too old, too young or not able to work. Only those members of the society would not receive help who were able to work but refused to do so ('idle poor'). Besides, the Poor Law stated that every parish had to institute a poor relief rate that was collected from the property owners and was used to support

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[97] See for example [Atki91] who defines all those programs as social security where the recipient has to be unable to provide for himself, [HuSZ95] who define social security as entitlement programs such as Medicare and social insurance as welfare programs or [DiOr05] who do not differentiate between the two at all.

[98] cf. [Dewi08]

[99] [Bloy07]

the ‘deserving poor’, meaning the people who were in a precarious situation without it being their fault.

During the industrial revolution, the situation for workers in Western Europe was often marked by exploitation, low wages and high risk for the own survival. This condition would become even more critical, if the person was not able to work anymore. At that time, first economists started to analyze the situation and tried to draw their conclusions. In the French turmoil of the Revolution, there was Marie Jean Antoine Nicholas de Caritat, Marquis de Condorcet, who was very optimistic that progress and innovation could lead to better conditions for society in general and thus for the poor in particular.[100] He fought for rights that would protect workers from ruthless employers, worked out ideas for a social system helping those in need and spoke in favor of low interest rates which would allow poor people to borrow money without sacrificing their future. His ideas died with him in the aftermath of the French revolution.

In England, the situation was quite different. Robert Malthus scared the ruling elites with his analysis, that the growth of the population would by far outweigh the growth in the production of food. This would inevitably lead to famines and a decrease in population to a sustainable level. Besides, people who have enough means to live and raise children will have those children. So, in order to limit the explosive growth of the population, the poor had to stay poor enough, so that they could not afford to have children.[101] This idea led to the “Poor Law Amendment Act”[102] which greatly limited the rights of the poor by, for example, stripping them from some rights to vote.

The situation in Germany at the end of the 19th century was also marked by social inequalities and the unhappiness of the workers who felt exploited by the ruling elites. The tendency of the poor people to support radical ideas of socialism and to stop supporting the state or the king led the German chancellor Otto von Bismarck to introduce social insurance, which started in 1883 with an insurance that paid the workers half of their salary in case of sickness where employers had to pay one third of the contributions and the workers paid the remaining two thirds.[103] In the following years, he added an insurance against accidents which would pay in the case of a continued handicap that would keep the person from working and an insurance for old

[100] [Stra06]
[101] [Fons03]
[102] [Gash73]
[103] [DHM08]

age and disability, which can be compared to today's retirement systems. In 1927, long after Bismarck's death, Germany introduced an unemployment insurance thus covering another risk that people face and that can destroy their capability of taking care of themselves.[104] Many other countries copied more or less closely the German system and today there is at least a basic standard of social security and guaranteed standard of living in every industrialized country.

The United States had already set up a pension system in 1776 but it was limited to war veterans. The characteristics and eligibility criteria changed over the years, making it a decent form of security for soldiers during the Civil War, except for those fighting as Confederates. The non-veteran US citizens had to wait for social security until 1935 when the Great Depression and its harsh consequences for the life of millions of people in the United States forced the government to act. The Social Security Act was passed and a general system of old age benefits was introduced. Still, there were some lacking points like disability or medical benefits, but the average person would be secured against the "hazards and vicissitudes of life"[105].

From the beginning, the German system was universal in its design, meaning that it included all workers. In France, authorities tried to introduce in 1945 a general system designed to protect all French citizens. Following a strong resistance in the population, it was modified to allow two groups to opt out of it: those employees who already had their own system of protections and those who were not employed and did not want such integration into a nation-wide system. So, the people themselves did not judge a universal system desirable for their own situation.

5.1.2 Goals of Social Security

When the German emperor, Wilhelm I., signed the first declaration that announced the introduction of social insurance, the justification and the goals were merely summarized in the statement "that the healing of the social damages is not only to be found through repression of social democratic riots, but to the same degree through the positive support of the situation of the workers."[106] The idea was to increase the support of the working class for the state, the nation and the governmental structure by giving them a real interest in a prosperous state. Even though the pensions would not

[104] [DSV08]
[105] [Dewi08]
[106] [BGSS03]: „dass die Heilung der sozialen Schäden nicht ausschließlich im Wege der Repression sozialdemokratischer Ausschreitungen, sondern gleichmäßig auf dem der positiven Förderung des Wohles der Arbeiter zu suchen sein werde.", in „Bismarcks Sozialgesetze 1880-1889", „Die kaiserliche Botschaft vom 17. November 1881", page 2

be higher than the cost of one loaf of bread per day[107], the first step towards a government that helps those in need had been taken.

In 2010, the German legal code contains twelve subsections of social laws where the first article states that the social laws are meant "to secure a decent life, to create comparable preconditions for shaping the personality […], to protect and promote family, to enable people to freely choose an occupation with which to cover their cost of living and to avert or smoothen […] exceptional burden".[108] The goals of social security are thus manifold. The most important and most historic reason of securing a life worth living is probably also the first, people would cite, when talking about the necessity of a social code. The other points are more the expression of a common standard of living that should be preserved and made accessible to everyone. Stating that everybody should have comparable chances of creating his own life or trying to give the free choice of profession to everybody are noble goals which may not be easy to achieve and which do not necessarily – if they are not met – imply that the person suffering is not able to live a decent life.

The French and German laws see the family as one of the central aspects integrated into social laws, while the US Code of Federal Regulations in its Title 20, Chapter III (Social Security Administration)[109] defines more limited goals. In general, it seems that the goals of modern social security contain at the very first a guaranteed minimum standard of living which allows people to lead a decent life without having to worry about what to eat or where to sleep. The most essential dangers to survival have thus been eliminated by the society.

In some cases, the social laws go even further and try to guarantee the person some freedoms like having a family, choosing his profession or being able to realize his goals. In those cases, social security offers more than just covering the basic risks of survival, but it guarantees the integration into society and with it a great possibility to carry on through trying times. The necessary means and conditions for living what can be considered a dignified life will change over time and between societies. Those standards are always relative to the standards and possibilities of the whole society which is concerned. It is easy to understand, that people in Sub-Saharan Africa will be

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[107] [BGSS03], in „Bismarcks Sozialgesetze 1880-1889", Film

[108] [SGBI10]: "ein menschenwürdiges Dasein zu sichern, gleiche Voraussetzungen für die freie Entfaltung der Persönlichkeit […] zu schaffen, die Familie zu schützen und zu fördern, den Erwerb des Lebensunterhalts durch eine frei gewählte Tätigkeit zu ermöglichen und besondere Belastungen des Lebens […] abzuwenden oder auszugleichen"

[109] [SSA07]

offered different social security measures than people in Western Europe. This is due to both the economic differences and the cultural differences between those regions. The same argument – the forms of social security provided depend on economic and cultural conditions – is also true between countries or societies that are more easily comparable than the two regions above.

5.1.3 Forms of Social Security

The fields in which social security helps are thus similar but not the same in most Western countries. In the US, France and Germany, there are four fields they have in common. First and foremost, there is an additional income for those who are not able to cover the minimum expenses to keep a decent standard of living. Even though the conditions to receive such an income and the lifestyle that it is meant to guarantee vary greatly, in each country people in need are supported financially through a "Supplemental Security Income (SSI)"[110], a "Revenu minimum d'insertion (RMI)"[111] or a "Grundsicherung für Arbeitsuchende (ALG II)"[112].

A second field where social security tries to soften the imponderability concerns the health of the people. Often times, health care costs are very high and it may not be possible for an individual to afford a treatment that will allow him to continue to lead a dignified life. In those cases, health insurance is meant to provide a basic care that will guarantee life-saving measures as well as return the person into a state in which he is able to participate in a social and professional life. Even though the Hippocratic Oath[113] requires physicians to treat people in need without mentioning any reward from that person in particular and is therefore interpreted as a general requirement for doctors to give life-saving treatment to anybody regardless of their ability to pay, a health insurance goes further in that goal. Even for people who could theoretically afford to pay their health treatment, getting this treatment could mean having to sell their house or having to sacrifice on other expenses in the household, which could have negative implications on, for example, the education and health of children. Through offering health insurance, the random risk of getting ill is covered.

The third common field between those countries is the retirement regime. People will receive certain amounts of money in their old age when generally they may not be able to work anymore or when the members of the society judge that they should not have

[110] [SSA08a]
[111] [SECU07]
[112] [BMAS07a]
[113] [Baue06]

to work anymore. While the US, Germany and France considered for a long time the standard age for entering retirement as 65 years, both in the United States and in Germany this has been raised to 67 for all those born after 1960 (US) and 1964 (Germany) in order to cope with the demographic change.[114] Besides, there are strong differences in the way the retirement subsistence is financed. Many western countries use a pay-as-you-go system where the money paid out to the retired people comes directly from the contributors compared to a system where the individual will save money in some form and will use it in his old age in order to secure his standard of living.[115] The phenomenon of aging societies will put additional pressure on the pension systems and may lead to a stronger shift towards fund-based insurance schemes.

Unemployment benefits form the fourth common sector. In the US, France and Germany, the amount which a person will receive is linked to the previous income of the individual. In the US, the duration of payments also depends on the last income.[116] Furthermore, in Germany there are certain rules where the duration of contributing to the system can have an influence on the amount of months an individual is entitled to unemployment benefits.[117] In any case, the amount of payment is linked to the last earnings and the subsistence minimum or a certain social standard is irrelevant for the decision about the amount paid out in case of unemployment. If this amount is too small then the person is, of course, entitled to claiming the social minimum additional to the unemployment benefits. The average sums received can vary strongly between the different systems in the countries and within each system depending on the previous income.[118]

From this short overview of the most prominent aspects of the system of social insurance offered in different countries, we will now turn to the more theoretical discussion of effects of such an insurance scheme on the welfare in the society.

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[114] Cf. [SSA08b], [BMAS07b], [SECU06]

[115] For a discussion of the advantages and disadvantages as well as an optimal mix between funded (fund-based) and unfunded (pay-as-you-go) systems, see for example [Mile00]

[116] cf. for example [MIUIA10]

[117] cf. [VfSL10]

[118] The values in the US can range from 37 to 84 percent of the last work income, in France from 67 to 85 percent and in Germany from 57 to 92 percent. The values after 60 month are even more different between the countries since in the US the receipts will drop to a range from 5 to 63 percent with an average of 32 percent during this time, in France from 24 to 74 percent (average 61 percent) and in Germany from 25 to 80 percent (average 62 percent). Cf. [OECD10a], [OECD10b], [OECD10c]

5.2 Social insurance and welfare effects

While it seems fairly straight-forward that a government should concentrate on the position of the economy in the Neo-Schumpeterian corridor and that it can set a regulatory framework designed to support innovation and channel the resources into promising paths as we have argued in section 4.1, it should be just as evident that this cannot be the only strategy and handing out money might not even be the most promising depending on the situation.

It may just as well be feasible and worthwhile for a public entity to improve on the infrastructure in order to enable people to be more creative and inventive or to facilitate the realization of innovation. As we will show in this section, there is some evidence and discussion that social insurance can serve as a measure to incite innovation. This idea will also be the starting point for our model and lies at the bottom of the question which we approach with the simulation.

In the subsequent part of this section, we will present two approaches and one implementation thereof which focus on questions related to our model. We will discuss their findings and the aspects where our approach tries to offer additions and further insight.

The first concept treats the question if a social insurance scheme can improve the incentives for individual members of a society to assume risk and therefore have a beneficial impact on the economy and the standard of living in a country or region.[119]

It starts by stressing the relevance of a social insurance scheme in a society. Theoretically, such a contract insuring against certain risks could entirely be organized without a public sector. If it is beneficial for an individual to have the security of a guaranteed payout in case of being on the loser's side and of having to pay for others if he is in the fortunate position of being on the winner's side, then it should be possible that a private insurance company offers precisely such a contract.

There are some problems, however, that limit the result the private sector is able to achieve. Once the "veil of ignorance"[120] has been lifted to a certain degree giving the individual an impression and an estimation of his situation later in life, then it will be difficult to convince him to agree to such a contract. If he knows that he might be on the less fortunate side, he will be happy to subscribe and be part of those who might profit from the contract. If he sees himself on the winner's side, then there is no reason

[119] The following discussion is centered around the paper "Social Insurance, Incentives and Risk Taking" by Hans-Werner Sinn [Sinn96]

[120] [Rawl08], p. 48: „Schleier des Nichtwissens"

why he should join a contract where most of the subscribers are likely to be net receivers of support. This would mean for him, that he had to pay even more than in the situation of a social contract as there are few contributors facing many receivers. So, agreeing on such a contract becomes more difficult the more the veil has been lifted.

The consequence of this analysis is that the social contract has to be underwritten as early as possible, at best even before the individual has been born. At that time, his abilities, capabilities, talents and features are still unknown[121] and every individual could profit from a contract securing him in case of a tough fate. It could, for example, be the parent's decision to have their newborn directly join such a contract so that it is insured over the course of an uncertain lifetime. If the new person grows up to be on the sunny side of life, he might, however, decide to sign out of the contract. In order for the contract to work as a private insurance, it would have to be impossible for the individual to opt out. The problem is that it is inconceivable in Western legal codes and contrary to Western ethics that a person may be bound by someone else for the rest of her lifetime. The only legal body that has the power to do so is a publicly elected government.

This is the reason why the public sector is necessary and irreplaceable in the function of providing such an exchange between members of its society who are more fortunate and others who are less fortunate.[122]

The model created in the subsequent part of the cited study focuses on an individual who can lose part of her income due to exogenous shocks and can undertake an effort to reduce the likelihood of such income shocks. Several cases are modeled where social insurance and redistributive taxation are implemented in different ways. Those equations are then mapped in a μ-σ-space in order to compare the mean income of an individual with the variance of his income. The more his income can vary, the higher the risk he took.

Private insurance cases where households receive a compensation for realized risks are then compared to social insurance cases where redistribution is used to compensate households and where everyone receives a certain lump sum regardless of the realization of any risks. The analysis finds that insurance has two effects on the risk behavior of the individual: on the one hand, since the insurance reduces the existential

[121] This may not be true thanks to today's possibilities in medical prognostics, but that would not hurt the argument. We can always find a point where the characteristics of a human to grow are unknown.
[122] cf. [Sinn96], p.263

risk for the individual, he will be more likely to accept risks and change his behavior to be more risk-seeking. This is not a case of moral hazard, since risk taking can make the individual as well as the society better off. The consequence is that the compensation he requires for accepting a new risk will be lower, which brings about more adventurous entrepreneurs.

On the other hand, a private insurance has the advantage that the marginal return to risk taking increases due to the fact that a part of the risk is now insured. The return which can be generated by assuming an additional risk has to be mapped against the uninsured fraction of the risk. This is, however, only true for private insurance since "redistribution only creates the first type of incentive"[123] because social insurance cannot take the individual's particular situation into account, but will only average over the society to achieve a fiscal equilibrium. Consequently, a social insurance is not fair in the sense of a private insurance.

Nevertheless, a private insurance is not applicable in the case of insuring lifetime risks such as discussed in the paper and in our model. One reason for this inadequacy is the aforementioned problem of the veil of ignorance. An individual can be "subscribed" to a social insurance and redistribution system before his veil is lifted. Furthermore, "[t]ypically there is a very narrowly defined set of circumstances under which a private insurance company pays indemnification. Social insurance, by way of contrast, is an all-inclusive insurance that protects against the risks of lifetime careers."[124] Therefore, the aspect of crowding out between a private insurance and the public system are not considered. The question is nevertheless relevant to our discussion since the agents in the individual model have to provide for their own risk and can do so by choosing investment funds. Even though those are not modeled as insurances, it could be possible to set them up in such a way that they are comparable to partial insurance plans as we find them in real cases.

The presented concept from Sinn concludes by stressing the importance to increase research on the beneficial role of redistribution and social insurance in societies thanks to their effects on the willingness to assume risk and to the induced increase in mean income in the economy. Our model follows a similar setup since we also model the consequences of risk realizations on the individual's income and look at the risk-taking implications which can be derived from the introduction of a public sector. Similarly, we look at the effects which a social insurance scheme protecting members

[123] [Sinn96], p. 270
[124] [Sinn96], p. 263

of a society from too harsh conditions can have on the risk behavior of individuals. Our analysis breaks open the abstract idea of risk into two categories: risk which reduces the income[125] and risk related to innovation which can be chosen to be taken and which can increase income.

In the presented case, an individual can choose to do an effort to decrease his risk of losing part of his income. The effort is understood as time and money spent on education which will reduce the chance of losing income during the course of his life. Our model differs from the presented case by allowing the income to increase and to decrease according to certain risk realizations. On the one hand, there is the possibility that external shocks can decrease the income similarly to the model just introduced. On the other hand, it is possible that there are positive shocks to the income such as fluctuations in the work pay (i.e. bonus payments) or increases in banking or investment interests leading to a rise in proceeds from capital. Furthermore, we consider the case that individuals assume the risk of implementing an innovation. Each successful innovation will lead to returns which can increase the agent's income. Therefore, our model can incorporate positive and negative shocks to the income while looking at the risk taking behavior.

Additionally, moral hazard in the model presented is designed as effort to reduce the probability of losses which is not tax-deductible. In the logic of the model, individuals may therefore choose not to undertake this effort and assume the higher risk knowing that the government will help them in case of distress. While this is certainly a plausible scenario, it may not be the only form of moral hazard relevant. In our model, effort is not tax-deductible comparable to the approach here, but we include more aspects into the risk-behavior of an individual such as the history of the simulation as well as the interaction in the individual's environment. Therefore the agents will be influenced to be more risk-seeking or more risk-averse depending on their character and factors in their environment. The agent-based setup allows us to enlarge the scope of the model towards a more inclusive picture making moral hazard an endogenously surfacing phenomenon. Besides, the pay-out behavior of the state in the Sinn-model is independent of the actual risk situation of the individual household. This means that

[125] The uncertainty in this position is further broken down in its parts in the simulation. A more thorough discussion can be found in the second part of this section where we analyze the implications of looking at different risks.

each household will receive a certain transfer from the government without taking into consideration if any loss-entailing risk realization has surfaced.[126]

In our model, we have heterogeneous agents. Therefore, the contribution of each of these agents to the social insurance system as well as their receipts from it can be defined in a more elaborate way taking into account certain characteristics of the individual as well as the society. We have chosen to model it as a median voter concept, where the median voter can decide on raising or lowering the subsistence minimum provided by the government. The government will then set the rate of contribution such that it can provide this insurance and still keep a balanced budget. The influence of the median voter is discussed in detail in section 5.3. In contrast to the presented model, the agent-based framework allows us to leave out a specific condition for a balanced budget in every single period. The government has the possibility to adapt its behavior during the course of the simulation to always refocus on the goal of a balanced budget therefore allowing to spend more than the budget in some periods and less in others. This is not possible in the model we have just discussed.

Nevertheless, the model shows that there are very elaborate approaches towards the risk-taking effects of a social insurance scheme pointing at positive influences of a redistributive taxation scheme. It finds that social insurance can – if it is well adjusted – increase the mean income in the population. This goes together with a pre-tax increase in the variance of the income meaning that more people take risks and, consequently, more people may fail and have a low income. There is no conclusive estimation of the post-tax effect since the redistributive insurance will provide some relief to the losers in the society. In our model, we find in section 8.2 that social insurance increases post-tax income in the society and reduces the variance of income therefore creating a more equal society.

Generally speaking, our model tries to add insight to this issue thanks to the different possibilities of the agent-based framework and shifts the focus by including innovation in the scope of the game in order to secure the future-orientation in a more specific way.

There is a study conducted by Bird in 2001[127] which builds on the just discussed model and which tries to single out those effects in cross-country panel data in order to

[126] This is not problematic for the model since it focuses on "an economy with ex-ante identical individuals who have the same preferences and who are endowed with the same set of probability distributions". [Sinn96], p. 273

analyze the effects of social insurance. It explores the standard deviation of income as the risk faced by households and looks at the US, the UK, France, Germany, Luxembourg, Hungary and Poland.

The study suggests that “the larger welfare states in continental Europe seem to encourage risk.”[128] Consequently, a country such as Germany induces risk seeking behavior in the population because it offers a high level of welfare.

Nevertheless, in a different regression, the data suggest that the welfare state is not able to considerably change the risk in post-transfer income, since “no country’s income insurance system changes its standing in the world with respect to risk”[129]. Surprisingly, it finds that the income risk is highest in Germany and lowest in Poland and Hungary. This means that people in Germany face the strongest oscillations in income while the income in the latter countries will not vary much on a year-to-year basis.

While the two results can explain that the income variation in Germany is highest in pre-transfer income, it is surprising to find that even in post-transfer income Germany has the largest variation. Consequently, the data show only a very small insurance effect generated by social welfare, which implies that it is almost sufficient to offer a basic level of social insurance. “[O]nce a country obtains the basic system of means-tested benefits and social insurance programs, further increases in the scale of the programs seem to have little effect on the system’s income insuring effect.“[130]

We have tested the influences of the different welfare systems in our model and have observed a similar effect as Bird just described. Even a fairly low level insurance scheme could generate more innovations than a system without any protection. A detailed analysis of the results can be found in section 8.2.

Besides this approach, we will now present another concept which tries to relate social insurance to welfare aspects. It is not directly focused at innovation or making a society more innovative, but it does look at different risks an individual is facing and discusses the different implications of the wide variety of uncertainty members of a society are confronted with.[131]

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[127] The following discussion is centered around the paper “Does the Welfare state induce risk-taking?” by Edward J Bird [Bird01]
[128] [Bird01], p. 380
[129] [Bird01], p. 378
[130] [Bird01], p. 380
[131] The following discussion is centered around the paper “Household Welfare, Precautionary Saving, and Social Insurance under Multiple Sources of Risk” by Ivan Vidangos [Vida09]

The model starts to break down the factors which can influence a household's income so that different sources of risk can be analyzed separately. It differentiates between the following shocks to the income level: disability, health related income shocks, unemployment, job changes, wage shocks, changes in work hours and other changes grouped in a residual. In estimating the different effects which the realizations of those risks may have on the individual's income, the author tries to infer the value of a social insurance on the welfare of households. He uses PSID[132] data to calibrate his model and creates a set of Bellman-equations used to recursively analyze the household's consumption development. Using the setup of the model, different insurance options are analyzed and discussed. The author finds that even an actuarially fair social insurance would only have very small effects on household's welfare measured as a change in consumption possibilities.

The model is constructed such that individuals are born at the point where their work life begins and they therefore only have two phases in life corresponding to working years and retirement years. Income is then estimated in both phases as well as for the last year before retirement because this will be used to define the retirement benefits. The welfare analysis is conducted by calculating the amount of money (in percent of lifetime consumption) necessary to make an individual indifferent between the insured life and the situation without the insurance. Two different insurance schemes are presented where the insurance always fully eliminates a negative effect of a realized risk supplying the household with the amount lost due to the shock.

Similarly to the model we set up, this approach takes the different wealth implications of various sources of risk into account and stresses the importance of including risk and insurance considerations into an analysis of welfare. The model is solved by numerical dynamic programming, which requires Bellman-equations up front and then evaluates the recursive formulae. It is therefore a fundamentally different approach to agent-based modeling since it necessitates that all assumptions and hypotheses on the individual's behavior and characteristics have to be brought into one equation which can then be analyzed. On the other hand, there is no option for agent interaction in a society or the introduction of historical time leading to different trajectories from comparable initial settings.

While the setup and parameter estimation is very thorough and valuable, there are some aspects to this model which are worth being discussed. For some of those

[132] This is the Panel Study of Income Dynamics which is conducted since 1968 on nearly 9,000 families in the US. [ISR10]

aspects, we feel, an agent-based model can offer useful additions. Firstly, the introduced scheme only evaluates the benefit of a social insurance after all other applicable insurance benefits have already been paid to the individual. This is due to the data used to calibrate the model. They show household income only at a time when all those insurance payments the household has subscribed to have already been paid out. A consequence of this situation is that household income increases with disability and unemployment, meaning that if a head of household became unemployed in a certain period, the household's income will be above the previous level due to either insurance benefits from contracts other than the investigated social insurance or from behavioral reactions such as a different labor supply of a spouse. The same is true for the income situation of a household where the head is retired. The parameterized model takes the household's income after social security benefits have been paid. This affects considerably the importance of a social insurance scheme, since any such payment plans are only additional to the contracts already chosen by the surveyed panel. The simulation we propose hereafter will be a basic insurance meaning that without the insurance, the individual would have to bear the full effect of a negative shock to his income. Consequently, the value of such an insurance scheme for the individual is expected to be much higher and the aggregate welfare implications should also be more important.

Furthermore, the value of the insurance is estimated against the situation where the individual faces his risk from a point of view before the work life begins. An individual therefore will not change his behavior in the case of a realized risk or will not attribute different utilities to certain consumption levels.[133] As the author states himself, though, "[m]easuring the value of insurance conditional on, for instance, being disabled or unemployed would yield higher benefits of additional insurance"[134]. The impact of the different valuation of a social insurance on other aspects in public life in the modeled society cannot be taken into consideration in the model and it is therefore assumed to be negligible for the analysis. An agent-based model, on the other hand, can incorporate such developments, and can, hence, offer valuable additional insight.

[133] One advantage of agent-based models is that they can more easily incorporate time inconsistencies and changes in preferences since every time step is evaluated separately compared to the situation where the future behavior has to be estimated in the initial situation.

[134] [Vida09], p. 29

Moreover, the definition of the specific set of Bellman-equations requires the author to take some assumptions concerning the characteristics of the households which are not integrated as variables into the estimated functions. In the present case, this includes factors such as the mean size and composition of a household with mean level of education. Again, the author draws attention to this issue and the limitations it generates for the interpretation of the results: “It is important to bear in mind, however, that a clear understanding of the role of heterogeneity is required in order to draw definitive conclusions.”[135] Therefore, a model which can respect the heterogeneity of the individual members of a society could lead to a better understanding of the role of a social insurance plan on welfare or the future-orientation of a society.

Additionally, an important aspect which is not specifically mentioned concerns the question on who can subscribe to this insurance and how the premiums are calculated. While the plans are fairly straight-forward in the design of the payout in case of a realized risk and the idea that the premium over the lifetime is actuarially fair, it is not clear how contribution is set up. It is important, however, if an individual has the right to subscribe to such an insurance or if it is obligatory for the society. The welfare implications will be considerable since it is impossible to create an insurance scheme, which is ex-post balanced meaning that for every insured person the actual payouts equal the premium paid. Therefore, it is important to take the aggregate emerging structure into consideration when discussing if such a measure is preferable.

Lastly, the important aspect of interaction cannot be included in such a numerical dynamic programming approach. Since every equation is set up to reflect the individual’s situation, it is possible to include parameters which take environmental variables into account. Those variables have to be defined at the start of the recursive run and will follow identical distributions for the different actors. In some models, including interaction may not be of larger interest, but when the whole lifecycle is to be analyzed then effects from other members of a group may have important repercussions on the agent’s behavior and characteristics. Furthermore, those influences can be reciprocal and include learning behavior by agents. The more complex the interrelatedness gets, the harder it is to analyze it through those numerical dynamic programming models.

[135] [Vida09], p. 33

Nevertheless, the two preceding discussions can hint at the important factors relevant when talking about social insurance and its implication on the lives of the individual members of a society and the future development of the economy in question. While the first model could shed some light on the relationship between insurance coverage and the willingness to take risk, the second model broke the different risks an individual is facing down into its parts and considered the individual effects on welfare.

5.3 Empirical evidence

There are several empirical studies which have tried to approach this question from looking at the data of different countries or settings. Their findings are not identical, however, when it comes to answering the question how social insurance influences the innovative behavior in a society. In many studies, entrepreneurship is measured by looking at the total early-stage entrepreneurial activity in order to grasp the amount of people who face up to the challenge of starting their own company. There is a crucial differentiation which is taken when entrepreneurial activity is analyzed: have people founded a company out of necessity or out of opportunity.

An enterprise founded out of opportunity means that an entrepreneur has taken the decision that the rewards – as diverse as they may be – compared to the risks and costs are worth taking the chance of starting a business. On the other hand, there may be people who will found a company out of necessity because of the lack of other opportunities. Especially in less developed countries, many people cannot find a job as an employee and are consequently forced to become entrepreneurially active.[136]

Still, we have to make sure that the qualification of an entrepreneur is identical in all cases. We have defined an entrepreneur earlier in the Neo-Schumpeterian sense as an economic actor who is willing to take the risk of creating something new in the quest for the increased return. The studies we refer to in this section do not necessarily follow this definition, but consider anyone an entrepreneur who is the founder or owner of an enterprise. Therefore, we have to be cautious when interpreting the results to the different ideas behind the concept of being an 'entrepreneur'.

On the one hand, there are studies pointing at the possibility that offering social insurance has an insignificant effect on becoming entrepreneurially active.[137] They note that the data certainly reject the hypothesis that social welfare programs work as a

[136] [BoLe10], p. 16
[137] [CoBy08]

disincentive for potential entrepreneurs. The personality of the individual is much more important when it comes to his willingness to start a new company: “individuals who are pre-disposed toward entrepreneurship will proceed regardless of the institutional barriers they face or the relative generosity of the social welfare system”[138]. This finding leads to two conclusions with respect to the general question of this work. Firstly, public policy and especially the social insurance scheme should be designed and justified with respect to other arguments and influences than supporting the entrepreneurial climate in an economy. Secondly, the goal of fostering entrepreneurial activity can only be achieved by addressing the intrinsic behavioral characteristics of each individual and trying to support his own future optimism as well as his willingness to start his own business.

On the other hand, we find studies which suggest a positive influence between social insurance schemes and the willingness of individuals to start their own company. There are some approaches comparing different health insurance schemes in the US system. The more common approach is that an individual is insured through an employer’s insurance plan. This leads to a situation where “[w]orkers may be reluctant to switch jobs when otherwise optimal because of the possible loss of coverage due to pre-existing condition exclusions, waiting periods on new jobs, loss of particular insurance plans, and disruption in the continuity of care with their healthcare provider”[139]. A general health insurance offer could then increase the propensity of an individual to start his own business. “More generally, the IHCP[140] provides an opportunity to examine the impact of social insurance on economic risk-taking like entrepreneurship”[141]. The political goal of enabling people to obtain health insurance through private insurance companies creates a valuable situation for researchers to compare the behavior of Americans with or without this deregulation. The results support very strongly the idea that self-employment can be spurred by offering a general social insurance plan: “My main findings suggest that the IHCP increased self-employment in New Jersey [...] by roughly fourteen to twenty percent”[142].

Besides, there is evidence that in states where such a scheme is not available, entrepreneurial activity only becomes attractive once an individual qualifies for

[138] [CoBy08], p. 634
[139] [FaKG09], p. 3
[140] IHCP refers to the Individual Health Coverage Plan of the US-state New Jersey implemented in 1993 and aiming at opening up the private health insurance market, so that people could obtain health insurance independently of their employer.
[141] [Deci09], p.1
[142] [Deci09], p. 23

governmentally provided Medicare which usually starts at the age of 65. A person who will receive medical services thanks to this program has less risk when he decides to found a company. Interestingly, "[b]usiness ownership rates increase from 24.6 percent for those just under age 65 to 28.0 percent for those just over age 65, whereas we find no change in business ownership rates from just before to just after for the remaining ages in our sample of workers ages 55-75"[143]. Consequently, it appears that social insurance can have beneficial effects on the entrepreneurial activity of an individual. This would imply that public policy should set up social insurance schemes not only for reasons of justice or equality within a society, but also in order to sustain future development and innovation.

Furthermore, there is evidence suggesting the opposite being true that entrepreneurial activity declines as a consequence of social security offered in a society. "As regards the level of social security benefits it is clear from the results of this study that the social security entitlements of employees have a negative effect on the rate of early-stage entrepreneurship."[144] Additionally, the social security contributions for an employer also have a negative effect on the willingness of a person to start his own business. Therefore, there are two negative implications which suggest that social insurance coverage works as a disincentive to entrepreneurial activity: first, a person risks losing his benefits and secondly, he will not only have to pay more for his insurance coverage since no employer will cover a share of the cost but he also has to contribute to the insurance costs of his employees. This creates a reinforced negative effect leading to the finding that the only way to induce entrepreneurial activity is by increasing labor participation. The suggested way of doing so is by reducing social security increasing the necessity for people to search for earning opportunities.[145] The same can be found for the case of unemployment insurance which is suggested to crowd-out nascent entrepreneurship both for opportunity entrepreneurs as well as necessity entrepreneurs.[146]

Following this logic, the conclusion for the public sector has to be that social security should be reduced to a minimum so that the state still fulfills its obligation to look out for its members but that it infringes as little as possible the entrepreneurial activity.

143 [FaKG09], p. 32
144 [HeVSBW07], p. 771
145 [HeVSBW07], pp. 772f
146 [KoMi09]

There are even those studies who argue that it might almost be impossible to find a regression using publicly available data which proves or rejects convincingly the hypotheses on social insurance effects on entrepreneurship.[147] Even though they find that the results do allow for a situation where employer-based health insurance does not have any effect on the decision of individuals to found a company, it is not unambiguous that this effect is predominant.

Obviously, it is impossible that all of the previously cited studies are correct on a general basis since their results are contradictory. The discussion in this section is meant to underline the difficulty in assessing the effects social insurance has on the innovative behavior of individuals in an economy. The model we present in chapter 7 will try to add insight to this question.

5.4 Influences of the median voter

We will design the model in such a way as to demand that the entire society adheres to one system – either the governmental system offering social insurance or the individual system where every agent will bear his own risk. The choice for which system will be chosen will be taken in a democratic choice problem which is reduced to a bipolar decision where agents can only choose between those two options.

This vote will not be modeled, however, since we do not allow for a change in regime during the course of the simulation. While this may seem interesting and might lead to insightful developments, it is beyond the scope of this work to integrate those cases.[148] Therefore, we will presuppose for every simulation run that the choice of system setup has already been taken and that this choice has led to either a governmental system of social insurance or to the individual system. We will then test how two identical initial setups of the system will evolve in the governmental model compared to the individual model.

Nevertheless, we will resort to the concept of the median voter[149] and its decision making influences in the simulation when it comes to voting on the scope of the social insurance offered within the society in question.[150] The median voter model is helpful

[147] [HoPR96]

[148] The model which we will present in chapter 7 nevertheless can easily be used to simulate such a change in regimes.

[149] cf. [Blac48]

[150] There are many more complex theories available on the choice of systems and how elections will evolve, see for example [Flec08]. For a critique on the median voter system, see for example [Hini77] or [RoRo79]. Nevertheless, up until today, the median voter theorem is often used thanks to its easy explanation of how parties will position when only two options are available. Cf. for example[Coma76], [WaPe08] or [BuWi10]

whenever there seems to be a set of choices which only differ with respect to one aspect and therefore can be represented in one dimension. Additionally, each voter will prefer the party which is closest to him with respect to this one characteristic, because this is the only difference between the parties. Once the political actors are aware of this situation, they will tend to move closer together in order to increase the amount of potential voters.[151] Consequently, the voter who occupies the median position in the society with respect to this criterion will cast the decisive vote, since the amount of voters on either side of him equal each other out. A political actor will therefore aim to receive the median voters' support.

In our simulation, we will use this theorem when simulating the process of voting for an increase, a decrease or no change in the level of social support offered to those people in need. While the government will always pay out to people who are incapable of securing their own subsistence minimum the required difference of money and therefore the expenditure side of the budget is fairly inflexible, the percentage of the revenues raised as contribution to finance the social insurance system is flexible and will be set by the government. The people can vote every four years for a change in the minimum level provided for by the state. This election will be held on a median voter basis meaning that we could imagine all voters in favor of a decrease on the left hand side of the spectrum, those in favor of an increase on the right hand side and the ones who prefer not to change the current level in the center. Since every individual in the simulation will be given one vote, we will see a decrease in the guaranteed subsistence level, if the group on the left counts more than 50 percent of the agents and an increase if the group on the right holds the absolute majority. In all other cases, the median voter will belong to the group of people who prefer to keep the present level.

[151] This refers to Hotelling's idea of the situation of businesses on Main Street in [Hote29]

6 Agent-based Modeling

There are many ways in which we could approach the central research question asking to what extent a government can influence the innovative activity in its society by offering a system of social insurance. Generally, we speak of inductive and deductive forms of creating insight. While the inductive approach starts by collecting data and tries to find structure inside it, deduction starts off with a hypothesis and tries to calculate its consequences on the real world. Neither approach is per se better or optimal, and it might even appear to be important to try several means to learn more about the cause-effect-relationships of a certain topic.[152] Following the enormous progress in computational power, simulation has evolved to be something like “a third way of doing science in addition to deduction and induction”[153]. Even though each simulation starts off similar to a deductive form of reasoning by setting assumptions, it then creates the data it will later investigate in an inductive way.

Similarly to all deductive approaches, we will have to abstract from reality in order to be able to draw any conclusion. This implies that it will be necessary to construct some kind of representation of the real world – in that sense a model – tailored to explaining the interactions we are interested in. Our model has to simplify reality to a certain degree: it has to be simple enough to allow the filtering out of interrelations and it has to retain as much complexity as necessary in order to be able to use the conclusions in the desired way. “Regardless of the approach, the quest of any model is to ease thinking while still retaining some ability to illuminate reality.”[154] Following this mindset, we have to think about the best method to set up our model.

In the following sections, we will introduce agent-based modeling (ABM) as a methodology and explain where it offers advantages for the theoretical understanding. Furthermore, we will focus on the branch of agent-based computational economics and explore some of the advances made so far in this field. This will help with understanding and evaluating the model presented in chapter 7.

[152] An interesting anecdote on the importance of being able to go beyond standard techniques can be found in [Ogle07b], pp. 40

[153] [AxTe06], p. 1650

[154] [MiPa07], p. 11

6.1 ABM[155]

Over the last decades, computational power has increased dramatically and has made it possible for many new ways of scientific research to be discovered. From the cellular automata and their impressive implementations in the Game of Life from John Conway[156] or Thomas Schelling's Segregation Game[157], the applications became more and more sophisticated and managed to show how very complex phenomena could be derived from fairly simply behavioral rules. Agent-based modeling provides one way of exploring functional relationships between different elements of a system.

6.1.1 Definition

We will use Gilbert's definition of agent-based modeling in order to introduce the full potential of this technique: "agent-based modeling is a *computational* method that enables a researcher to create, analyze, and *experiment* with *models* composed of *agents* that interact within an *environment*."[158] Gilbert's highlighting already stresses the most important terms and we will address those shortly.

The most basic term in this definition is "model", since anyone who creates an agent-based model is always a modeler. No matter how a researcher may approach a theoretical question, he will most likely have some kind of model in his head about how things relate and he will choose a technique that should be able to provide some insight to his research question. In all those cases, he will have some kind of mental model as the basis.[159] In order to find more details on relationships in the world, he will have to create some simplified representation of the world where his specific subject can be addressed. "Models don't stand or fall on their detailed verisimilitude, but on their capacity to capture the essence of what is already known about a phenomenon and to generate expectations concerning what more might be discovered if the scientist were to look where the model pointed."[160] This means that we have to make sure that our model will be rightly aimed at our research question and that we have to be able to justify the diversions from reality.

In order to increase the understanding of mechanisms in a social system, some forms of modeling are better suited than others. Gilbert introduces four different types of

[155] Sometimes, ABM is also referred to as multi-agent simulation (MAS) stressing the importance of simulating the interaction of several distinct entities.
[156] cf. [Gard70]
[157] [Sche78]
[158] [Gilb08], p. 2
[159] see for example [EpstJ08]: "Anyone who [...] imagines how a social dynamic [...] would unfold is running *some* model."
[160] [ThDe09]

models and argues that scale models – small scale representations of the explanatory situation –, analogical models – metaphor representations of the problem in question –, and ideal-type models – the environment is stripped of some complicating aspects – may be best suited to explain why systems react the way they do and help understand emergent structures. Mathematical or equation based models – the fourth form – may have limits in explaining why certain structures emerge, because they follow a different approach. They are often designed to fit to underlying data, but not necessarily from "theorizing about the behavior of the firm"[161]. Furthermore, often dynamic general equilibrium models use numerous restrictive assumptions and it is not clear "how far findings, obtained under theses simplifying assumptions, carry over to scenarios where agents are heterogeneous or out of equilibrium"[162].

The model we will develop is based on the scale and the ideal-type approach meaning that we will reduce complexity of the model by both reducing the amount of dimensions which could be relevant as well as removing some factors which will further complicate the situation. The important task will be that our model does not lose the explanatory power because we may have removed important aspects.

Agent-based modeling is further defined by the use of agents. While there is no universal definition on what an agent is[163], there are certain characteristics which are widely accepted:

An agent is "a discrete individual with a set of characteristics and rules governing its behaviors and decision-making capability."[164] This means that each agent is an object which can be distinguished from its environment and other agents which may live in the same space as the one in question. Consequently, this makes it possible to give each agent an individual set of characteristics in order to create a heterogeneous world and allow for the simulation of diversity.

Furthermore, an agent has four distinct categories of behaviors and characteristics.[165] Firstly, it has to be able to act autonomously in its environment which means that the agent can execute behaviors at certain points if it feels that this is favorable for reaching his goal. In our simulation, it can be a successful inventive endeavor which the agent chooses to implement into an innovation or the choice of a high risk or a low risk capital investment.

[161] This paragraph is based on the argumentation in [Gilb08], pp. 4. The quote is from p. 5
[162] [DaGHKWN08], p. 251
[163] Useful definitions can be found in [JeWo98], [Axtel00], [Gilb08] or [MaNo06b].
[164] [MaNo06b], p. 74
[165] The four points presented draw on [JeWo98], pp. 2

Secondly, the agent has to be responsive, which means that it has to be able to react to changes and input from its environment. This creates a more realistic scheme of interaction where the individual agent will take into account everything that happens in its specific surroundings which is different from the situation of other agents who may be exposed to different environmental stimuli. In our model, agents will, for example, react to a change in the interest rates offered in their neighborhood.

Furthermore, an agent is supposed to be proactive, which implies that it is capable of generating actions by its own initiative in order to reach some goal or desired objective. Through this capacity, they change from being objects to agents who will actively decide to implement some action or show a certain behavior. In the presented simulation, we will find this proactive behavior for example when the agent decides to move somewhere else in his environment.

Lastly, the agent has to be able to interact with its environment and the other agents in the simulation. This means that an agent can exchange messages with another agent and react to those inputs. Furthermore, it allows for an interaction between the actors in the simulation. The model which we will explain in chapter 7 will have agents who communicate with their peer network on risk related aspects and can therefore influence others as well as they are influenced by others. Consequently, this creates very quickly a complex structure of reciprocal influence.

Our definition above also referred to the environment in which the agents are placed. This may be understood to be a space but it can just as well be a theoretical context in which agents interact. In our model, the environment has the simple representation of a square on which the agents are living. Nevertheless, the funds for example can be understood to be close or distanced from an individual not in spatial dimensions but relating to their investment strategy.[166]

Furthermore, agent-based modeling is mostly based on computational methods since the calculations can grow very complex and their amount grows very large once we allow a number of agents to interact with each other and with the environment in several consecutive time steps. The great advantage of the last years is that computational power is highly available and many complex calculations can be left for the computer.

Lastly, Gilbert's definition above pointed to the idea of experimenting. In social sciences, it is very difficult to conduct experiments as we do in physics. Since we deal

[166] We elaborate on this argument in section 7.3.3.12.

with humans, we can never start two experiments with identical points of departure since we either have to choose groups of different humans or – if the same group of individuals is taken – they will have the experiences from the first experiment when the second starts. Furthermore, they will know that there is an experiment done on them and they might change their behavior, or we may face some ethical concerns because of the implementation. Besides, an experiment which might last for several years can probably only be run a few times in the course of a researcher's professional life. So, it is impossible to create the situation where a treated group can be compared to an untreated group and we can generate a "ceteris paribus"-situation where only the one impact which we are trying to investigate is changed. Therefore, experiments in social sciences always have to accept considerable limitations if they are attempted. Modeling has the limitation that we have to find a way to define, in very precise terms, the world which we try to analyze and that we probably have to reduce the complexity in order to be able to present our research question. But once that is achieved then we can experiment very well and in a very extensive form with this model and see if we can derive valuable insight from its results.

6.1.2 When to use ABM?

Computational modeling offers great benefits, but it also has its shortcomings. We will use this section to shed light on the advantages that this form of theorizing offers and discuss the aspects where other theoretical approaches may lead to better solutions.

There are several reasons why agent-based models may be employed. Their usage may be valuable even though a mathematical representation of the situation is possible and solvable. Nevertheless, the main advantage arguably lies in the simulation of relationships which cannot be solved mathematically. In such a situation, if an agent-based model can be formulated which uses the same or related assumptions then the insight created from its different runs can help solve the research question.[167]

Furthermore, we have to note that agent-based modeling requires the researcher to be very specific about each and every assumption he takes in the model. "[T]he simulation format does impose its own constructive discipline in the modeling of dynamic systems: the program must contain a complete specification of how the system state at $t + 1$ depends on that at t and on exogenous factors, or it will not run."[168] This quote underlines that in order to program a model that is supposed to

[167] cf. [Axtel00]
[168] [NeWi82], pp. 208

show some cause-effect relationships you will have to specify every detail of the process. No implication or self-evident linkage can be left out and this makes a computer based model extremely transparent and reproducible.

On a general basis, we can identify three large advantages of agent-based models:[169]

ABM can show developments:

Once several individual agents interact over a longer period of time, we can see certain patterns and structures emerge among them. It is either very hard or maybe even impossible to figure those out by analyzing the behavior of a representative member of this group. This can be due to the fact that the sum of the interactions does not equal the development of the overall system. For example, we can observe that traffic jams move "backwards" along highways.[170] This can be explained by the fact that cars may be able to drive again at the beginning of the traffic jam, but that the newly arriving cars still approach cars standing at the end of it and are forced to stop. Consequently, the traffic jam is growing at the end while it dissolves at the beginning and we can see it moving backwards along the highway. This development may seem to also be analytically presentable in this example which is due to the low complexity. Nevertheless, it serves very well to illustrate the possible discrepancy between the individual behavior of members of a system and the system's behavior we would intuitively expect, and the observed phenomenon in the overall structure. The way agent-based models are designed we can easily grasp those developments.

ABM offers a natural way of describing a system:

While classical methods tend to try to describe the activity within a system through sets of equations, agent-based modeling starts at a very different level. Instead of an analysis of aggregate values, it can start with a description of the behavior of the individual elements which make up the system in question and watch the aggregate states which emerge from it. Traditional methods could, for example, measure the density and the flows of visitors of a shopping mall and represent those at least in an approximate way by equations. ABM, on the other hand, can offer a system where the behavior and the moving patterns of the individual shopper can be modeled and the consequences on density and flows of visitors can be endogenously created. "Agent-based models are well designed to handle any of these situations, since they can specifically model agent interactions in any arbitrary space."[171] This bottom-up

[169] cf. [Bona02]
[170] For an example, we point to a very intuitive simulation and presentation from [Trei10]
[171] [LeWi08], p. 143

approach furthermore offers the ability to explore in the model the effects of changes in the behavior or the environment, which may not easily or intuitively be predicted in a classical representation.

ABM is flexible:

Agent-based modeling offers in many dimensions a higher degree of flexibility than other methods. It is possible to vary the amount of agents within a system or change their setup fairly easily, because the simulation will then integrate those changes and it is possible to watch the outcomes change. This allows for an adaptation of behavioral patterns, a change in reaction and interaction structures or a modification of properties of the individual agent. Furthermore, different levels of aggregation can be watched at all time steps during the simulation and simultaneously, making it easier to find the underlying reasons behind an observed development. Often enough, the overall behavior or even emergent strategies in the individuals' actions and reactions may surface and evolve during the course of a simulation making it possible to include group effects from an individually based perspective.[172] Thanks to this flexibility it is not necessary that we find in the beginning the one exact calibration of the model or define the desired level of aggregation. It allows the analysis of the model's evolution and its outcomes from many different perspectives. Furthermore, it allows other researchers to possibly use the same model for research on a different research question.

Those are the most prominent advantages of the agent-based modeling. We will now discuss some of the difficulties which have to be respected when creating or analyzing the models. One dilemma which every modeler is facing is that he has a vast array of possibilities to make the simulation ever more realistic and refine the assumptions so as to match the real world example. This will however create a complexity in the model which requires the designer to specify how many underlying processes evolve. "These all involve many design choices and may include many low level parameters for which economic intuition is almost nonexistent."[173] Consequently, it is important to demonstrate very diligently why specific design choices have been taken[174] and open the source code allowing others to reproduce the results and test other specifications.

[172] cf. [LeWi08]
[173] [LeWi08], p. 145
[174] This includes the fact that the implementation in the software environment should be presented in a way which is understandable to researchers who are not fit in the specific programming language.

Another aspect that is often criticized in agent-based modeling refers to its ability of precise predicting. It seems that when it is impossible to give a clear outcome of a situation that then, the model is not worth anything. The computational model then appears to be hard or impossible to test because there is no way that this result can be mapped to reality. In fact, while it is true that computational models will hardly ever come up with one (equilibrium) result and therefore seem to be incapable of predicting, we have to stress, though, that agent-based models offer ranges of outcomes.[175] Most mathematical models which will offer a single point solution are then compared to a set of data from the real world, where we try to factor out the influence investigated and try to falsify or support the formulas employed. So this means that traditional approaches compare a point to a cloud. In computational models, we run a simulation a number of times and will receive a cloud of results from those different runs. In order to test the model for its plausibility, we can then see if the reactions seem comparable. So, now we do not have to eliminate all kinds of noise from the results in the real world, but take the real world data as is and compare it to the different outcomes of the simulation. This means that we do not match a point to a cloud anymore, but that agent-based modeling allows us to compare one set of data to a second set. In other words, we are "comparing clouds to clouds"[176].

Furthermore, the simulation may lead to a cloud of different outcomes given a set of assumptions for a model. This leads to the situation where each researcher can compare the model setup to a real-world problem and find linkages or differences which may allow the reasoning of why situations evolved differently than in the model or how changes to the real system may influence future development. No economic problem can be dealt with by using easy methods because of the complexity of the world in general. Even Marshall noted this when writing: "The fact that the general conditions of life are not stationary is the source of many of the difficulties that are met with in applying economic doctrines to practical problems."[177] Since we cannot systematically forecast what will happen in the future, having models which may highlight certain influences and dependencies on a broader scale can increase the possibility of keeping a certain flexibility in the system in order to respond adequately, even to unexpected and therefore unprepared events.[178] In this context, agent-based

[175] cf. [MiPa07]
[176] [MiPa07], p.75
[177] [Mars61], p. 347
[178] cf. [Dwye07]

models can serve as “computational laboratories”[179] where it is possible to test and explore the effects and consequences of certain characteristics on the entire system.

6.1.3 Particularities of ABM

In this section, we will introduce some aspects which are worth considering when analyzing agent-based models in order to be able to evaluate their concepts and estimate the potential usage of a specific simulation.

6.1.3.1 Dimensions

With respect to the multitude of agent-based models and simulations referring to different societal phenomena, it may be worthwhile to structure them in different dimensions in order to better evaluate their concept:[180]

Abstract vs. descriptive models: we can differentiate models by the degree to which they are meant to focus on the reality as prototype. Some models prefer a high specificity in details in order to mimic certain developments while other models use strong abstraction in order to better illustrate the underlying research focus.

Artificial vs. realistic models: Some models use assumptions which cannot be met in the real world in order to analyze the potential of certain development paths.[181] On the other hand, modelers may wish to design their models as realistic as possible.

Positive vs. normative models: Positive models are generally used to explain phenomena and developments and find the underlying reasons leading to their emergence. Normative models, on the contrary, focus on generating policy recommendations which can be used in real world problems.

Space-related vs. network-oriented models: The former will try to simulate agent behavior in an environment which can be understood as a clearly defined space. The large field of geographical information systems (GIS) simulation includes very precise geographical data in the simulation in order to improve the interaction of the agents with their environment. On the other hand, models may not require a clear space-based definition of the agents’ environment and may focus on the networks between the different actors in the simulation in order to focus on different aspects of interaction.

Complex vs. simple agents: Finally, we can create agents with high artificial intelligence which can adapt in a very elaborate way to their surroundings or we can

[179] [PyFa07], p. 473
[180] cf. [Gilb04], pp. 6
[181] [Dora05], for example, simulated the behavior of agents who already knew their future.

create agents with precise and simple behavioral rules depending on the goal of the simulation. We will treat agents more closely in section 6.1.3.4.

6.1.3.2 System setup

In this section, we will sketch a rough draw of the central components needed in an agent-based model[182], so that the presentation of the design in chapter 7 will be comprehensible.

Discrete time steps: most models are created in an environment where we use discrete time steps which can be understood as different durations in the real world, such as for example a year or a week. There are models where the simulation is event-driven and not every agent will be active at every time step[183], but even then time is evaluated in discrete ticks.

Agents: The agents are the heart of the simulation since they incorporate the behavior and will act or react to environmental stimuli. We will treat them in more detail in section 6.1.3.4.

Micro States: Every agent will have a set of properties which can change in reaction to his own actions or as a consequence of influences from the environment. Some may even change on a regular basis such as for example the age of the individual. Other possible variables in this category include the income of the agent or his risk aversion.

Micro-Parameters: There are certain parameters which are innate in each agent and which cannot be changed during the course of the simulation because they do not rely on any endogenous development within the model. In our precise case, micro-parameters of an agent can be the amount of innovations the agent's ancestors have successfully implemented.

Macro-Parameters: While micro-parameters are linked to each agent and can be different between agents, macro-parameters apply to the overall simulation environment and are constant for every agent and over time. This means that they characterize the fixed surroundings and settings in which the simulation is placed. Examples for macro-parameters include minimum ages required for working, the available levels of education or the geography of the space in which the agents interact.

Interaction Structures: They describe the relationship which may exist between agents and which express the influences and interactions which are possible on the micro

[182] cf. [PyFa07]
[183] cf. [Gilb08]

level. The interaction structures can be modeled as networks or as spatial possibilities to reach, communicate with and influence other agents in the simulation.

Micro Decision Rules: The rules shape the behavior of the agents. Depending on his micro states, his micro-parameters, the macro-parameters, and the interaction structures an individual will decide on his actions and reactions in the current time step. The agent's micro-states and his interaction structures can be influenced by his decisions and the consequences of his choices. Moreover, his actions may have an effect on the environment and specifically other agent's micro-states or their interaction structures leading to possibly very complex structures.

Aggregate Variables: In order to analyze some meso- or macro-level influences and cause-effect-relations, it can be useful to aggregate micro-states of the agents to higher level variables.

Consequently, a certain initial setup of the environment and the agents will lead through the application of the micro decision rules as well as the interaction structures to a situation, where the system can start a dynamic development on its own and where the outcome may not be readily guessed.

The difficulties lie in judging the complexity which should be included in the model design and in the way the problem is approached. The dilemma lies in the fact that the more realistic and detailed a simulation gets the less transparent and understandable it will become.[184] This leads to a situation where it may be more difficult to infer certain relationships between influences. It seems that most agent-based modelers have tried to solve this dilemma by stressing to use the KISS-approach. [185]

Models are first and foremost meant to be simple, so that they do not carry in them ideas and influences external to the research question. "Modeling is like stone carving: the art is in removing what you do not need."[186] Once a model is set up, understood and running, we can add complexity and try to reshape it to better serve certain ends. Nevertheless, it is important to keep a clear and well justified system setup to which more and more aspects can be added through future research. Otherwise it may be hard to identify the mechanisms and the cause-effect relationships within the system which limits the explanatory power of the system.[187]

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[184] cf. [PyFa07]

[185] KISS is the acronym for "Keep it simple, stupid!" Cf. for example [EpAx96], p. 22, [MiPa07], p.246, [GiTr05], pp. 19 and 201, [Gilb08], p.33

[186] [MiPa07], p. 246

[187] cf. [DePy09]

6.1.3.3 Time

One aspect which is different in computational modeling is that we have to devote special attention to time in the simulation process.[188] In regular neoclassical models including dynamic programming approaches as we discussed in section 5.2, all actions are supposed to happen simultaneously or sequentially and then we can derive certain conclusions. This leads us, for example, to the conclusion that in a homogenous market with perfect information, the price will settle in a position where supply matches demand. Time is not considered to be a decisive criterion since both actions – the adaptation of demand and of supply – are considered to be equally influential for the eventual equilibrium found in the market.[189]

In a computational model, we can easily match this behavior by defining consuming agents and supplying agents. The consuming agents will look at some values (maybe prices for homogenous goods) and make a decision about how to behave during their next move. Similarly, the producers will look at some values and decide which quantity and which price to offer upon their next step. This will not yet uniquely define a computational model, however, since nothing has been said so far about the frequency of the different behaviors. How often will the consumers make their decision and how often will the producers react and revise their action? It is important in agent-based modeling to consider the timeline of events and justify why an event is triggered at a specific moment. Additionally, while this issue may be left implicit in any other kind of model, the computer needs the specification about which action to implement and when.

While it may seem trivial at the example of finding a market-clearing price in one market, this becomes a very important aspect in more complex models where interaction between agents happens at different levels.

Additionally, it is important to figure out where the simulation will start. While it is easy to define the time to start in the model, it is not trivial to relate it to a starting point in the real world problem which the simulation is meant to help shed light on.[190] This means that while the simulation has a clearly defined starting point, there is hardly any development in reality which starts at a given point zero. Therefore, the

[188] cf. [Vale99], pp. 3f

[189] In his *Principles of Economics*, Marshall stated that "[w]e might as reasonably dispute whether it is the upper or the under blade of a pair of scissors that cuts a piece of paper, as whether value is governed by utility or cost of production"[Mars61], p. 348

[190] cf. [Gilb08]

modeler is required to explain the specific initialization methods of the model which create the starting point for the simulation.

6.1.3.4 Definition of the agents

In many models of traditional economics, the behavior of the people is assumed to be that of a homo oeconomicus who will behave rationally in a utility maximizing way and in always the same manner given the same decision problem. This assumption has allowed many great models and advances in explaining economic phenomena and it proved to be very valuable for numerous economic theories.

Nevertheless, there are many critiques to using this hypothesis and – particularly in the strand of behavioral economics – economists have tried to abstract from this principle. In many experiments[191], economists have shown that in countless cases humans do not follow a simple strategy of utility maximization but that they also try to use simplifying heuristics and surface a "satisficing"[192] behavior meaning that they will not necessarily try to reach the best case solution but that they are willing to settle for a successful solution. Nevertheless, abolishing all kinds of rationality from an individual's behavior would not be a sensible solution either. "Our modeling of social agents tends toward extremes: we either consider worlds composed of remarkably prescient and skilled agents or worlds populated by morons. Yet, we know that real agents exist somewhere in between those extremes."[193] It is therefore important to carefully shape the agents and their behavioral patterns to be designed in a somewhat similar way to how they would behave in a real world environment which may be governed by bounded rationality, chances, or accidents.

"It is specifically the stochastic nature of innovation processes in particular, and economic processes in general, that leads economic agents to use routines."[194] So, while some concepts can be analyzed on a macro basis ignoring the underlying interdependencies on the micro and meso levels, it may seem shortsighted to explain the creation of economic structures without a micro economic theory supporting it. In some cases, reducing the model to a macro-based approach can help limit the complexity of a model and can be the only possible way to actually analyze some effects. Nevertheless, today's computational capacities and the strengths of the

[191] see for example [Xlab10]. For a critique on those experiments and their explanatory power as well as a defense for the concept of the homo oeconomicus, see [EpstR08]
[192] [Simo59], pp. 262ff
[193] [MiPa07], p. 28
[194] [Engl94], p. 227

simulation tools, enable us to set up a much deeper analysis model and include the micro economic factors that actually create the macroeconomic structures.[195]

Consequently, we will define sets of rules which govern the agents' behavior and will allow them to act and to react to certain environmental stimuli or to input from their peer network. The rules we define are meant to be simple and easy, so that the model will not lose too much transparency. Further research can add to those rules and enlarge the model in order to increase the explanatory power.

A second aspect concerning the agents is the homogeneity of their characteristics and their behavior. In many traditional models, we had to assume an average person of the group to be the "representative agent" and we would set out to model his behavior. Yet, while it may be possible in some cases to assume homogeneity in the specification of different members of a group, this may be harmful in some other cases to the conclusions drawn concerning the overall dynamics of a system. Homogeneity and average behavior can lead to inferences which defer widely from a heterogeneous representation of agents within a group.

We will use an example to show where those differences come from and why it is not possible to make up for them in a model using average behavior.[196] We will consider two different cases where heterogeneity will have a stabilizing effect in the first setup and a destabilizing and reinforcing effect in the second. Both effects cannot be reproduced in a model based on homogeneous representative agents calibrated to reflect the average member of a population due to the lack of including feedback loops.

In the first case, the idea is that bees can help control the temperature in the hive. If all bees start their cooling or their heating activities at the same time because the "average bee" is feeling uncomfortable, then the hive will see strongly fluctuating temperatures. If, on the other hand, bees have different temperatures at which they engage in those regulating activities, then we can observe a fairly stable temperature curve for the hive. This is due to the decentralized reaction of the individual bees which will not all cool, heat or stop at the same moment.

The second example takes the defense reaction of the hive to show how positive feedback in a heterogeneous setting can lead to a rather instable situation. If in the homogeneous case, each bee will start to defend the hive once it sees more than 50 bees engage in defensive action, then this will be the threshold below which the

[195] [Day08]

[196] This example is taken from [MiPa07], pp. 14

population will not show any reaction and above which the whole hive will start defending. In a situation, however, where each bee has an individual threshold which can range from 1 to 100, then stimulating one single bee to a defensive reaction will make the whole population defend the hive. A bee with a threshold of one, that sees one other defending the hive, will join the action. Since now there are two of them, those with a threshold of two will join in. Consequently, while in the homogeneous case the impulse had to be of at least 50, an impulse of one is sufficient in the heterogeneous case for a reaction of the entire hive.

From these two examples we can see that the emerging behavior of the overall system can be dramatically changed by assuming heterogeneity within a population and including feedback processes into the group behavior.

An advantage of computational models such as agent-based models is the possibility of diligently specifying the individual agent's behavior. Then it is possible that there is no longer the absolute need to homogenize the group of individuals allowing different agents to react differently in seemingly identical situations due to different preferences or characteristics. Moreover, we can open the behavioral rules to interaction, learning and adaptation and therefore integrate a social component into the dynamics. Accordingly, the agents can be specified in a more realistic way and we can allow the model to become more complex.

6.1.3.5 Verification and validation of the model

Once the model is designed and set up in a sufficient way and implements the desired behavior, the modeler will have to test if it runs properly and without errors and then he will focus on the validation of the model.

The more complicated a model gets, the harder it is to make sure that certain results are due to emergent behavior within the system and not mere effects of programming errors. The task is even more complicated when dealing with computational models since they often use random numbers in order to simulate stochastic processes. Consequently, each run of the simulation will be different and it may be tedious to track each program step since the amount of random numbers entering in the process can be substantial. Sometimes "it is only the distribution of results which can be anticipated by the theory."[197]

Therefore it is crucial to devote sufficient attention to the debugging process of the model as well as the verification of the integrity of its interior methods. It may also be

[197] [GiTr05], p. 22

useful to add some control variables to the model which help to verify the proper run. Besides, tracking certain steps or specific agents may help find programming errors or the causes of unintended consequences within the behavior of the simulation.

The validation part of checking the model is no longer linked to finding internal errors, but rather deals with the question if the model is designed to meet its target and provide insight to the research question considered. There are several issues which can make it difficult to actually validate a model on real world data.

The more abstract a model is the more difficult it will be to validate it against any data because the modeled scenarios do not exist in such a form at all.[198] Validation can then consist in checking if the emergent structures lead to an expected or an explainable result and if it is possible to add theoretical insight from the models' outcomes. Then those results can be mapped against real world observations in the desired field of attention and they can be judged at least on the plausibility of the argument.

The goal can be in finding certain characteristics that may be important both in the real world and in the simulation and to add those to construct less abstract models in further research where certain emergent situations can be better related to data.

Furthermore, there are some important arguments to respect which make a clear validation difficult and which have to be considered when interpreting the results.[199] Since most simulations include random number and since we find stochasticity in the underlying real world phenomena, we can certainly not expect a direct correspondence of the results. Comparing clouds of results to clouds of data may help estimate the validity of the model. Additionally, most results depend on their own history. This means that the initialization is crucial to the results and it may be impossible to start them with the same setup as the realistic prototype situation. This can also lead to situations where models may be incapable of reproducing certain realistic aspects even though they seem very well calibrated and show expected developments. Then the validation has to rely on sensible interpretation and explanation of why certain aspects may distort the results. Sometimes, however, the problem may not be on the simulation's or the programmer's side, but it can be hard or even impossible to obtain correct data about the modeled target. Then again it is important to check if the model's results can be explained by a theory or if the reasons for certain developments within the system can be found through the observation of the individual agents.

[198] [Gilb08], pp. 40

[199] The discussion follows the argumentation in [GiTr05], pp. 23

Once a model is believed to be valid, sensitivity analysis will help check for the robustness of the emergent developments and may show certain thresholds and tipping points to consider. It may also add to the insight on the usefulness of certain assumptions if the model seems to be overly sensitive or not reactive at all to changes in certain variables which are supposed to be important for the simulation. Therefore, a sensitivity analysis should check the results of different runs[200] and different initial situations.

6.2 Agent-based Computational Economics

Generally, agent-based modeling is possible and feasible for all kinds of sciences and domains where individual entities interact in a certain environment. Since we will focus on an economic research question within the field of social science, we may turn to the field of agent-based computational economics (ACE). It can be defined as "the computational study of economic processes modeled as dynamic systems of interacting agents."[201]

We can point to four distinct focal points of ACE which also suggest the wide field of potential application. The first deals with the understanding of the emergence of global structures in a decentralized economic setting even though there is no planning or control of any superior institution. The main idea is to explain why specific individual actions of intelligent and independent actors can lead to regular structures in the overall market. As we can see in the many real world economic developments and as Adam Smith has explained so accurately as an invisible hand[202], we often find situations where the result would make us suppose a concerted action while no central coordination between the individual actors generating this result has ever taken place. The micro-based explanation of emergent patterns and structures which may be stable over time or keep evolving is the central aim in this strand of agent-based computational economics.

The second aspect where ACE-methods show promising opportunities is that an agent-based model can serve as a form of laboratory in which different consequences and situation can be analyzed. The goal is to test, understand and possibly predict in a normative way the consequences and effects that different specific socio-economic

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200 This could be done, for example, by using the same initial setup but different random numbers.

201 [Tesf07]

202 Smith puts it very fittingly when he points to the fact that it seems as if the actions of an individual are "led by an invisible hand to promote an end which was no part of his intention." [Smit76], Book IV, chapter 2.9

constellations have on the behavior of individuals, on the interaction within existing or newly formed networks, and on economic growth and wealth in general.[203] "The general approach is akin to filling a bucket with water to determine if it leaks."[204] It is all about creating and installing a system where it is possible to test and explore which circumstances make it efficient, fair or structured.

The third focal point is a descriptive approach where the main goal is to explain why certain structures and forms of collective behavior can be seen in the real world and why others are not apparent. Models following this idea are mainly trying to promote the understanding and theoretical insights in the economic theory. Agent-based models will then be used to test which influences, characteristics and interaction patterns are theoretically suited to create such a development or which ones can be ruled out to be responsible for creating observed structures.

The fourth strand of ACE-research finally concentrates on factors which can improve agent-based models so that they can provide better use for economic research questions. This relates on the one hand to a better use of the technology available meaning the computational power of the hardware as well as the offered potential of available software environments. If the technological progress can be used to improve the scope of agent-based models, then this way of theoretical reasoning may increase in acceptance. On the other hand, part of this argument is also the work on existing models and their processes of creation, implementation, documentation and exploitation.[205]

The individual behavior of agents, their reaction to the specific environment and surroundings as well as the influence which the behavior of other agents triggers in the them often limit the ability to express those interrelations in a formal way and make it difficult or even impossible to solve these problems in a mathematical way.[206] In those cases agent-based modeling offers a very powerful alternative; for some researcher it seems to be the only one which can be used.[207]

Agent-based modeling has started to appear in several fields of economics with highly different research questions.[208] The same is true for many fields of business

[203] cf. [Tesf01]
[204] [Tesf07]
[205] cf. for example [PoPBG08]
[206] cf. [LeWi08]
[207] cf. [AxTe06]
[208] [LeWi08] cite in their "Special Issue on Agent-Based Models for Economic Policy Advice" eight additional special issues from the years 2001 to 2007, not including the "Handbook of Computational Economics, Vol 2" by [TeJu06]

administration where agent-based modeling offers just as valuable a way to approach decision problems.[209] Nevertheless, there are some drawbacks linked to this gain in popularity. Since there is no unique form of standardizing agent-based models, many researchers work in their own ways making the comparability of models difficult.[210] This has the great advantage that many different possibilities will be examined, explored and tested. Nevertheless, it requires a larger effort to evaluate the validity and the relevance of models and simulations. Therefore, it is crucial to secure the reproducibility and the transparency of the model, as well as to specify clearly the implementation of the simulation. Unfortunately, this has not always been the case in the past.[211] Consequently, we devote special attention in the next chapter to a thorough presentation of the setup, design and implementation of our model along with the entire source code in the appendix.[212]

[209] see for example [DeKl10], p. 11
[210] cf. [PyWe09], 1.2
[211] see for example [DeKl10] for a critique
[212] The complete source code is reprinted in appendix A, the additional files used in Repast S will be voluntarily provided upon request by the author.

7 Modeling the relationship[213]

Since we can argue with Schumpeter that the understanding of modern Western lifestyles is more and more focused on a culture "in which the economy in its social totality does business by making the individuals or groups be economically active"[214], we will focus on the individuals in this model and their role in the process of generating innovations. Our model will try to provide some insight from a micro-based perspective by focusing on the individual agents and by analyzing the emergent structures. This chapter will be used to present the model design and explain its setup.

There are tendencies in agent-based modeling suggesting that models should also be able to offer normative approaches and insights for political questions and topics. "ABMs can and should be employed to address policy issues as well. [...] Thanks to the flexibility and the power of agent-based approaches, it is easy to conceive frameworks where policy experiments are carried out to evaluate the effectiveness of different policy measures (e.g. anti-trust policies), for a range of different institutional setups and behavioural rules."[215] Corresponding to this idea, the model presented here is meant to take a closer look at the consequences of a political decision of voters – to individually deal with existential risks or to see them covered by a social insurance scheme - on the future orientation of a society. Even though the model is certainly artificial and abstract, it may open up new ways to approach this topic and offer new insight.

Every model is connected to some assumptions and hypotheses which are taken in order to be able to find any correlations and cause-effect-relationships. Those assumptions necessarily simplify the modeled situation and consequently, the results can only be partially copied in any real world situation. Nevertheless, establishing a model at a 1:1 scale would not be a copy anymore but an image of the real world and it would not allow drawing any more conclusions than we already can in the real world. Accordingly, we will use our assumptions in order to sufficiently simplify the situation so that we can point to some underlying mechanisms and correlations.

The model, which we will develop here, will deal with two extreme situations where we will suppose no social insurance whatsoever on the one hand with agents who face their risks on their own and an unconditional insurance scheme on the other which will

[213] For reasons of simplicity and to avoid misunderstandings we will refer to the agents in the models with female pronouns while we used the male pronouns in the theoretic foundation.

[214] [Schu34b], p. 133: "in denen das soziale Ganze wirtschaftet, indem es die einzelnen Individuen oder Gruppen wirtschaften läßt"

[215] [PyFa07], p. 485

always pitch in when an individual finds itself in existential distress. The analysis will then look at the different innovation potential in each situation corresponding to the two very distinct ideas of social life.

When it comes to implementing the ideas we described above in the model, we have to be very thorough as to watch at the proper transformation. Therefore, we will proceed very diligently to present the model and its underlying ideas as well as the precise implementation.

7.1 Interest of the model

Most western economies offer some degree of social insurance and as we have discussed in chapter 5 there are very different practices of securing the standard of living of members of the society who are in need. On the other hand, the history of social security shows that most of those systems have been developed as a reaction to similar problems and with the same ideas in mind. Poverty and extreme forms of distress which were perceived to be exorbitant in the society – probably compared to the predominant standard of living – and which lead to a feeling that society had the obligation to help those people. If this was forced upon the system by worker's demonstrations or by the discomfort of the ruling elites is not important for the outcome. Yet, we realize that the logic of social insurances is based on very static arguments of fairness and social peace. Those may be very valuable arguments, but they will leave the dilemma for each politician that they could potentially endanger the economic goals of increasing the overall wealth of the members of the society. Therefore, the model which we will develop will approach the question of social insurance from a future-oriented perspective and will try to add insight to the idea that a social insurance scheme might have a positive effect on the innovativeness of the citizens and therefore serve as a motor for future development which will benefit the entire society. As a consequence, we could argue that the static dilemma of relocating resources for reasons of fairness and social justice, is one side of the coin which holds the promise of successful growth in the future on the other side.

On the other hand, our analysis could have shown that the perceived dissonance between social security and an optimal allocation of resources is even strengthened when we look at a dynamic situation. Then we would have had to think of new or better forms to achieve our goal of social peace and basic protection for those in need while aiming for sustainable and advancing development of the economy.

The interest of the model is therefore to propose an evolutionary perspective on the justification for social security measures and to provide evidence from a dynamic modeling environment towards the question of innovation promotion through the protection against existential risks.

We could now propose a model which only focuses on the activity of innovation where we leave out the generation of income and abstract from the provision for risks in the behavior of the individual agents. There are some advantages that such an approach would entail. It could be enough to generate a model of innovation where we set up a concept of how risk, uncertainty and other criteria influence the propensity of heterogeneous individuals to innovate. This model could already give us a good idea if it is possible at all for a government to stimulate innovation by risk management. It would ease the burden of defining the behavior of individuals in many decisions such as related to their consumption or their risk provision. By keeping the model as simple as possible we could better concentrate on the underlying dynamics and their foundations in the agents' actions.

Yet, when trying to assess the influences which a social insurance scheme will have on the innovativeness of the society and therefore its future orientation, we may not overlook that such an insurance will have repercussions on the saving and provision strategy of an individual which will in turn influence again the innovative behavior. By focusing only on the field of inventing and innovating, we would deprive the model of this influence and therefore ignore one of the great advantages of agent-based modeling which is the integration of those reciprocal cause-effect chains. Consequently, it is important to implement the entire life-cycle of the economic life – which may be abstracted and simplified more or less strongly – in order to include the dynamics of this process even though this adds to the complexity and requires more assumptions on the behavior. Still, further models will be able to use those results and approaches to relax some assumptions or use different hypotheses to further increase the robustness of the conclusions which can be found in this context.

We will now present the fundamental hypotheses relating to the two different basic models and will then explain in detail the setup of the model.

7.2 Fundamental hypotheses

"All theory depends on assumptions which are not quite true. That's what makes it theory."[216] Whenever we try to explain economic or social outcomes, we need certain hypotheses which help us to abstract from the real life cases. Any model has to simplify reality otherwise it would not be a model. Following this approach, we have used a few fundamental hypotheses around which the simulation has been designed.

The basic idea of this work is the juxtaposition of the consequences which different societal systems have on the innovative activity in the community. Intuitively, almost everybody will agree that the form of organization of the public life will have an effect on the life and the way of living of the people. Similarly, it is possible to compare historically different systems and one will find that there are differences in the inventive activity and the speed of technological change.[217] It is beyond the scope of this work to empirically explore the exact influences which the societal structure had in each case, but from these two aspects, intuition and historically visible differences, we derived the motivation to try to model a correlation between the innovative activity of a society and one component of its form of organization, the insurance against life risks.

The innovative activity has been chosen as ultimate goal since it is both in the CNSE and in the Neo-Schumpeterian approach the central variable which guarantees future-oriented dynamics and progress in a society. Without innovation, an economy will eventually find an equilibrium state and will end in stagnation.[218] Innovation, therefore, is the driving force behind any improvement of the living conditions of the people. Even though not everybody can be an inventor – since you would need a certain know-how and high creativity – and not everybody can be an entrepreneur – many people will most likely lack the sufficient capital or the risk seeking attitude – every society needs a certain amount of inventors and entrepreneurs who will promote change and develop new products and services. The realization of innovations will create jobs and markets with a future potential – both of which are elementary preconditions for the prospects of the following generations. While it is true that not every job is in those highly innovative sectors, those are nevertheless the ones which drive the development and are able to attract the more traditional industries and their employment opportunities.

[216] [Solo56], p. 65
[217] cf. for example the data from [HeSA02]
[218] [Schu34b], pp. XXII

In the evolutionary context, it is important that many new entrepreneurial endeavors are undertaken since they will create competition and force the existing companies to be more dynamic.[219] The founders of the new firms generally do not hold a sufficiently large stock of capital and may face – especially in the beginning – large difficulties obtaining venture capital. This makes those drivers of innovation very vulnerable and dependent on future-oriented bankers. The close connection between the young firms and the financial markets as well as their consequences has been discussed in detail in section 4.2 and 4.3.

On the other hand, we will use the societal form of organization as a second important variable. The central question is if and how much the insurance aspect of the public system influences the innovative activity and, as a consequence, how much it contributes to securing the future of a social group. “In a capitalist economy, there are essentially two methods by which social choices can be made: voting, typically used to make ‘political’ decisions, and the market mechanism, typically used to make ‘economic’ decisions.”[220] Schumpeter goes even a step further and defines the three most important moments for an economy to be: (1) the goal is the carrying out of new combinations; (2) the basic phenomenon is the entrepreneurial function and the behavior of economic agents; and (3) the means to reaching the goal given the situation is the choice of the “social form: authority or credit”[221]. As a society we have therefore two distinct choices to make when discussing those topics. Based on these two ideas – the central focus on innovation and the decision about social choice – we construct our scenario which is implemented in the model.

We start from the idea that humans will gather in distinct groups and that these groups show different forms of organization. Those groups can most easily be thought of as different nations even though this is not a necessary interpretation. It could just as well relate to different regional cultures or forms of societal living or even supranational networks. The decisive assumption is that all people within one group are also living in the same system. This means that all choice processes which are done by moving to a different system[222] have already occurred and that everybody is happy enough with the one he is living in. In elections, there can be a choice of tightening or loosening the

[219] cf. [Welf99], pp. 105f
[220] [Arro63], p. 1
[221] [Schu34b], p. 110: “sozialen Form: Befehlsgewalt oder Kredit”
[222] This is to be understood in the sense of Tiebout’s model, where individuals may move because they do not like the system setup which has been voted to be used in this public entity. [Tieb56]

system's welfare guarantee, but at no times will a system switch from one state to the other.
As a reaction to the different attitudes people have towards different risks, different forms of insurance have formed just as we have explained in chapter 5. Following this analysis, we have chosen two different forms of societal order which will be modeled and investigated for their effects on the amount of innovations in a society. In the first form, the median vote has been cast for the solution that every individual bears her own risks ("Individual model") and in the other one the individuals will have chosen to bundle their risks collectively ("Governmental model").

The relevant risks fall into all phases of life. We assume that a person will be right away aware of her risks and will provide for them. As a child, she usually would not need as many resources as an adult to survive, but she will need money she can put into her education and training. We will abstract from the thought that generally a child is not able to make the supposed risk and preference considerations. The important thing is that the money she will use for her survival and her education and training are linked to her person. Since every youngster depends therefore on foreign resources in the beginning of her life, she will have to receive loans in the individual model in the simulation.
Once she starts working, she will be concerned with her job security and the potential threat of unemployment and provide for trying times when there will be no sufficient work income to finance her living. Besides, work income might be reduced due to health limitations. If the person is struck with illnesses, sicknesses or other impairments then she will not be able to generate the same income as in a healthy state.
Furthermore, an individual has to provide for the times when she will be retired and will no longer work. It is important to note that pension payments in our case refer to a basic guarantee of the subsistence minimum and not to a pension payment as it can generally be found in Western societies. The reason that we stress this differentiation is that there is a different incentive. While people today are happy when they receive their retirement payments for a long period of time, it is still not a desirable situation for the person living off the subsistence minimum in our simulation. Therefore, we can treat those pension payments just like the payments for the other risks where each time an individual has no interest to remain in this situation for a prolonged period of time.

From the different forms of facing the risks in societies, we design the two models and will explain those in detail here.

7.2.1 Individual Model in the CNSE

In this section, we will show how the individual model will blend into the three-pillar-design of the CNSE approach. We will focus on the way in which the citizens living in such a system will interact with the three different sectors, the real or industrial sector (I), the financial sector (F) and the public sector (P). In this setup, there is no public assistance in the case of a realized risk. Every individual lacking the funds to consume her subsistence minimum has to apply for a credit and find the necessary resources. If she fails to do so, she will starve and die.[223]

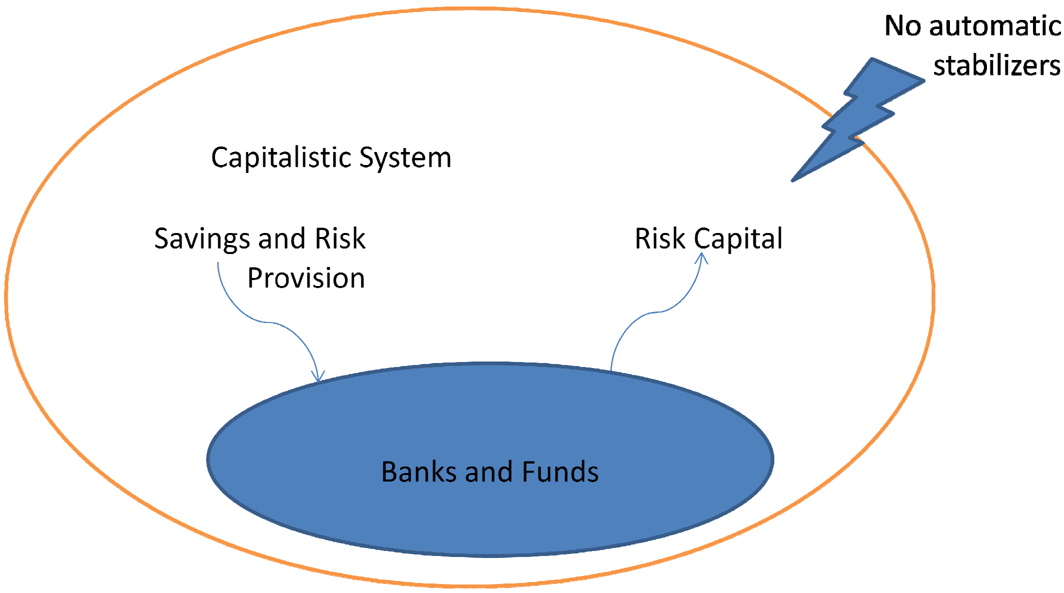

Figure 7-1: Individual System

In this situation, the capitalistic system is applied to the entire scheme of public life. It encompasses all forms of doing business, is present in all social activities and there is no influence from outside factors. This does not imply that there is no philanthropy or social life in this model; it only refers to the organizational structures. This means that any private initiative designed to help those in need will have to face the competition with capitalistically oriented alternatives.

[223] This is comparable to the two scenarios used in [DoFR08]. The starving is meant in a figurative sense and signifies that the agent will be removed from the simulation. In reality, there will most likely be some kind of welfare program helping the most desperate members of a society. For our simulation however, the most extreme case is the model of choice in order to show the different influences of the two forms of organization. For a further discussion of this issue, see section 7.3.3.7.

In such a system, creative destruction can fully exploit its beneficial potential of abolishing overcome technologies and products. There is no force which limits or slows this process of renewal which is solely able to secure a development on a growth path for the economy. The unlimited and unconstrained possibilities in this organizational design should contribute strongly to a high speed of technological change.

On the other hand, the creative destruction can also harm the society to a considerable amount. As we have explained in chapter 4 when introducing the Neo-Schumpeterian Corridor, a system can fall into pieces when the speed of change is too high. This means that in the present case, the market forces may overshoot and eventually destroy the whole system. A situation which we might consider to be best apt at securing a positive future development turns out to be in itself catastrophic. Therefore, we can expect a stronger “up and down”-process in this simulation.

All risk provision happens within the system and all money put aside for harder times can only be invested in a capitalistic market context. To be clear, this does not have to be a bad thing, but the individuals in this model do not have the security which they will experience in the governmental model. The system is designed in such a way that the money either flows into banks or is invested in funds which can be thought of as venture capital companies. An individual who will want to secure herself against risks can choose the low risk, low return bank investment or the high risk, high return fund investment. The banks will serve as lenders for credits needed to finance the agent’s subsistence level consumption or the additional consumption desired. Their role is to serve as financiers of the regular activity which is in no way linked to innovation. The investment funds, on the other hand, are designed in a way to correspond to Schumpeter’s banker in its best sense. They will provide the funds needed to realize innovative ideas and to implement new combinations. Without their money, the inventor would happen to have the necessary funds – and be willing to risk them – in order to be able to implement her invention into an innovation. Thanks to the risk-oriented investment strategy by both the agents, who invested their money in the funds, and the fund managers, the inventors can find the necessary financial assistance to carry out the innovation.

Nevertheless, this system does not have any automatic stabilizers that may serve to rebalance an overshooting development or serve as a boost in a period of underperformance. We will explain those stabilizers in more detail when describing the governmental model.

From this characterization of the model, we can now focus on the different flux of money between the sectors and their interrelation with the agents. In a schematic way, we can represent them as follows:

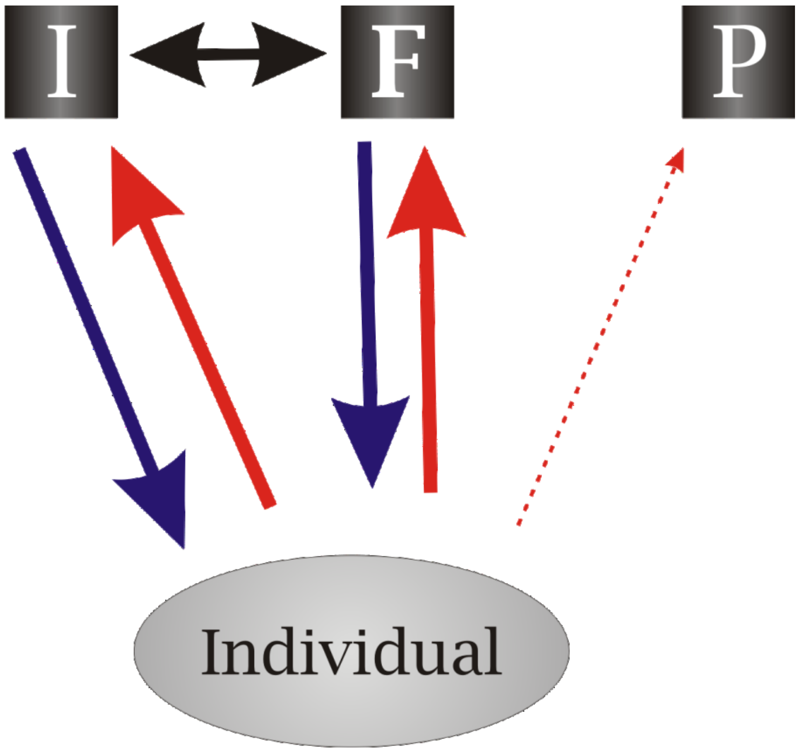

Figure 7-2: Individual model in the CNSE

The blue arrows represent each a financial flux from the corresponding sector to the individual while the red arrows refer to the monetary flow from the agents to each sector. The black arrow between the financial and the industrial pillar signifies that there exists a certain monetary exchange between those two sectors. Other relations between the sectors, which all may be possible, are excluded intentionally from the model, since they are not of decisive character for the interpretation of the simulation.

The exchange with the industrial sector or real sector (I) is on the one hand created by the consumption of the individuals. Every agent consumes a certain amount of goods produced by the industrial sector. This includes the consumption of the goods and services necessary to survive (subsistence minimum) as well as those goods and services she consumes for her own satisfaction. The monetary flux for all consumption expenditures corresponds to the red arrow in the figure. The thickness of the arrow matches the importance of this budgetary position for the individual.

On the other hand, the blue arrow going in the opposite direction relates to the money which flows from the industrial sector to the individuals. It is mostly made up of work income, revenues from entrepreneurial activities and income on investments such as dividends.[224] It may be surprising that the income stream is not considerably larger than the consumption stream since the agents will not use their entire income for consumption. Nevertheless, since there are funds which are withdrawn in the financial sectors used for consumption we have drawn the inflowing and outgoing streams between the agents and the industrial sector to be similar.

The connection with the financial markets (F) is substantial since the agents will not only invest their savings in the financial sector, but will also hold their risk provision accounts there. Accordingly, we find large flows of money between the financial sector and the individual agents. The incoming and outgoing streams are approximately of the same magnitude since it can be considered that there are just as many people withdrawing their money as there are people saving money.[225] The actual situation in every time step, however, may be very different since the behavior of the individuals is not concerted.

The streams represent the saving and dissaving behavior of the agents as well as several forms of income on capital (e.g. interests, proceeds from capital, income from lease or other investments)[226]. People have very different saving motives and it is not always easy to discern those. We will settle for a differentiation of three different types: (1) precautionary saving, (2) special purpose saving and (3) residual saving.[227]

The category of precautionary saving groups all those reserves which are set up to sooth future risks. This includes irregular or infrequent payments, expenses which are well into the future such as the money used for living after retirement and money which is saved to reduce the fear of unforeseen events. We consider all the savings related to the existential risks and to the uncertainty which every human faces as precautionary savings.

We call special purpose saving all those sums where an agent decides not to spend them in order to acquire certain specific goods at a later moment, in order to create personal wealth or in order to earn interests on the savings. The third category of

[224] cf. [Seit04], p. 26

[225] It is unlikely that the system is balanced in every (or even any) period and there are certainly reasons to believe that a society might for a prolonged period save more than it withdraws, but we will abstract from such a situation and consider the system fairly balanced.

[226] cf. [Seit04], p. 26

[227] cf. [DeBu00], p. 190

residual saving includes for example virtuous saving[228] which is only rooted in the belief that saving is a proper thing to do.
The financial sector will then invest the money in the real sector (black arrow) either by spurring consumption because they award credits to the agents who desire to consume or by investing in innovative endeavors of creative agents lacking the financial means to implement their invention. Therefore, the interaction and interrelatedness of the financial and the real sectors is twofold through the consumption and savings decision of the household and its implication on the concerned agents, and through the financing of innovations. Furthermore, the real sector will return dividends and rents on the innovations to the financial sector which will then be rerouted to the individual investors. This underlines the strong influence of the households on the real sector.
We have only sketched a dotted line to the public sector (P), since we have not modeled this monetary stream explicitly. It is, however, implicitly assumed so that the government can provide a general basic infrastructure which will allow us to compare the general setup of the societies in either model.
Furthermore, we can ask the question if a private insurance should be designed comparable to an insurance company which will collect a premium from the insured member and then spends an agreed amount in the case of a realized risk or if it should be thought of like a funds system where the individual cumulates private savings which he will use once he needs the money.
Both options can be found in the real world and both can be implemented. The advantages of an implied insurance solution are that no individual will fall entirely out of the system. In such a case, the choice of the individual is not fundamentally different to the one in the public system. An individual now has the option to change insurance companies and it is possible that the insurance company fails. The individual would now choose his insurance company based on the personal risk perception and we might be faced with the problems of moral hazard mentioned in section 5.2. This case can be implemented, but it would limit the insight the model could offer and would require us to take more assumptions on the behavior linked to the insurances.
The other alternative, designing the private sector as a capital funds market similar to pension funds will work in such a way that the individual saves money for his own

[228] cf. [BrLe00], p. 18

purpose and leaves it in the financial market where it can serve as risk capital. On the other hand, an individual may choose to invest his money in a more secure way, which will be designed through low risk, low interest loans to individuals asking for credit. Once a risk is realized, he will withdraw the money needed and will cover his subsistence minimum with those funds. In the case that the money which he possesses is insufficient, he will face starvation. This situation needs less additional hypotheses in the risk provision decision and increases the transparency of the model.

Therefore, we have chosen this second alternative. In a more elaborate model, adding private insurance companies may well be an interesting option.

7.2.2 Governmental Model in the CNSE

This section will now focus on the opposite organizational design and develop a scenario in which the governmental model is situated. On a general basis, we suppose that the government will cover all risks of the individual. This means that whenever an agent faces a realized risk, she will receive the necessary monetary means to cover the damage and secure her own survival by receiving the subsistence minimum. Just like in the individual model, we find the real, the financial and the public sector and have a look at the interactions and connections between them.

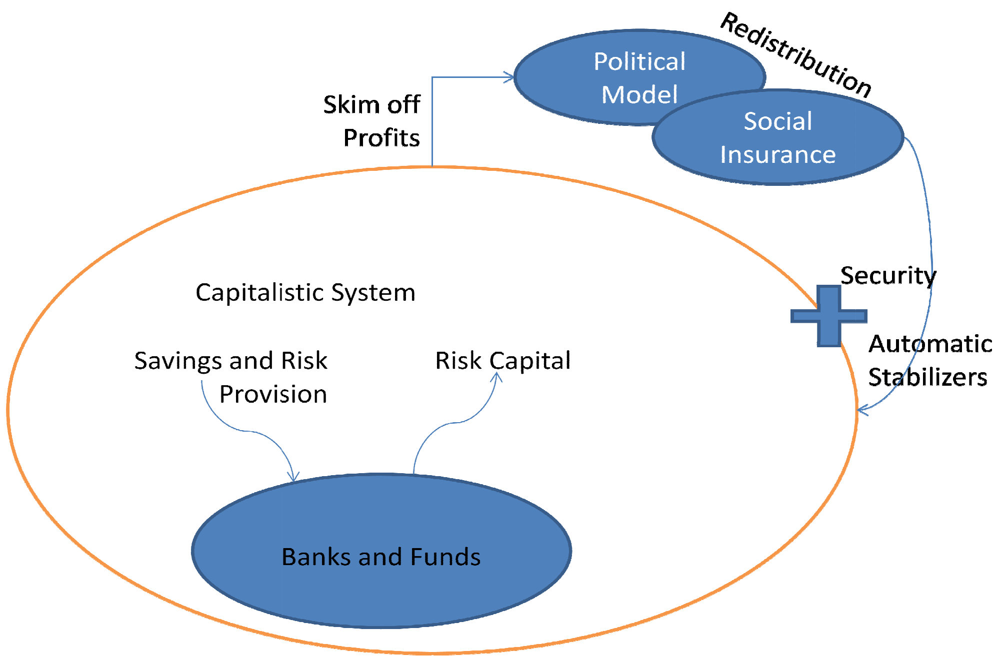

Figure 7-3: Governmental System

In this concept, we find a situation which is once again based on the capitalistic system and most of the actions and interactions between the agents will be based on capitalistic rules and processes. The system is comparable to the Individual system except for the social insurance component added through a political model of redistribution.

In that situation, the agents will have voted to have a public system of coverage against certain risks in their lives and so there will be a government providing the necessary financial means in the case an individual is unable to procure for her own living.

The agents will have the opportunity to vote on the magnitude of social protection by increasing or decreasing the subsistence minimum guaranteed by the state. This will be implemented through a vote of the median voter. Therefore we generate a situation where the members of the society have a direct influence on the amount of redistribution within their country.

Furthermore, we would expect the social insurance to serve as an automatic stabilizer in this situation. At times, when many people face difficulties, the government will spend considerable amounts as support for those in need and at times, when the economy is going well, the money paid for the contribution to the social security is taken out of the system and will not spur further growth. This may lead to a situation which is less erratic than in the individual model.

On the other hand, the available risk capital may be reduced due to the fact that some of the money which was invested in the individual model is now redistributed through the state. Still, the agents in the governmental model do not face an uncertainty as pronounced as those in the individual model which could lead to a situation where the people in the former will more likely invest their savings in risky positions than those in the latter model.

The situation will likely lead to the following monetary flux between the sectors:

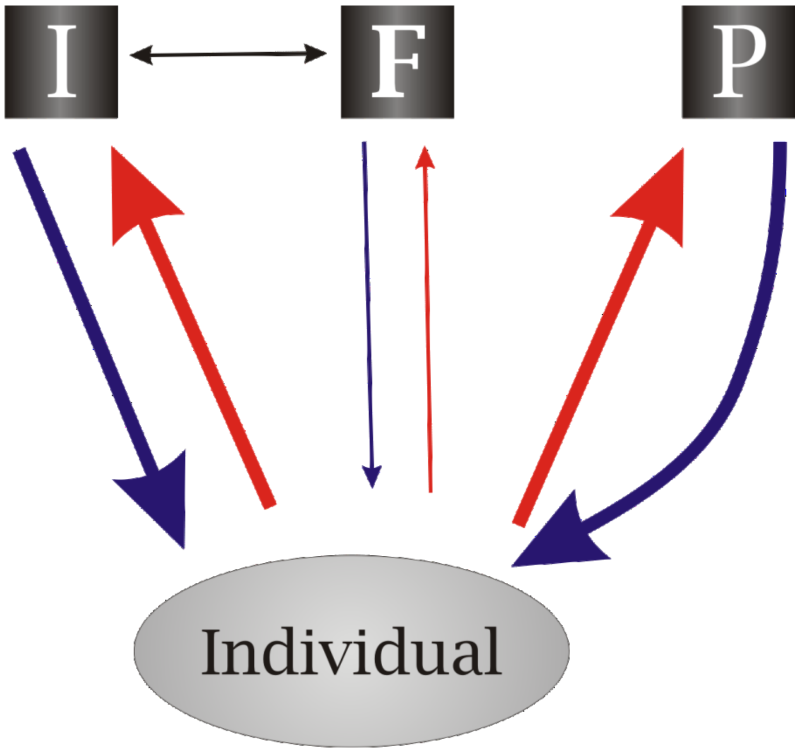

Figure 7-4: Governmental Model in the CNSE

Similarly to the situation in the individual model, the streams between the agents and the industrial sector are comparable in size and fairly big. Once again, the stream going from the individuals to the firms depicting consumption spending is approximately as large as the opposite flux since now the withdrawals from the financial sector and the money handed out by the government to those incapable of providing their own minimal consumption needs are added to the consumption flux.

The financial sector is less pronounced in this setup because the individuals will only use it for their special purpose saving and the residual savings motives. All precautionary saving is substituted by the governmental social insurance coverage. Nevertheless, the financial sector is still relevant because of its role as investor in the real market which will spur innovation and return dividends and rents to the individual depositors and investors.

The governmental sector has changed in a very significant way because its role is much more important now. Every individual with sufficient income will transfer a certain amount of money to the state. This sum is used to secure the survival of every member of the society through social security payments to all those people who live from less than the subsistence minimum.

While it is fairly easy to imagine the monetary flux towards the public sector, the opposite stream can be fairly diverse. On the one hand, it includes direct transfers to the households disposing of insufficient financial means such as for example the unemployed or the retired. On the other hand, it covers expenses which the government will spend on the quality of life and the infrastructure in a society including the aforementioned merit goods.

From those two basic concepts, we design the model which we will describe in detail in the next section.

7.3 Design of the model[229]

The way those models work, it is important to carefully describe the implemented routines and their underlying justification because all emergent structures will originate from the way the scenario is set up. This means that when analyzing the results of the simulation, they will be dependent on the initial design of the model. If this design is not explained in a very detailed way then it is difficult to evaluate where the resulting conclusions may be applied and for which arguments they may not hold.

While several different programs and software environments have been created over the last years, we have chosen to implement this model in Repast Simphony[230] ("Repast S"), which is an agent-based modeling toolkit based on the Java and Groovy programming languages. We have chosen Repast S because it is best suited for projects rooted in the social sciences[231] and since it is built for the simulation of systems representing living agents in a social environment. Even though Repast S is by far not the easiest modeling toolkit on the market, it offers the highest modeling power and therefore is best suited to be used in our case.[232] The biggest advantage Repast S offers, however, is that it allows us to present the model and the implementation in a way which is understandable even for economists who may not be familiar with programming. The way Repast S is designed the simulations can be very easily represented and explained thanks to the possibility of a visual model development, which illustrates the underlying structures of the model in a very intuitive way. This makes it easier for economists who may not be familiar with the Java or Groovy programming languages to follow through on the model's logic and to evaluate its content.

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[229] The name of the model in the program is "InnoEasy" which has been chosen to show that we will look for an easy way to model our situation.

[230] Repast is the acronym for Recursive Porous Agent Simulation Toolkit and is provided for free by the Argonne National Laboratory, a US Department of Energy library managed by UChicago Argonne, LLC. It can be downloaded at http://repast.sourceforge.net/

[231] [NiMa07], p. 95

[232] [MaNo06a], p. 26

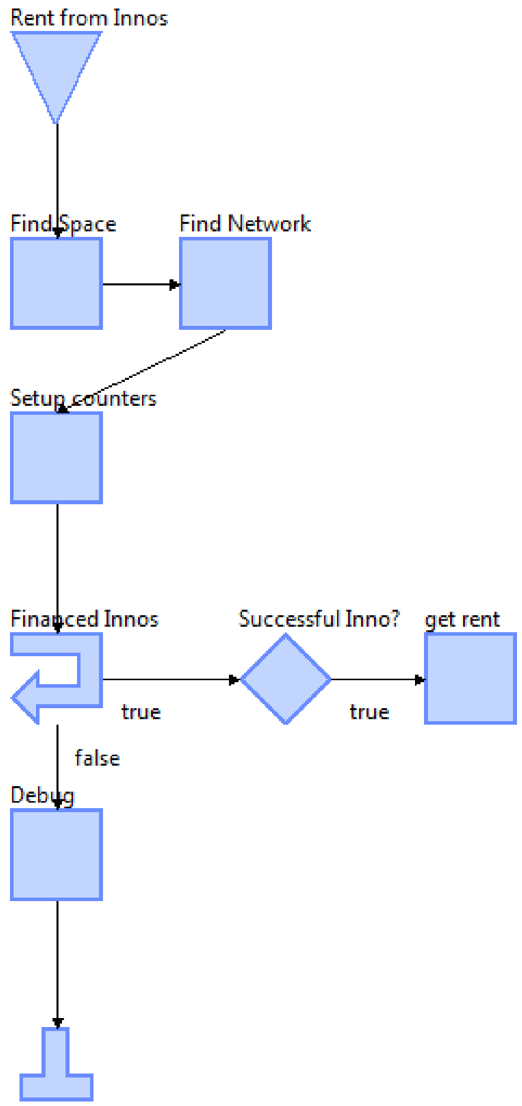

Figure 7-5: Graphical presentation of behavior "Rent from Innos"

Figure 7-5 shows how the procedure "Rent from Innos" is presented in the modeling environment. This behavior belongs to the Fund agents and guarantees that the fund will receive the return from the successful innovations it financed.

We can see that this procedure will start by selecting the space and the network which are relevant in this step. Then it will define counters which will be used for statistical purposes. From the different symbol in the next step, we know that the simulation will loop over all those innovations which have been financed by the corresponding fund. Since this group includes failed innovations, the next step is to check if the selected innovation has been successful. Only then will the fund receive its rent.

This is done as long as there are still innovations available which have been financed by this fund. Once all of them have been analyzed and the rent collected, then we add a debugging task which helps track possible mistakes and, finally, end this routine with the inverted "T"-symbol.

A click on each of these symbols in the Repast environment will show the programming code behind it. Consequently, it is fairly easy for an economist to get an idea of the logic behind the program.

7.3.1 Global simulation environment

The specificity of the model creation in Repast S allows us to explain the model setup in a step-by-step approach. We use a proper file to define the overall model environment so that we can create the context in which our agents are placed.

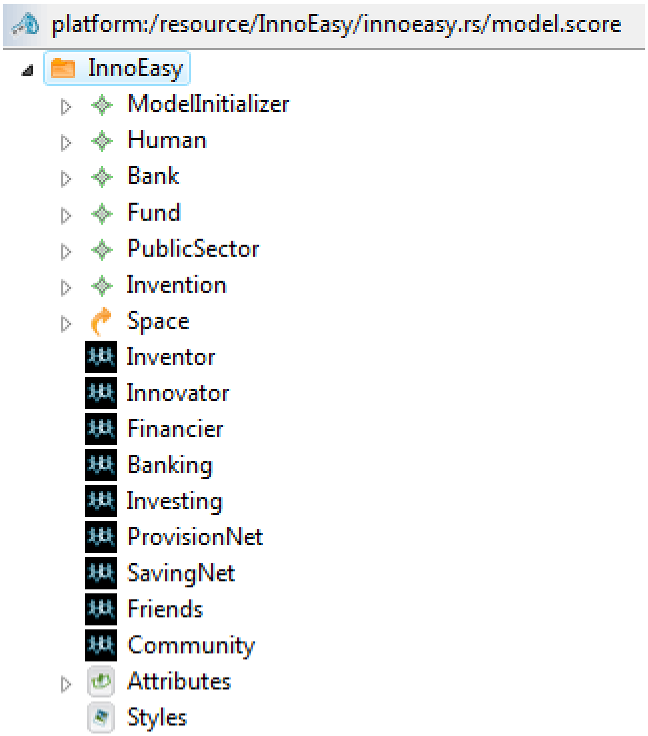

Figure 7-6: Design of the model environment

The first six entities represented in Figure 7-6 show the agents which are present in the simulation. They will carry out the actions and generate the development of the system. Our agents are the Model Initializer as well as the Humans, Banks, Funds, the Public Sector, and Inventions. The former is only used in the first time step to instantiate the model and to create the agents which will then interact. The other five will be presented in the next section.

The next element defined is the space in which the agents interact. We have chosen to model it as a field with fixed dimensions which we can imagine as a piece of land with boundaries to the north, south, east and west. The agents are able to step on any point within this field which means that we do not have to impose a set of places to move to comparable to a chess board but that we can allow the agents to move freely to any location within this space.

Furthermore, we have designed the borders to be fixed. While this may sound trivial it is an important question in simulations to ask what happens if an agent tries to exit the space to one side, say to the east. The first possibility is that it bounces off the border just like a billiard ball and sees its movement mirrored in the opposite direction. The second option is that the agent exiting the space to the east will reappear on the western end of the space and continue with the same dynamics. This will lead to a torus of genus one.[233] The third way of modeling the borders is to see them as a sticky fence, where an agent who will try to exit the space to the east will not be able to go beyond this line and will stay at the border. Since our model is meant to represent a single regional body comparable to a country or a state, choosing the borders to be fixed and sticky seems to be the approach which corresponds closest to the model we try to represent.

The next nine positions define the networks which are implemented in the simulation meaning the different channels through which agents are allowed to interact. The different networks are used to define the relationships between different agents and the influences such relations have on the behavior of the agent.

The first three networks, Inventor, Innovator and Financier, are related to the Inventions. Every invention has an inventor and therefore the Inventor-network links the invention to the inventor. This helps identify the inventor in case an investor is willing to finance the invention. Once an invention has turned into an innovation, the innovator network will be used to connect the innovation and the original inventor since this is the channel through which the money, which the innovator receives from the innovation, is transferred. The Financier network, on the other hand, links the invention to a fund which is willing to invest money into the realization of the innovation. If the innovation is successful, then the fund will receive its share of the innovation rent through this channel.

The next four networks, Banking, Investing, SavingNet, and ProvisionNet, are linked to the savings and investment decision of the individual agents. With every amount,

[233] cf. [Weis10]. Note that such a situation will not lead to a structure comparable to a globe. As an easy example, imagine going north on a globe until you are back at the point where you started. If you draw the traveled route on a flat map, you will see two lines crossing from North to South since you will have travelled on two different longitudes. In a torus you will always stay on the same longitude.

which an agent is willing to invest, she has the choice between the low risk/low return option at the banks and the high risk/high return option at the funds. Whenever she will save money at a bank, her account is represented as a link between the bank and the agent in the Banking network. In the case of an investment at a fund, the link will be established within the Investing network.

Since an agent in the individual model possesses two separate accounts where one contains all the precautionary savings meant to serve as coverage for the agent's own risks and the other one includes all other savings, she will have to decide twice on her investment strategy of choice. Therefore, we will use the SavingNet network to store the savings account and the ProvisionNet to represent her risk provision account. By so defining, we can be sure to always refer to the correct account and we do not need to open customer accounts at every fund or bank which simplifies the simulation considerably. This makes it possible to allow the agents to invest their entire savings at funds or their entire savings at banks as well as to split it between the institutions depending on the individual risk behavior.

Additionally, we have implemented a Friends-network which establishes links between Human agents. As we will explain in detail in section 7.3.3.7, the individual behavior of an agent is influenced by the people in her surroundings. Therefore, we have to make sure that this influence can be included which is achieved through this Friends-network. The network is set up in the beginning such that an individual will know every other Human in her immediate neighborhood. As we will explain below, there is a differentiation between simple 'friends' and so called 'cool friends'. 'Cool friends' will only be identified in the specific rule.

Finally, we find the Community network which is only important in the governmental model since it links the Humans to the Public Sector and allows them to vote, to pay their contributions or to receive the social security benefits. This network remains unchanged during the simulation since every individual has to be linked to the government at all times.

Agents can also interact with other agents outside of the networks, for example, when an agent is looking for a bank that will give her credit. In order to keep stabilized links between different actors, we will use those networks allowing us to implement those relationships in a very straight forward and intuitive way.

The next step is to introduce all the attributes and constants which are included in the Attributes position in the aforementioned schema.

Variable	Explanation
Initial Number Of Humans Initial Number Of Banks Initial Number Of Funds	The three variables take the amount of each type of agent which we will create at the initialization stage of the simulation. The values can be chosen freely knowing that the more agents are created the stronger are the interaction effects, but also the more computational power is required. In our cases, we have set the initial number of Humans to 50 and created 10 Banks as well as 10 Funds.
Individual Model	This is a variable which can only take the values "true" or "false" and signifies if we run the simulation as the individual model or the governmental model. Theoretically, it is possible to change this value during the simulation which would lead to a shift in the societal setup used. This option might be interesting, if there is a research interest in the consequences of a strong change in the political climate. Nevertheless, we have not analyzed any runs using this change.
Subsistence Minimum	The initial subsistence minimum is defined exogenously and defines the amount of money needed by an individual agent to secure her survival in a given period. In the governmental model, this value can be varied through the voting mechanism in order to make sure that the social security contributions from the state will grow or decrease. We have defined it to start at the value of 8, corresponding to 8,000 €.[234]

[234] In 2010, the income in Germany is tax exempt up to an amount of 8,004 €. [BMF10] Since this may reflect the idea of a subsistence minimum as it is used in our simulation, we have chosen to retain this value.

Influence Merit Goods	As we have argued in section 3.2.3, there is a positive influence which the public sector can exert in the governmental model through the provision or promotion of merit goods or other actions with positive externalities. We have included this effect in the simulation in the propensity to invent following the above mentioned example as well as the idea that an improved infrastructure will enable more people to use their creative potential. This variable is defined as a global variable in order to be able to change it in an easy way.
Invention Threshold	The invention threshold is defined exogenously as the amount of inventive potential which a Human needs at a minimum in order to come up with an invention.
Minimum Work Age	The minimum work age is set to be the lowest value at which individuals will be allowed to search for a job. While this may seem overly strict, it is used to integrate the different effect which can be generated by a prolonged education span on the wealth generation process of the individual agent. The value is set to 16 for individuals with the lowest level of education. We explain the choice for this amount in section 7.3.3.1.
Maximum Initial Age	The following constants are only used at the beginning when the agents are instantiated. In order to spread the age span in which we find our agents, they will receive an age uniformly distributed between 0 and this maximum initial age value.
Average Retirement Age	The simulation attributes every agent a certain age at which she will retire. This age is set randomly and uniformly distributed between 57 and 77 with an average age of 67[235].

[235] 67 is chosen to be the average retirement age since this is the current political vision in several countries, see for example [SSA09] or [Bund07] as well as our explanation in section 5.1.3.

Minimum Death Age Maximum Death Age	Since we fix an age at which the agent will die, we set upper and lower boundaries on the age range which an agent can reach. We have chosen to set the minimum age an individual reaches if no existential risk makes him starve earlier to be 60. The maximum age an individual can attain is 100. The individual levels float between those two values.
Maximum Education	In order to keep the simulation flexible to the integration of the education dimension we have chosen to set the maximally attainable level of education as an exogenous global constant. The simulation has been run with three different levels according to the classification of "primary education", "secondary education" and "tertiary education" used by the OECD.[236]
Years For Education	In order to take into account that it takes different times to reach different levels of education, this variable takes the number of years of schooling necessary until the next level can be reached. We have set this value to three. In the basic setting, agents with an education level of 1 will have to be 16 to be able to work, those who will reach education level 2 can start to work at 19 and agents with a level of education of 3 will have their education finished at the age of 22[237].
Average Unemployment	The average unemployment rate serves as a value around which the true unemployment rate in the model oscillates. We have set this value to eight percent.[238]

[236] [UNESCO06], p. 19. Even though the OECD lists seven different levels ranging from "pre-primary" to "second stage of tertiary education" we have chosen to limit the simulation to the three main stages described above.
[237] Those values correspond approximately to the values for adolescents starting their apprenticeships in Germany in 2008. [BIBB10], p. 2
[238] Looking at data from Eurostat [Euro09] and the US Bureau of Labor Statistics [BLS10] for the unemployment rate over the last years, then 8% seems to be a reasonable average value to use in the model. Besides, this value can be easily adapted in the parameter setting during the simulation.

Health Probability	This value shows the mean of the health levels in the population. We have chosen this value to be at 95 percent which means that an average agent can realize 95 percent of her potential. This can be either due to some days where she cannot work due to an illness or a general health state which only allows her to use 95 percent of her resources.[239]
Average Risk Provision	The average risk provision shows how much an agent will save on average from her income to provide for risks. We chose this value to be easily adaptable so that different scenarios and risk aversion behaviors can be modeled. We have set this value to 20 percent, which corresponds roughly to the amount which Germans have deducted from their gross work income as contributions to the social insurance system.[240]
Average Consumption Ratio	The average consumption ratio is similarly designed to serve as an anchor around which the true consumption decision of each individual in the respective period oscillates. This value has been chosen to be 90 percent.[241]

[239] There is evidence that the average value for the health level of individuals might be higher in the governmental model since humans have a tendency of non-compliance, which could be reduced or limited in the governmental model thanks to general measures affecting the health infrastructure. See for example [Müll08]. We have not implemented such a difference in this model in order to limit its complexity.

[240] Even though the employer contributes another 20 percent, we have chosen to take only the fraction in account which an employed individual finds on her pay slip. This is meant to serve as a starting value, since individuals adapt their risk provision behavior during the simulation.

[241] The savings ratio in Germany has been floating around ten percent in the years between 2000 and 2007, which means that the consumption ratio amounts approximately to 90 percent, cf. [IW09], p. 64

High Edu Inc Factor Mid Edu Inc Factor Low Edu Inc Factor	The income always also depends on the level of education. Therefore we adapt the randomly assigned work income of an individual by her level of education according to the statistical distributions[242] and by multiplying her work income with the corresponding factor.

Table 7-1: Global constants

Using those constants and the agents which will be explained below, the simulation can be executed and the results can be analyzed. Nevertheless, it is important to include the discussion on the execution schedule of the different events within the simulation meaning that we have to explain when which agent is allowed to act or intervene.

As we have stressed in section 6.1.3.2, it is important to specify in which order and through which mechanism agents are allowed to act. Since agents' actions have an impact on the environment as well as the behavior of other agents, changing the order in which events are executed can change substantially the outcome of the simulation runs.

For our simulation, we have decided that each of the different behaviors which we will develop in the next sections has a random priority – meaning that they will be executed in a random order – without any single one being preferred over another. This is due to the fact that each agent will execute her rules only once during each time period but there is no reason to think that any of these rules has to be executed before another one. We could argue that the recalculation of the interest rates in the banks or the percentage which an individual has to contribute to the social insurances should be done at the end or at the beginning of each period, but this is not realistic. Banks, funds as well as the government do not schedule to change their conditions at January 1st every year, but changes can very well happen at any day during the year. Accordingly, it is possible that two agents will have a different savings behavior in

[242] In the data, we find for Germany that people "below upper secondary education" earn 91 percent of the average earnings of the population with income from employment, people with "post-secondary, non tertiary education" earn 107 percent of the average earnings and all individuals with "tertiary education" can expect 162 percent of average earnings. To compare the data, the values for the US are: 65 percent; 109 percent; 172 percent and for France: 84 percent; 94 percent; 150 percent. [OECD09], pp. 144f, Table A7.1a

one period even though all of their characteristics are identical just because one is acting before a bank's interest raise and the other one afterwards.

This setting may also lead to a situation where the government is trying to balance its budget and will nevertheless be faced with a deficit at the end of the year, because it was asked to decide very early. Such an approach appears to be much closer to the real life stream of events compared to a fixed chain of evolution which would otherwise have to be assumed.[243]

From the environmental aspects, we will now turn to the individuals and their actions in the simulation: the agents.

7.3.2 Definition of agents

The model is created in an agent-based environment which requires us to define agents who are able to act and to react to external stimuli. Furthermore, we can define and specify the environment which can be influenced by agent actions. As stated above, we have defined the following five types of agents: Human, Bank, Fund, Public Sector, Invention[244].

The reason for the first three is that Humans are our central actors in the simulation. We care to find system characteristics for creating an environment where their innovative potential is best stimulated. The Bank and Fund agents represent the financial sector and the activities related to it. Furthermore, the Public Sector is implemented as an agent due to its two predominant functions: offering a sensible form of social insurance and holding elections in certain intervals. Finally, the real sector is reduced to the inventions since all other activities are indirectly implemented in the Humans. Inventions however have to be made and can be transformed into innovations if Humans dare to accept the risk and uncertainty connected to them and if they can provide sufficient financial resources – either by themselves or through a financial investor implemented in the Funds following the idea that "[t]he central actors in this process are entrepreneurs and investment bankers, who create 'new purchasing power out of nothing'"[245].

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[243] We also stress that the agents in each category (Humans, Banks, Funds and Inventions) are called in a random order which can change in every time step. This is important whenever the simulation is run on serial computers where agents can never act simultaneously, because we would otherwise insert patterns which are only due to the execution schedule. See also [EpAx96], p. 26

[244] To avoid misunderstandings, we will capitalize all agents in this thesis. This means that "Public Sector" always refers to an agent and "public sector" characterizes the economic institution.

[245] [Mccr08], p. 96: "Die Hauptakteure in diesem Prozess sind Unternehmer und Investmentbankiers, die 'neue Kaufkraft aus Nichts' schaffen."

7.3.2.1 Human agent

We have modeled an agent who is living her life in a very step-by-step form without much planning ahead and without an overall optimization strategy. While many economic models refer to optimization as the underlying behavior of humans and use the enormous set of utility maximization methods to analyze, predict or direct the way how people behave in certain economic decision situations, this may not be plausible for an individual in the situation where the decision matrix grows more and more complex.[246] This is only possible when very few options are compared which are easy to grasp for a human mind. Once the offered bundles between which an individual has to decide grow too large, it might be impossible for him to compare the utility levels which he will gain from choosing either of the alternatives. Even choosing the optimal consumption bundle worth 100 € from a super market may be a choice where it can be argued that an individual will be able to maximize his utility level. Yet, in our model we add interaction with other individuals to this situation of choice which will further complicate the decision structure for the agent. Additionally, the agent is embedded in a dynamic model with historic time meaning that she would have to derive her optimal decision, taking the time as well as the history of her experience into account. Last but not least, the uncertainty of the life in the model adds to the difficulty of making an optimal, utility maximizing choice even if all other difficulties could be controlled for. Therefore, we have implemented the agent to use a satisficing behavior by assessing each individual decision singularly and without an idea of maximization[247].

The individual's life will run in a very structured version as we will explain in section 7.3.3. She will have to take several decisions in each year and her choices depend on her current situation as well as her environment. Our model runs generally with 50 agents which are distributed randomly in the space of the simulation.

An agent is created with a set of characteristics which we can group together and speak of its 'personality'. This means that the values of each of these traits will influence the way she acts and reacts in each situation during the simulation. We will present those here:

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246 see for example [Pott00], p. 33

247 this is comparable to the approach taken by [GrPH01]

Variable	Explanation
Age	The agent will be initialized having a certain age and we will increase her age in every period. This means that each period can be considered representing one year. The age of the agent will be used for her decision about learning, working or retiring. Furthermore, an agent will seek friends in her own age group.
Retiring Age	The retiring age of the individual agent is set within a 20-year span evenly distributed around the average age for retirement which we introduced above. The reason that an agent will retire early or late can be manifold, but they are not modeled here. Since the agent does not know her retiring age, and the veil of ignorance is not lifted until the very moment, it will not influence her behavior. Consequently, we could just as well assume that some random events during her life determine the retiring age. The simulation would only change if we would like to allow the agent to influence endogenously the moment when she retires.
Death Age	In a similar way to the retiring age, the age at which the agent will die is also set at the initialization of each agent. It varies in this simulation between 60 and 100. An agent can only die earlier if she is unable to provide for her existential needs, which means that she possesses less than the subsistence minimum and has not been able to receive a credit. Consequently, accidental deaths like car accidents are not modeled in this simulation because they would not add any explanatory power to the relationship between social insurance offering and innovativeness. Those events can be compared to some random occurrence which limits or nullifies the innovative capacity of an individual.
Work Income	The Human agent also is attributed an income which she will receive when working. In order to keep it simple, we set the work income at the moment of initialization. The income is then allowed to oscillate around this value during the course of the lifetime. The income calculation is achieved using a log-normal distribution around a mean of 40.[248] This value has been

[248] In the simulation, we use the values for μ of 3.35 and for σ of 0.47 which relate to a mean of 32. This is due to the fact that we do not allow a work income which is below the subsistence minimum. Therefore, we add the subsistence minimum amounting to 8 in our default setting to each individual's work income.

	chosen according to the data for Germany, where the average income resulting from employed work amounted to 3.182 € per month[249], leading to almost 40.000 € per year. Since we chose to understand a period in the simulation as a year and to reduce monetary terms to be comparable to thousand €, we set the mean income to 40. The log-normal distribution seems to best mirror the income distribution in a society[250], because of its specific characteristics. Opposite to the normal distribution which follows the well-known symmetric bell-shape, the log-normal distribution has a skewed form where the mean in the distribution is rather low compared to the overall span of possible values. Income in a society can reach very high values but the mean income is rather towards the low end of the range. Besides, we can use the log-normal distribution in cases where the values cannot be negative which is certainly true for the work income an individual can earn. Therefore, each individual receives a value for work income which is log-normally distributed. Since work income also depends on the educational level[251], we multiply the value of the variable Work Income of the individual with a factor corresponding to her education. This reflects the fact that work income increases with education. Since the OECD-data also looks at three levels of education[252], we can easily attribute each of these levels to the education levels of 1, 2 and 3 in our simulation. Therefore and according to our explanation in section 7.3.1, the work income is adapted by the factor corresponding to the education level group of the individual in question.

[249] [IW09], p. 56, Table 6.4 “Bruttomonatsverdienste der Arbeitnehmer”
[250] see for example [Blüm75] or [LiSA01]
[251] [OECD09], pp. 144f, Table A7.1a
[252] Note, however, that in the quoted study, the three levels retained are “below upper secondary education”, “Post-secondary, non-tertiary education” and “All tertiary education”

Tinkerer	As we have explained in section 4.2, some people have a certain inclination towards being creative or inventive. This personal trait is subsumed in the tinkerer property of an agent. It can take the values 1 or 0 depending if an agent has a tendency to engage in creative thinking. This does not mean that someone without this predisposition cannot come up with an invention or be innovative, but having this 'tinkerer-gene' will increase the probability for an agent to come up with an invention.
Experience	The experience variable in the agent reflects the number of years she has been working, so that we have a measure of the professional routine building and expertise for each agent.
Education	As we have explained in section 7.3.1, we have defined three different educational levels in the simulation. Upon initialization, each agent is attributed a certain level which cannot be changed unless when the agent dies. Once again, the agent does not know the level she will attain and therefore we do not have to control for behavioral influences such as her effort in school or her aspirations for a work career. There is one aspect, however, where the education is taken into account even though the individual may not yet have reached the level and that is the inventive capacity. In order to calculate the propensity to invention, the educational influence for each individual is included based on the final level. While this certainly simplifies the model, it may not overly distort the simulation because we can assume a certain drive, motivation and curiosity for a student to reach higher educational levels and those may be the same characteristics which support the creativity and inventiveness in the individual. We assign educational levels not uniformly, but based on data from the OECD study[253], which finds that 30 percent reach the lowest level, 44 percent achieve upper secondary education and 27 percent will attain a tertiary level education[254].

[253] [OECD09], p. 28

[254] Since the values add up to 101 and the source does not give more details, we reduce the tertiary level education to 26 percent.

Risk Aversion	The individual's risk aversion is set at the beginning of the simulation to a value uniformly and randomly chosen between zero and ten. Through interaction and experiences during the course of the simulation, the value of the individual risk aversion will vary.
Time Preference	Each individual has a certain time preference which is also defined in the initialization process and set to a value between zero and ten. Similarly to the risk aversion characteristic, this value is subject to changes during the simulation due to environmental stimuli in the peer network. The time preference also reflects the future optimism of the individual. The lower the value, the more the agent is willing to forego today's consumption for one in the future.
Cool Friends	An individual will retain the amount of cool friends she has since this will have an effect in her inventive behavior. Agents have two categories of friends (regular friends and 'cool friends') which have different influences on the individual's behavior. Agents do not look for new friends but rather try to strengthen their network of cool friends by moving closer to those individuals in their network. In section 7.3.3.7, we present the rule how agents make friends and how 'cool friends' are differentiated from 'regular friends'.
Happiness	Each agent will start with a certain indicator for her happiness and she will update her mood regularly depending on her experiences and stimuli in her environment. The happiness will also be included in the inventive propensity as we will explain later.
Health	The health level which is randomly attributed follows a Poisson-distribution with a mean health level of 95 percent.[255] The level is then allowed to fluctuate during the simulation and will influence the individual in different aspects, such as it impacts the achievable work income or the risk aversion of the individual.

[255] The Poisson distribution is often used in health related studies (see for example [Shaf06]) because small health infractions are common while larger ones have a very small probability. In a society, most people will have a high health status but some will have a lower one. We estimate values with a mean of 5 and subtract them from the perfect health level of 100. Therefore, health will vary between 100 and 0 with a mean of 95.

Retired?	We will also track the working status of the individual and set the two variables "retired?" and "unemployed?" to true if an individual is retired or if she is unemployed. She will be retired upon reaching her individual retiring age and she may be unemployed if she is unable to find a job according to the routines described in section 7.3.3.1.
Unemployed?	

Table 7-2: Variables of Human agents

At this point we can also stress that the simulation is focused around the individual agent as an actor and that there is no implementation of firms or companies. Even though there are many arguments which support this choice, adding companies to the simulation would necessarily add an enormous amount of complexity but could help design the real sector in a more realistic way. Nevertheless, we will leave this for further research.

The reasons why we feel that using the individuals also in the innovative endeavor is that "[e]ight out of ten new entrepreneurs work alone"[256] and that even the influential GEM-studies use the individual as their focal point for the analysis of entrepreneurship because "[n]ew firms are, most often, started by individuals. Even in established organizations, entrepreneurial attitudes, activities, and aspirations differ in each individual."[257]

This is the general setup of the Human agent and we will present the rules which govern her behavior in section 7.3.3 after having introduced all other agents which we will use in this simulation.

7.3.2.2 Bank agent

Since the model we present here is the first implementation that we know of which tries to implement the three sectors into a micro-founded agent-based model and since we try to stick to the KISS-approach by keeping the simulation as simple as possible and justifiable so that it can be well understood and extended in future projects, we have chosen to set most detailed attention into the design of the Human agent and to specify the additional actors in the simulation only to the most necessary degree.

The Bank agent fulfills the function of granting consumption credit to the Humans and of providing a low-risk/low-return option for individuals to save money. The bank will

[256] [Destatis06]: "Acht von zehn Existenzgründern arbeiten allein"
[257] [BoLe10], p. 13

have to make sure that it can only lend out as much money as it has received from the agents who deposited their savings and that it sets an interest rate which it can afford. The Banks are designed to have the following variables:

Variable	Explanation
Interest Rate	Arguably the most important variable for a Bank is the interest rate it offers to the customers as the return on deposited savings. This rate will be paid on money an individual will invest at this bank. In the case of a credit request, the bank will charge the individual an interest rate which is one percentage point above this rate in order to simulate in a very easy and transparent way the integration of transaction costs. Furthermore, this is meant to model the interest spread which is observable on the market and make it relevant for the agent's behavior. The interest rate is set to three percent at the beginning of the simulation and each Bank can adapt it once in every period by increasing or lowering it by one percentage point. Nevertheless, we require the interest rate to be positive or zero.
Interest Payments	In this variable, the Bank stores the amount of money it had to pay in interests to investors who deposited their savings at the bank.
Interest Receipts	Accordingly, the variable Interest Receipts stores the amount of money a Bank receives in interest payments from the individuals who received a credit in the previous period. As stated, the interest rate negotiated for credits is always one percentage point above the general interest rate.
Client's Credits	This variable maps the stock of credits lent out to customers. It is changed whenever an individual will receive a new credit and is lowered when the credit is repaid. Therefore, it reflects the true amount of credits awarded at every time.[258]

[258] The other option would be that once a year the bank updates its accounts and will set a new lending strategy. This situation would be in line with the adaptation process of the interest rate which also only happens once per period. We have chosen to allow it to take all changes directly into account and to only adjust the interest rate once, since we feel that this relates better to a simplified view of the banking decision structure: handing out a credit depends directly on the amounts awarded so far and the amounts available. Adapting the interest rate may follow more long-term oriented goals and strategies, and does not depend on single credits awarded.

Client's Savings	The variable client's savings is also updated as often as an individual deposits or withdraws money from her account. Furthermore, this variable is used together with the next one – credit requests – to calculate the interest rate.
Credit Requests	Whenever an individual demands a credit, then the amount requested is stored in this variable. This is used so that the bank can evaluate its interest strategy, because if there are too many credit requests and the bank does not have enough deposits to accept them, then it should increase the interest rate in order to receive more savings from individuals and to reduce the amount of credit demanded. On the other hand, in a situation where the bank holds sufficient money from deposits but cannot find customers willing to buy a credit, it will have to lower the interest rate to become more attractive to those demanding a credit and to reduce the cost generated by the interest payments on the deposits. Besides, this may reduce the amount of money deposited at the bank, but since there are no sufficient credit requests to lend money out to, the bank could not use it productively and therefore hardly forgoes any future business.

Table 7-3: Variables of Bank agents

In the general setup, we define ten banks at the beginning and grant individuals the permission to start a new bank when they live too far away from the next bank.

7.3.2.3 Fund agent

Following the implementation of the Banks, we will present the setup of the Funds agents, since they are the second actor in the financial market. Their activity is focused on receiving a high rent by investing in innovative endeavors. Consequently, this strategy is also linked to higher risk and the individuals cannot be sure that they will earn any interest on their funds and they may not even receive back the invested money.

Similarly to the Banks, the Fund agents are designed as simply as possible in order to keep the simulation transparent and understandable. Nevertheless, their setup is much more complex since we cannot make the same assumption as for banks concerning the stock of capital available. We explain those differences in detail in section 7.3.3.10. Here, we will present the variables which characterize each Fund:

Variable	Explanation
Interest Rate	Since the Fund cannot guarantee an interest rate to the investors, it will always ex-post calculate the return it received on its investments and will hand out half of it as interest to the individuals who have invested their money in the Fund. The interest rate is set to three percent in the first period in order to have a balanced situation compared to the banks and it is allowed to float freely, but cannot be negative.
Interest Payment	This variable stocks the amount of interest paid out in a period and takes it into consideration before the fund starts her new investment cycle.
Capital Stock	The capital stock is the amount of money which the fund possesses and it may well turn negative. Client's investments are added to the capital stock and their withdrawals are taken from the stock. Besides, investments will be financed with money from the stock, and one half of the rents from innovations is fed into it. Therefore, it reflects the amount of money which is still available at the Fund.
Client's Savings	This variable shows the amount of money which individuals invested in the current period.
Cumulated Client's Savings	The variable "Cumulated Client's Savings" is the sum of savings which are still invested at the fund. When interest payments are made, then the Fund will have to calculate them based on this variable since it reflects the amount of money entitled to profit from the investment returns. Whenever a client withdraws her money from the capital stock, the initial amount she had saved is also withdrawn from this variable's value.
Invested Money	We use this variable only for statistical means in order to track the amount of money which a Fund has invested in innovation projects.
Rent from Innovation	Each successful innovation endeavor will lead to a rent for a period of up to twenty years. The rent is always split in half between the inventor and the financier. This variable stores the amount of rent the Fund received in the current period.

Low Interest Years	A fund which has not been lucky with her investments may think about redefining its strategy and its orientation. In order to decide if its latest developments have been successful we count the years marked by a return rate less or equal to zero percent.
Negative Years	Similarly, a negative capital stock is a major problem for a Fund and therefore, we count the years with a negative amount of money available. In case this number grows too big, then the fund can be wound up and removed from the simulation.

Table 7-4: Variables of Fund agents

Even though the CNSE-approach includes explicitly the intra-sector interaction as important, we have chosen not to allow banks and funds to interact in order to reduce the complexity. Nevertheless, as we have seen in the current financial crisis, exactly this interaction can lead to dangerous bubbles and increased risks as well as uncertainty in the market.

We start our simulation with ten funds. There is no possibility to found new ones but as we will explain in section 7.3.3.12, Funds are allowed to fail and consequently it is possible, that the amount of funds reduces over the course of the simulation.

7.3.2.4 Public Sector agent

The Public Sector is defined as an agent since this allows us to make it independent and better identifiable in the simulation. Furthermore, the model setup facilitates the interaction with the Public Sector if we define it as an agent. Not surprisingly, in each simulation run there is only one Public Sector agent. The model allows however for the inclusion of several such agents which could open the simulation to create regions with different societal choices and therefore might allow a direct comparison of the governmental and the individual system.

The variables in the Public Sector are the following:

Variable	Explanation
Subsistence Minimum	The subsistence minimum is the amount of money each individual needs in one period in order to survive. As we have explained in section 7.3.1, it is defined to start at 8 corresponding to a value of 8,000 €. During the course of the simulation in the governmental model, the individuals are invited to vote on the size of the subsistence minimum which is linked to the social contributions. Therefore, by raising the societal subsistence minimum, the government will have to pay this amount to those people who are unable to provide it for themselves. Consequently, the vote of the median voter can also lead to a reduction of the minimal amount of money provided for by the government.
Rate of Social Contribution	In order to be able to financially support those agents in need, the government needs funds it can hand out. Each agent who receives revenue above the subsistence minimum will have to pay a percentage of this money to the government as contribution to the social services. The rate of social contribution defines this percentage and is set by the government with the intention of keeping the budget balanced. A change in the amount which is collected or handed out can only occur through the voting mechanism by changing the subsistence minimum. The rate can be adapted once a year and it will take the last years into account in order to limit constant changes in the percentages. In the beginning it is set to the value of the average risk provision in order to have both the governmental and the individual model start from an identical state.
Current Social Receipts	The Public Sector will use the amount of money it received in the current year in order to estimate if the rate of contribution is adequately defined. This variable takes all the money which is paid by the Humans in the current period.

Social Receipts	In order to make sure that the government can have a balanced budget, we also track the cumulated amount of social receipts over the years. The important task is not that the budget has to be balanced in every period, but that the behavior of the politicians (and therefore the Public Sector) is restricted to having to aim for a balanced budget.
Current Social Expenses	Similarly, we define the variables which map the expenses of the government. This variable "Current Social Expenses" takes the amount of money spent in the current year to people who need some support in order to provide for their living.
Social Expenses	In the variable "Social Expenses", we cumulate all the amounts spent since the beginning of the simulation in order to be able to compare this value to the amounts received.
Inheritance	Whenever an agent dies, her offspring will inherit her wealth.[259] In the case that the wealth was greater than zero, then the offspring will have to pay an inheritance tax of 50 percent, which means that the newborn will start better into her life than other children, but that it cannot possess the same resources as its parent. If the wealth of the individual was negative, then the offspring will not accept the inheritance and the government will have to bear the debt. Therefore the account "Inheritance" adds to the budgetary restrictions of the government. In most simulation runs, however, the balance of inheritances turned out to be positive and therefore the burden on the public budget is rather an advantageous way to ease the pressure on the budget.

[259] For a justification and a detailed explanation of the death and reincarnation procedure, see section 7.3.3.7.

Bad Year Good Year Excessive Year	In order to be able to qualify the rate of social contribution as appropriate, we have to record the budget influences in each year. This means that if the social expenses exceed the receipts, then we record a bad year. If the receipts are larger than the amounts which the Public Sector had to spend, then we record a good year. In the event that the receipts are more than twice as large as the expenses, we note an excessive year. The reaction to a series of excessive years is much faster than to a series of good years.

Table 7-5: Variables of the Public Sector agent

Note that all those variables as well as the behavior of the Public Sector agent are only relevant in the governmental model.[260] All public activity which is assumed to take place in the individual model is also present in the governmental model and therefore cancelled out of the simulation. Specifically including the provision of basic public goods could further enhance the model.

7.3.2.5 Invention agent

The only agent for which we cannot imagine that some human will take decisions is the Invention. It is defined as an agent because each individual invention is a distinct object and this makes it easy for us to keep the connection between inventor, financier, innovation and invention. The simulation always starts without any inventions since they have to be created by the Humans. Once an Invention is made, it will have the following attributes:

Variable	Explanation
Rent	Each invention is assigned a certain rent upon creation. This will be the amount of money it will return in the first period if it is successfully turned into an innovation. No individual knows how high the rent of the innovation will turn out to be. Funds will know the rent, however. It is randomly set and follows a Poisson distribution with mean 25.

[260] This means also that the subsistence minimum will not be adapted in the individual model.

Cost	The value of this variable is also set at the beginning of the simulation and it takes the amount of money which the inventor has to pay to try to realize the invention or which the financier will have to invest. The cost of the implementation of the invention is randomly set and depends on the rent. It can take any value between half the rent and double the rent. While this span is arbitrarily chosen, it guarantees that the invention has a positive overall return even if the financier is a fund and therefore only receives half the rent. Only if we make sure that the return is positive can we assume that an investor is willing to finance the innovation. Otherwise we would have to add a new evaluation mechanism which could only lead to the rejection of the invention which is a similar situation as if the agent did not create an invention. Therefore, we do not feel that a considerable explanatory power is lost by this assumption.
Weight	A new invention is assigned a weight of one. Every period it is reduced by five percentage points so that it will equal to zero after twenty years. The reason for this is that an innovation may not be as valuable towards the end of its life cycle as in the beginning. While there are certainly some innovations where the opposite is true, this assumption simplifies the characterization of inventions. The innovator as well as the financier will receive in each period the weighted rent where we use this variable as the weight.
Financed?	There are three variables which show the state of an invention. If it is not financed, then it is interesting for a Fund which may have the financial means to carry out the implementation of the innovation. Once this process has been started, the value of this variable is set to “true” because we define that each invention can only be financed once even though it may have failed at the first attempt.
Failed?	If it has been financed and the individual has been willing to take the risk of the implementation, then it is possible that the invention failed. A failed invention is no longer of interest for funds and the inventor will not be able to receive any rent from it.

Success?	Once the implementation of an innovation worked, then this variable is set to “true”. Consequently, the innovator agent and the financier will each receive half of the weighted rent every period.

Table 7-6: Variables of Invention agents

Finally, inventions are used to inspire the inventor to come up with new creative ideas and implement them. Once the inventor has died, however, and the weight of the invention is zero, we remove it from the simulation context.

After having presented the general setup of the simulation and the design of the agents, we will now turn to their behavior.

7.3.3 Presentation of rules

An agent-based model offers the possibility to focus on the individual behavior of the micro agents in a given environment. It is not necessary to conceive a system which is reducible to a mathematically solvable functional form or to resort to data analysis which is by definition fixed to a specific set of historical outcomes. Instead, an agent-based model can be created from rules applied to the agents and the emerging structure can be analyzed. Therefore, the only condition we have to impose on those rules is that they have to be plausible and consistent meaning that influences should not be counted twice in different rules or variables should be passed on correctly. Other than that, the interest of the model lies in the macroeconomic structure which emerges from the simulation, so that it is not necessary to foresee the outcomes and tailor the simulation towards it. On the contrary, it is much more possible to run the simulation with different setups and consider the effects certain changes have on the results. Therefore, we need to pay special attention to the choice of rules in the model.

The entire simulation is based on 15 rules which are implemented in the agents. An agent rule is a specified set of behaviors an agent can or will implement in certain situations. These rules are following the aforementioned principles and ideas and are designed in such a way that they should mimic the economic behavior. A list of all rules can be found in appendix B. We will now discuss each one of them in its details, showing and explaining its setup, its functioning and the reasons that lead to such a design. Overall, the rules only vary parametrically between different agents of the same class but not structurally. This is in line with the setup in the Sugarscape[261]

[261] [EpAx96], p. 18

model where the algebraic form of the rules will not change over the course of the simulation but the parameters which will be fed into them certainly do so. This means that, for example, the rule for generating the revenue is the same for each Human agent, but the input factors "work income" or "savings interest" can vary both across different Humans as well as over time for an individual Human.

In this section, we will first introduce all rules which Human agents have to follow, and then we will present the rules applying to the Public Sector agent and the Bank agents as well as the Fund agents. Finally, the rules of the Invention agents will be discussed.

There is a specialty about the rules for Humans, since every Human will call each of the rules once every period. This means that she will first update her variables (7.3.3.7), generate her revenue (7.3.3.1), then use either the social (0) or the individual risk provision rule (0), save or consume her money afterwards (0) and decide on her innovative behavior (0)[262].

7.3.3.1 Revenue generation

As we model the lives of individual human beings, we have to make sure that every agent will have the opportunity to earn her own living at some point during the simulation. This process is integrated in the rule Generate Revenue:

Generate Revenue	Human	(1) *if human is neither retired nor unemployed nor too young to work then* receive work income depending on health level (2) receive rent from innovations (3) add or subtract interest payments (4) pay back credit from earlier period[263]

Table 7-7: Human rule "Generate Revenue"

For every rule, we will present the name used in the simulation in the first column and the agent this rule is linked to in the second column. The third column then contains the major steps which are executed in each rule. They will be called in the order listed.

In this rule, we run through the different sources of income the agent receives. While the German tax code knows seven different sources of income[264], we group most of them together to form a position called "work income". This position contains all

[262] We change the order of presentation and explain the rule for updating the variables at the end, since we feel that it is easier to understand the update process once the behavioral rules are laid out.

[263] The credit has to be paid back directly so that the savings accounts can be balanced. Otherwise we could have the problem, that a bank could go out of business because it lacks the funds to pay out the savings invested.

[264] [BMJ10a]

those forms of income which the individual may earn when she is healthy and able to work. It includes the income paid by an employer as well as the profits an entrepreneur can reap from his business. It can be understood as those forms of income that will not be included in the other two categories: the rent from innovations and the interest payments from banks and funds.

The work income is then defined as a certain amount of money which the individual receives under certain conditions. The work income each individual agent can reach is assigned following the logic we have explained in section 7.3.2.1. In the rule “Generate Revenue”, the individual will receive her work income depending on some environmental and personal characteristics. First of all, the agent has to have her education accomplished. This means that a Human who is too young will not be able to work and in order to keep the simulation simple this implies that she will also not have a work income.

If the individual is old enough to work, we will make sure that she is not retired. During the initialization of an agent, she receives an age at which she will retire. If the agent has reached this age, she will be retired and her work income will be zero. The fact that this age has been set in the beginning without taking her environment or her life path into consideration is not a limit to the simulation, since the agent herself is not aware of this age barrier and it does not influence her decisions in the years before. Consequently, the start into retirement is an event the individual cannot time very well. While there are work lives and careers where the age of retirement can be estimated fairly confidently, there can always be incidents which may require a person to stop working earlier or to continue earning money. The simplification in setting a given retirement age for every Human is therefore an assumption which does not necessarily make the simulation less realistic. It rather takes into account the unpredictability of the different turns each life may take.

For an individual who is old enough to work and who is not yet retired the only danger for the work income is unemployment. Becoming or staying unemployed is a random event. For an agent who has been unemployed in the preceding period, the risk of staying unemployed is twice as high as for someone who used to have a job. For each one, we find a random number between 0 and 100. If this number is lower than the average unemployment rate, then the Human is unemployed. This will lead to a randomly fluctuating unemployment rate for the simulation’s population. Since we have not modeled the industrial sector, we have no indication why this rate should be changing at certain time steps. A random oscillation is then preferable to a constant rate, since the random change in the unemployment rate seems to be more realistic. In a more elaborate and more complex simulation which actually models the industrial sector, the unemployment status of every individual might depend on intrinsic characteristics of this Human. In our case, adding such a functionality, such as for example making an uneducated or an older individual more likely to be unemployed, would not add much insight to the simulation because there are additional factors which significantly influence the likelihood of an individual to become unemployed such as her work attitude or the economic situation in her specific sector of employment. The last two are not available in the current simulation setup and therefore choosing only a few characteristics which influence the unemployment status of each Human will not make the simulation results more reliable.

If the individual is not unemployed, not retired and not too young to work, then she will receive her work income depending on her health status. The health status for the current period is set at the beginning of each year in the rule “Update Variables” and ranges from 100% to 0%. An individual who is 90% healthy will accordingly receive a work income of 90% of her “work income” value. Since most modern economies have systems in place where a low number of health related absence is not punished by an income reduction, this assumption should be interpreted with caution. The precise work income of every person varies over the years also depending on the health of the worker. In some years, an individual has the opportunity to earn more and in other years, her income may suffer. This variability in the work income is now entirely reduced to being health related. It can be argued that this assumption is rather strong but since we have not modeled the industrial sector in detail and since we consequently do not have specific insights in the reason why the work income for the individual might vary, we could not include other factors influencing the precise amount in each period. Therefore, we do need a random term which will generate an oscillation in the amounts the individual is earning per year. The health values are calculated including a randomization. Consequently, we do not feel that this simplification in the generation of the work income of the individual is overly simplistic.

After having received her work income, the individual will reap the profits from her innovations. Each innovation has a fixed rent which degrades over time. Every period, the value of the rent is reduced by five percentage points. The inventor will receive half of the rent and the financier the other half. In case that the inventor has also financed the innovation, she will receive the entire rent. Programmatically, this behavior is implemented in a combination of actions taken by the agent as well as the invention, since the agent calls the “Pay Rent”-rule of each of her successful inventions and the invention will then return the corresponding rent.

In the next step, the individual will receive her savings’ or investments’ interests or will have to pay interest on her credits. The banks always demand an interest rate which is one percentage point above the interest rate they offer their customers. The calculation rules for funds and banks are explained below in the rules “Calculate interest rate”. For the agent, the interest received is added to the revenue from the two other sources and the interest paid is deducted.

The last step in the process of generating the revenue for the individual is that if she had a credit during the last period she will have to repay it. We use this strategy to make sure that a bank cannot fail and that we can consider the bank savings as low-risk investments. Each individual will have the opportunity to receive a new credit during the course of the year in order to finance her consumption behavior. Therefore, it is possible that an individual can receive a credit for several consecutive periods. If we had allowed banks to negotiate long-term credit contracts, then we would have to make sure that an agent who wants to withdraw her savings can be served by the bank. Otherwise it could be possible that her savings are lent out to other individuals and she will not be able to use her money. Including this functionality into the simulation would add an enormous amount of complexity. The solution proposed in our model has the advantage of being simple yet allowing the credit market to be working properly and in a balanced way.

7.3.3.2 Risk provision

The next step an agent will take is to provide for the life risks we included in this simulation. There is a growing strand of literature arguing that a life in poverty is not only marked by an insufficient income but also by the lack of the possibility to participate in social life.[265] It is therefore important to define the risks an agent will face in the simulation and the ways the individual can react to them or protect her from them.

[265] See for example the capabilities approach introduced by Amartya Sen and the concrete interpretation by Martha Nussbaum. For overviews of both theories, see for example [Clar05] and [Garr08]

An individual will face multiple risks which can include losing money because she will be unemployed, but it can also happen that she falls on a snow-covered pavement and breaks an arm. Possibly, her income situation will in no way be affected by this injury, and therefore no revenue focused insurance system would help her. Nevertheless, she might have to use part of her income to cover the cost of regaining full health and, consequently, has a lower amount of money available. Besides, we could imagine a case, where situations are not touching at the disposable income and still the utility of life is reduced like for example when a person has to move into an area which she feels less comfortable in. Each government will have to decide in which cases the society should step in and help the individual and to which degree and in which form it should try to soften the consequences from a realized risk.

In this simulation, we have chosen to consider risks mostly from a monetary perspective. It would have been possible to implement utility characteristics for the individual which could then influence the overall happiness and by consequence, the innovation propensity or welfare in general in a society. However, following the approach to keep the simulation simple, this idea has not yet been implemented. As of now, the model only takes monetary effects of risk realization into consideration and will only try to cure those effects by monetary terms. There is, however, a certain influence which the public sector may have on the creativity and the inventiveness of the individuals linked to the provision of social insurance. We will explain this in detail below in section 7.3.3.6.

Furthermore, we will have to look at the provision the individual takes for her risks. Depending on the willingness and the degree of help of a society, an agent will take different decisions on protecting herself against those risks. Therefore, there are different rules for the individual and the public model. We will present both in the following paragraphs.

7.3.3.3 Social risk provision

In the public model, we know that the government will help the individual if she is unable to cover her subsistence minimum. On the other hand, each Human is obligated to contribute to the social insurance funds which will then be used to help those fellow-countrymen in need.

This is summarized in the following rule for risk provision in the case of the public model:

Social Risk Provision	Human	(1) *if Revenue > Subsistence Minimum then* pay percentage of contribution required (2) *if Revenue < Subsistence Minimum then* receive difference from social insurance

Table 7-8: Human rule "Social Risk Provision"

The idea of the public model is that the individual agent will not have to analyze her individual risk or provide for it on an individual basis. Instead, the social system will protect her in case her income is insufficient to cover her subsistence minimum. On the other hand, the agent will have to contribute to the public funds if she has enough money.

In the present form, the individual who earned a sufficient income will first consume her subsistence minimum, which is designed to be exempt from the contribution. The reason for the exemption is that an agent, who will pay a contribution to the social funds, might then lack the money to finance her own subsistence minimum and will then require the support from the society again. This is comparable with a tax exemption for low incomes in many countries[266] and is reflected in the discussion on fairness in the public health literature[267]. The current subsistence minimum is set endogenously in the voting process described in the rule "Set Subsistence Minimum" implemented in the Public Sector.

There is a long literature on the question how a premium-based insurance system should be designed[268]. There is a discussion on systems with fixed premiums per individual since the risk of a person to be in distress is not necessarily linked to her

[266] Even though many countries offer a tax exemption for low incomes, this is not necessarily the case for the contribution to social insurances. In Germany, for example, the employer will have to pay the integral contribution up to an amount of 400€ per month [DRVKBS10]. In this model, it is not relevant if the employer will pay – partly or entirely – the contribution since we do not model the wage negotiation process. Therefore, we can just consider any income below the subsistence minimum to be exempt from any social contribution or taxes.

[267] See for example [MuKMXK01].

[268] See for example [RoCa05] for a good overview.

income. Furthermore, there are debaters in favor of a system with a fixed percentage of income which an individual has to pay. The argument put forth is that every individual has to pay according to her "capacity to pay"[269]. Third, it is possible to include the social insurance contribution in the progressive tax system. This would imply that a person who earns more will also pay a higher percentage of her income towards social contribution therefore reducing the burden for those members of society with a lower income.

The way our simulation is set up, every individual will pay the same percentage of her income towards the Public Sector. In order to keep the model simple, we have chosen to refrain from implementing a progressive contribution rate depending on the income.

An individual whose revenue is not sufficient to consume the subsistence minimum will receive a contribution from the state. The contribution will raise her to the subsistence minimum. There are several issues related to this decision.

The first question we have to ask is if we should include the savings of the Human into the calculation of the contribution she is entitled to. This would imply that an individual with an insufficient income but high savings will have to first use her savings before she can receive the social insurance payments to cover her subsistence minimum. The discussion in Germany has just been restarted during the 2009 federal election campaign when all five parties which have been elected called for a higher amount of savings to be disregarded for the calculation of social benefits.[270] At first glance, it seems to be the best choice, to design the model such that the Human will have to exhaustively use her savings before receiving a subsidy from the state. This implies that an individual will only receive help and support from the society when she is really not able to care for herself anymore. In our model, however, we aim at simulating a world where the government covers the essential risks an individual is facing during her lifetime. From a behavioral perspective, she would not have a high incentive to save if she might risk having to use her savings in a period of financial distress. Besides, we have assumed that the public model allows the individual to ignore the provision aspects of savings since it is covered by the public insurance system. Consequently, the savings stock an individual forms is not meant to be used for helping to overcome situations in which the available financial means are insufficient. It is therefore necessary to disregard the savings of an individual in the public model when calculating the social contribution from the state.

[269] [MuKMXK01], p. 10

[270] see [CDUCSU09], p. 30, [SPD09], p. 37, [FDP09], p. 9, [B90Gruen09], p. 95, [Linke09], p. 26

Secondly, we have to take a look at the incentive effects of the welfare system which we have modeled on the individual's propensity to accept a new job. Regardless of the behavior or the effort an agent has undertaken to be able to support herself in a period, she will receive social benefits if she is unable to cover her own subsistence minimum. This may lead to moral hazard behavior of agents who will be content with the benefits they receive. Besides, they do not have any incentive to accept a job which pays less than this social minimum.

The subsistence minimum in our simulation only allows the individual to satisfy the basic existential needs. Consequently, any work income above this threshold earned by an agent will make her better off on a monetary scale. Since the average work income is 40,000 €, we can hypothesize that a subsistence minimum of 8,000 € will hardly distort the work effort for the majority of the population.

The groups for which it may be interesting to show moral hazard behavior and to shirk the effort of finding a new job are those who have very low paid jobs or who do not earn enough money because of their health status. From the simulation setup we know that any income of a healthy person is above the subsistence minimum. Therefore, there is only a very small amount of agents who might be tempted by trying to come to terms with living off the subsistence minimum. Some of those will prefer to work and earn the additional money, and some might certainly fall prey to moral hazard behavior.

Nevertheless, since the latter group is very small in this simulation and since we find moral hazard behavior endogenously implemented in the inventive activity, we have not added a shirking behavior to the working decision of the agent.

7.3.3.4 Individual risk provision

The counterpart to this social risk provision rule is the rule which explains the agent's behavior in the individual model. We have implemented it as follows:

Individual Risk Provision	Human	(1) *if Revenue > Subsistence Minimum then* a. *if satisfied with returns then* pay money into one's own provision stock according to risk aversion and time preference. b. *if dissatisfied with return then* move entire provision stock to different bank and pay money into one's own provision stock according to risk aversion and time preference. (2) *if Revenue < Subsistence Minimum then* a. take money from the risk provision stock and from other savings if necessary to add up to the Subsistence Minimum b. *if Money left Available < Subsistence Minimum then* try to get a credit from the financial market c. *if no credit available then* die of starvation (3) deduce subsistence minimum in all cases unless death

Table 7-9: Human rule "Individual Risk Provision"

An agent will first compare her revenue to the subsistence minimum. If it is sufficient, then she will satisfy her basic needs and therefore spends the subsistence minimum. The second step is to invest a part of her left over money into her risk provision account, so that she can care for herself if the revenue should be insufficient in a later period.

In order to provide for herself, she will save a certain percentage which depends on her risk aversion and on her time preference. The higher the risk aversion, the more the individual will save out of her precautionary savings motive in order to be better protected in the event of a realization of an existential risk. It is quite the opposite with the characteristic time preference of the agent. The higher the time preference the more she values consumption today and the higher are the opportunity cost of saving. A higher time preference of an agent will therefore lead to a lower percentage of risk provision. In order to reduce complexity where possible we have not included the actual revenue into the decision to provide for her risk. There are different strains of thought to be respected if this behavior should be respected as well. An individual with a higher income might save a lower percentage of her revenue since she might fear a similar cost related to a realized risk as someone with a lower income. Consequently, she will reach this amount in her risk provision account faster.

On the other hand, she might be willing to save a higher percentage of her income for the risk provision since she aspires to have better care in case of a realized risk and since she can more easily cover her consumption wants beyond the subsistence minimum. The current implementation is also in line with the design of the social model which therefore adds to the comparability and the transparency in the model's outcomes.

The individual will then invest the money she wants to save to protect her against the imponderability of life at a bank or a fund. Before doing so, she might, however, look for a better bank or fund to save her money at, if she was unhappy with the interests that were paid in the previous period. The only criterion for her choice is the interest rate. The agent accordingly looks at all the financial institutions which she can see in her surroundings. Depending on her risk aversion and the interest spread between banks and funds, she will choose either of the two types of institutions (bank or fund) and then select the bank or fund with the highest interest. This decision will be explained in detail in section 7.3.4.2. The bank can then use the money to hand out consumption credits as explained in the rule "Award Credit" in section 7.3.3.11, or the fund will use the money to invest in innovative projects. The individual has now provided for her existential needs as well as her life risks, therefore she can use the remaining amount for consumption or savings purposes or she might use it to finance her own innovations.

On the other hand, we can have the situation where the revenue of the individual is insufficient to consume the subsistence minimum and therefore to provide for her basic needs. In this case, she will have to attack her savings and her risk provision account. The first reflex is to empty the savings account. The agent will take all this money which she had set aside to fulfill future consumption wants to overcome her present difficulties. Besides, in the case of a risk realization, she will try to reduce the risky positions in her portfolio and keep the less-risky resources as a guarantee for future hardships.

If the savings in the savings account are not enough to cover her subsistence minimum, then she will tap on her risk provision account and withdraw the remaining amount. In both cases, she has used her savings to cover the basic needs and therefore she has no more funds available to consume or save more and she cannot finance any of her own inventions.

It is possible that her entire savings – combined from the savings account and the risk provision account – are too low to finance the most elementary consumption. Any agent who is too young to work will be in this detrimental situation. Unless she inherited means from her parents, she will be faced with a situation without income and without resources to cover the subsistence minimum.

In this situation, she can turn to the banks to ask for a consumption credit which she will be awarded if the bank has sufficient funds available. The policy of handing out credits is explained in detail in section 7.3.3.11. In order to find the most preferable bank, the agent will take quotations from each bank in her field of vision and then chooses the one with the lowest interest rate. If no bank offers a credit, the agent will die due to starvation. This may seem to be a very harsh and crude assumption, but it is the long-run consequence of any system that leaves the individual to her own fate. The model therefore does not know of neighborly help or agents who will support an individual in existential difficulties.

7.3.3.5 Save and Consume

It is difficult or maybe even impossible to capture all the factors that influence the personal consumption and saving decision of an individual. "Personal saving is inherently a dynamic process that depends on expectations about future income and retirement benefits in ways that cannot be fully captured by the current income level and the actuarial present value of social security benefits. Such things as the changing demographic structure and the anticipated changes in real net-of-tax rates should in principle be included but cannot generally be measured or summarized adequately."[271]

Therefore we have to simplify the consumption and saving behavior of an agent if we want to be able to include it in the simulation.

[271] [Feld82], p. 640

The rule which the agent follows when deciding on her consumption and savings behavior is set as follows:

Save or Consume	Human	(1) compute savings ratio by varying average consumption ratio with a. amount of savings relative to revenue (+) b. time preference (+) and c. offered interest rate (-) (2) compute amount consumed from amount available (3) *if remaining amount > 0 then* place remaining amount in savings account and find bank to invest money (4) *else* look for bank to lend the money

Table 7-10: Human rule "Save or Consume"

When an individual has satisfied her basic needs and is still left with money, she will have the choice of consuming or saving it. When modeling the consumption process, we have to start at the decision of the budget for immediate consumption.[272] Only in the subsequent steps will an agent decide on which products to spend her money or where to save it. The Human in the simulation will behave accordingly and first compute her consumption ratio.

The individual consumption rate will oscillate around an average consumption rate[273] in order to calibrate the model. Each agent will then value her savings and her debt against the revenue. The higher the ratio of her wealth to income, the more she is willing to consume. This means that an increase in savings will also raise the consumption rate of the individual, where the consumption rate is then multiplied with the disposable income to calculate actual consumption. In the case of an increase in revenue, however, the consumption ratio will fall. This may or may not result in a reduction in consumption. There is a large literature on the influence of income on the consumption behavior.[274] While there are many theoretical approaches to how an increase in income should replicate in the consumption behavior, the data does not always follow those theories. The setup in the simulation follows the results from empirical studies and takes into account, that an individual with a higher income will consume a smaller share of her disposable income.[275] This is also in line with the KISS-approach of the model.

[272] cf. [RoZW84], pp. 3f
[273] We chose 10% since the current average consumption ratio in Germany between 2000 and 2007 amounted to 10.1%. [IW09], p.64
[274] for an extensive overview, see [Wärn99], pp. 120-160
[275] see for example [MaPa01]

Furthermore, the higher the time preference of an individual, the higher will be her consumption rate in the current period. Humans with a high time preference assign a strong value to today's consumption and face therefore higher opportunity cost when they have to postpone this consumption to a later moment in time. Often, time preference is supposed to decrease with age and increase as an individual is retired. This follows empirical findings that age has a considerable impact on time preference[276]. We have decided not to vary time preference with respect to age in order to keep the model as simple as possible. This is due to the fact that there is still a debate how and according to which factors time preference is changing. In the future, varying the measure of impatience with respect to age could render the model even more realistic, and as we explain in section 7.3.3.7, the time preference of agents is influenced in the simulation because of the interaction with other agents in their friends-network.

We have also taken the decision to ignore the risk aversion of an agent as a decisive input factor for her consumption behavior. While it is fairly undisputed that risk aversion and risk behavior do influence the savings decision of an agent[277], it is not clear if it has to be integrated in the savings decision in this simulation. The precautionary savings motive has already been covered when an agents reaches the decision rule about saving and consuming. This means that she has already had the opportunity to provide for her risk and should not have to worry about it anymore.

Nevertheless, we can argue that risk aversion does play a role when an individual has to decide about her savings behavior. There are two motives which could surface: a high risk aversion could make her choose to consume less today to buy better products in a subsequent period. So, instead of buying a regular TV today, she might choose to save the money to buy a better TV in the next period or use the money in case something unexpected happens. On the other hand, a high risk aversion could make the agent be afraid of changes in the future and therefore she is more akin to consuming today. Maybe a consumption option could vanish or the desire for a product disappear. For example, this could be the long sought boat cruise where an individual is afraid that her health status could worsen while she is saving up for the event. The risk aversion could therefore have positive and negative implications on the consumption ratio. In order to keep the model simple, we chose to leave it out entirely of the consumption decision of the individual.

[276] see for example [Bish04]
[277] see for example [Knol08]

Even though Keynes has not been favorable to adding the interest rate into the equation on the consumption decision[278], the classic IS-curve maps this correlation in a very explicit way. In the simulation, we follow this approach that an individual will save less the more interest the banks offers her. With an increase in the interest rates, the opportunity cost for consuming an additional euro increase as well. Therefore, she will save more. The agent will take the rates of banks and funds into account when deciding on her consumption ratio. The higher the interest offer by funds and banks is the lower will be the percentage of her income which an agent will consume. Every individual will have her individual average interest rate, because she will calculate it from the financial institutions she can see in her environment. Since no individual has perfect information, otherwise comparable agents may take different consumption and savings decisions only because they are offered different interest rates in their region.

Once the consumption ratio is defined, the agent will calculate the amount she wants to use for consumption. Since we have not modeled the real sector in detail, it is not important where the agent spends her money. We also do not inquire if it is spent on innovative products. The only importance in the demand equation is the time when the income is spent by an individual. If the Human possesses enough money to fulfill her consumption desires, then she will spend it and save the remaining amount. This could also imply that she takes money from her savings account and uses it for consumption purposes in the current period.

In the case that she would like to consume more than she has, she will have to apply for a credit. This is a fairly straightforward task in the individual model since the agent contacts all the banks around her and checks for the best quote. She will then choose the bank with the lowest offer until she finds one who is willing to lend her the money. The consumption credit will have to be paid back at the beginning of the consecutive period.

In the governmental model it is less clear, however, if agents should have the right to take out a loan on consumption wants. An indebted individual always faces the risk that she is unable to repay the credit. This will certainly have repercussions on her risk behavior and probably her economic behavior in other fields as well. Since we have taken the assumption that Humans in the governmental model can see all their existential risks covered by society, it can be argued that they consequently do not have the right to take out loans from banks.

[278] cf. [HaKC02], p. 291

In this model, we have taken the opposite strand of thought. Even though an individual has all her basic needs covered and insured, she may want to consume more money than she holds in a certain period. The increased risk of accruing too much debt will be met by introducing the possibility of filing for personal bankruptcy in her lifetime which will then deny the agent any more consumption credit.[279] We also discuss the issue that this will not create a negative incentive to take out excessive debts in section 7.3.3.7. The agent can therefore follow the same consumption behavior as in the individual model. This adds transparency and comparability to the model.

Besides, there is a model-related reason which also points towards allowing agents in the governmental model to ask for credits. If the banks had no credit request they could not offer any interests on the low-risk savings market. Therefore, the financial sector would have to be entirely redesigned which would further complicate matters without adding insight to the model's outcome on the relationship between innovation and social insurance schemes. Nevertheless, a researcher building upon this model has to keep this influence in mind when adapting the model.

7.3.3.6 Innovate

Each individual will then have the opportunity to invent and innovate. As we have outlined earlier, not everyone feels comfortable or is creative enough to think of an invention. Besides, not everybody who invents something has the ability or the potential to implement it as an innovation. The entire innovative activity is designed in this rule and will be explained below:

Innovate	Human	(1) Compute invention propensity according to her education, work experience, innovation experience, network stimuli, her happiness, merit goods, her tinkerer propensity and her risk aversion
		(2) *if an invention is made then* compute financing propensity according to her wealth and the cost of the innovation
		    a. *if willing to finance then* compute risk propensity according to risk aversion, risks privately borne and innovation experience
		        i. *if willing to risk then* carry out innovation
		            1. *if successful then* add innovation to portfolio

Table 7-11: Human rule "Innovate"

[279] This is in line with findings from [HaLi09] stating that a person who had filed for personal bankruptcy usually has difficulties when trying to get new loans afterwards.

As we have explained in chapter 0, the focus of the work is on the individuals and their role in the innovation process. This means that we restrict the innovative activity to the individual entrepreneur as well and not to a firm-like conglomerate of several actors. The reasons which lie behind this decision have been discussed above so that we will now present the actual implementation and design of the entrepreneurial activity in this section.

In order to become innovative, an entrepreneurial agent needs an invention which can subsequently be marketed. The process of implementing an innovation is therefore split into three separate and subsequent steps which have to be accomplished: inventing, financing the invention and risking carrying it through. Nevertheless, not all the steps have to be taken by the same individual.

So in a first part, we will explain how an individual can come up with an invention. The characteristics of the individual inventor, of her environment and of the circumstances surrounding the invention are important when it comes to modeling the way inventions are created. It is important to stress that the inventor and the innovator do not have to be identical and often enough they are not the same person. In our simulation, however, we will define them to be identical for reasons of simplicity. A more complex model could certainly allow for the possibility that an individual who has a propensity to being innovative will buy the invention from someone who is creative and inventive but not willing to carry out the innovation. In the abstract form of our model, we feel that the argument is not hurt by requiring each entrepreneurial innovator to have to find an invention first.

While it is difficult to find a general rule to describe how people become creative and find inventions, we will outline and discuss the design which we use in the simulation and the reasoning which led to the implemented setup. Modifications in the modeling of this rule could be used to include different theories on how innovation occurs in an economy and a society.

In order to model the process of invention, we have chosen to set up a system where we include all factors which influence the creativity and inventiveness of an individual and then calculate her propensity to invent. If a random value between zero and this propensity to invent is above the invention threshold which is exogenously chosen, then the Human finds an invention in the given period. This means that the better the qualifications are, the higher is the probability for an individual to be inventive, yet there is no certainty to find an invention. We will now present the factors which influence the inventiveness of an agent and will then present how an individual can manage to transform her invention into an innovation.

The first characteristic we take into account is the education level of an agent. There is considerable evidence that the higher the education of an individual, the more she is likely to be creative. “Overall, the correlation between a measure of human capital and technological productivity can therefore be empirically confirmed”[280]. Higher education will increase the capabilities of an individual to see similarities and linkages between different aspects or to find more elaborate solutions to certain problems. Though this does not mean that a person with higher formal education will be an inventor and those with lower education achievements will not, it only states that the increased level of education increases the likelihood of an individual to become an inventor. Consequently, it is not sufficient for an entrepreneur-to-be to be smart[281], but this makes the task easier.

The next aspect, we take into consideration is work experience. While the educational level helps us estimate the amount of knowledge a Human has access to and has been confronted with, work experience is a measure which shows us how much she may have learned in her job. The more experience an individual has, the more she is able to judge if creative ideas related to her field of activity are worth being explored.[282] “Looking at the results from the literature review carried out for each country, the slogan could be ‘nobody is born an entrepreneur’. Level of education and previous experience are essential factors“[283]. When an individual knows the tasks she is fulfilling well and how they blend together with the general production process, she is able to find those points where a simplification or improvement could be achieved at a reasonable cost and with a valuable effect. “Specialised labour builds up enough experience through learning by doing from which to create inventions as a problem solving exercise”[284].

As a next step, we have included the experience in inventions into the propensity to be creative. An individual who has already invented certain things, processes or methods is likely to have all those characteristic traits which make a new invention likely. Furthermore, she knows how to carry through a creative process so that she can reach

280 “Insgesamt kann der Zusammenhang zwischen Humankapitalbestand und technologischer Leistungsfähigkeit daher empirisch bestätigt werden.“, [DoFH06], p. 91; see also [Witt87], p. 167
281 [Ogle07a], Chapter 5
282 cf. [Dono10]
283 [EUComm03], p. 29
284 [Swan09], p. 120

a state where the invention is usable. The success and the failure to invent and find new solutions will increase or respectively decrease the search intensity of an individual.[285] Since we have not modeled a failed process of invention, we can only take the successes as stimulating events into consideration.

One of the aspects which influence people to become creative and to try to find new things certainly is due to their surrounding environment. Human beings are part of their peer group and their network and there are effects of interaction, assimilation and differentiation which are induced by the network. The indirect effects are modeled in the rule "Environmental Influence" where the preferences of an individual can change according to her peer group. We explain the detailed methods of this rule in section 7.3.3.7.

We have also included the very direct effect of the size of the network of the individual as a relevant criterion for her inventiveness. The peer related effects can stimulate creativity in the individual and can open up idea-spaces which are seemingly unrelated. "The larger the network of people from whom we can learn, the greater the prospects for invention"[286]. Accordingly, we have included the size of the network of those friends which an individual considers to be important for her into the equation to create her inventive potential. The choice is made for the more important friends[287] because the more valued a contact is the higher is her influence on the friend. In this first step, we do not investigate if the network of friends is inventive or innovative.[288] We follow the logic that an agent who is exposed to many different ideas as a consequence to having a large network is more likely to see coincidences which others do not.[289] So, it is not necessary that the friends and acquaintances be very creative for the individual to increase her own inventiveness.[290]

Additionally, we take the happiness of the individual into account. The happier an individual is the more likely she is to be creative because she does not have to worry about other things in her life. Happiness can also open up the possibility of thinking outside the box and trying new ideas.

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285 [Witt87], pp. 162f

286 [Swan09], p. 119

287 In section 7.3.3.7, we explain how a friend can become a "cool friend".

288 cf. for example [Ogle07b]

289 cf. [Dono10]

290 Note that we have included the innovativeness of the friends-network in the decision whether an individual is willing to assume the risk of realizing her innovation. This effect is presented below in this section.

The subsequent point is that we included the provision of merit goods, where we consider all the expenses and provision the state is able to offer its citizens in the governmental model thanks to the social insurance contributions. They include infrastructure expenses, service offers as well as the provision of certain amenities such as health regulated expenses and regulation or publicly run hospitals at certain distances. Furthermore, they may include publicly funded programs for reintegration into the labor market or services for the elder. We have tested the model with this factor included and without it and find in both cases that the inventiveness and the average income are statistically significantly higher in the governmental model. A detailed analysis of the outcome can be found in section 8.2. The reason for including this influence is that a government will not only provide social insurance in monetary terms but that it will also use this money to provide goods and services for the citizens which can increase the welfare of the members of a society.[291] In such a situation where an individual can benefit from the provision of certain public services, she might be more creative. The argument follows a similar logic as the one for including happiness above since the better the provision of goods and services in the public space, the less a Human has to care for such things herself or bother with difficulties which might not be standardized or trivial in the absence of a public influence. Consequently, she can concentrate on other things where she might be more creative and have more insight. Examples for such influences may be a working infrastructure of different services or roads which are in good shape, furthermore public safety and the different degrees of comfort which people may feel with regard to homeless people or beggars. Social insurance can provide for a certain standard in the life of the people which may give them the possibility to focus on their creativity.

On the other hand, we just argued that we ignore the taxes in the model since we assume that in both situations – the individual model and the governmental model – the state provides a certain basic level of public goods such as roads and clean drinking water in order to be able to compare the results of the model. We can now argue whether the merit goods influence in this rule is contradicting this similarity in basic public services. We feel that it is not problematic to use this influence since there is a large range of additional public provision available to the state in the governmental model which can lead to additional benefits for the population and which enable the individual to exercise her creativity more easily.

[291] cf. for example [Sinn96]

Furthermore, the inventiveness of an agent is also dependent on her so called personal characteristics and disposition towards inventions, creativity and new approaches. As we explained in section 4.2, the personality of the innovator is very important. There have been many specifications of how such a personal tendency, which Schumpeter called "entrepreneurial genus"[292], can be described. It relates to the fact that two people can share most externally visible and measurable endowments but that they nevertheless have a different personality when it comes to novelty.[293] The one trait which is important in this rule is the inclination towards being creative which we call 'tinkerer'-characteristic in the simulation.

In the simulation, an agent who does not have this disposition towards inventions and innovations can nevertheless be creative and come up with an invention. But this 'genetic' predisposition increases the probability of an individual to be inventive and is consequently part of the invention propensity calculated for each Human.

Finally, the risk aversion is an essential criterion when it comes to the willingness of an individual to strive for an invention.[294] The creative process is unforeseeable and it is unpredictable. This means that a person who is willing to invest herself in such a process can never be sure that she will eventually reap a profit from the endeavor or that she will even bring the project to a fulfilling and satisfying stage. At this point in the simulation, we include risk aversion into the propensity to invent in such a way that an individual with a medium risk aversion will have the highest probability of being inventive. It is not the tendency towards accepting to take the risk of the innovation, but it is the general disposition towards risk which makes an individual more apt at inventing. A very risk adverse person will be less likely to take on an unsecure costly endeavor of creating something new. On the other hand, a person who is a risk seeker may not have the perseverance to carry the invention through until it is marketable. She may look for new thrills before having finished the last project. Therefore, we increase the propensity to invent for those individuals with a moderate risk aversion.

From those factors, we establish a measure of invention propensity and compare it to an invention threshold. Only if a random number between zero and this invention propensity is above the threshold, the agent finds an invention. The threshold for inventions can be exogenously set which increases the possibility to test the model for

[292] [Schu34b], p. 217: "Unternehmergenus"
[293] cf. [Dono10]
[294] cf. [Witt87], p. 167

robustness in the inventiveness. This means that we can test if social insurance has comparable effects on innovativeness, if invention is easier or more difficult. We have tested the model with three different threshold levels (40, 60 and 80). From the results we can infer that the harder it is to find an invention, the larger is the advantage of the governmental system. Nevertheless, the lower the threshold and the easier it is to be inventive, the more innovations are generated and the higher is the average income in the society.

For reasons of simplicity, we assume that the process of finding an invention does not entail any costs for the individual. This is due to the fact, that every agent processes the rule "innovate" even though she may not at all be inclined or capable of finding an invention. Then she should not have to face any cost linked to this process.

Besides, for all those who do find an invention, the cost factor will be treated when it comes to financing it to turn it into an innovation. The cost she will have to bear then can be understood to include all the costs linked to the inventive and the marketing processes. If the agent cannot implement the invention, it can still be realized through the help of an investment fund who will then cover the cost and therefore the inventor once again does not have to bear any cost of her invention. Including a cost for an invention would consequently only influence the simulation in the case of an invention which will never be carried out. We decided that this case did not justify rendering the innovative process even more complex by setting a cost for this invention and having to include it in all subsequent calculations for the agent and the investment funds.

Once an agent has found an invention, she will see if she is able to finance its implementation. We used a very simple and transparent procedure to do so, because if the sum of the agent's savings exceeds the cost of carrying out the innovation, then we consider her ready to finance it. It can be argued that she will be able to receive a credit from the banks to finance it if the invention is promising, but then we have a similar situation as when an investment fund steps in as financier. Consequently, such a situation would not add considerable insight to the simulation's results.

Besides, it could be possible that an agent who has made an invention will rethink her consumption behavior and save for a subsequent year so that she is able to implement the innovation at a later point in time. While this seems to be very intuitive and understandable especially for those inventors who do not seek the support of strangers, it would require another set of strong assumptions on the behavioral change incurred by the desire to finance the proper invention and on the subsequent consumption and savings decision. It could then be argued that such a situation also leads to an increased supply of working hours and easily we would have to add a new set of complex rules to the simulation. So, we have not implemented this possibility in order to keep the model as easy and transparent as possible.

Therefore, we consider the financial capacity of the inventor in the very moment of the invention and if she can bear the cost of implementing it, she will next consider the risk linked to it and assess it. As we have discussed in sections 0 and 4.3, the risk borne by the entrepreneur is not directly linked to her function as innovator but rather to her acting as capitalist and financier of her own innovation endeavor. Therefore, in this situation where an individual is willing to finance the implementation of her invention, we also have to look at her willingness to bear the risk.

Consequently, whenever the inventor takes on the role as financier, then she will also have to reflect on the risk connected to the invention and judge if she is willing to accept the possibility of the innovation failing and her being liable for the cost of it.

Comparable to the situation in the first step where we took several characteristics of the agent into account in order to calculate her propensity to invent, we will now look at those aspects which are important when she has to decide if she is willing to assume the risk connected to an innovation.

First of all, she will have to consider her risk aversion where it follows from our discussion in section 4.2 to consider an individual with a higher risk aversion less likely to be willing to realize the innovation. Nevertheless, we have integrated a random factor into the risk aversion of the individual which allows the value to be increased or decreased by 20 percent. This can be seen as the different assessment of the innovation endeavor compared to other risks an individual faces in her life. There might be some people who will be fairly risk adverse when it comes to securing their standard of living and protecting them from existential risks, but who are willing to accept the risk connected to the innovation. On the other hand, it could be that a person is not too risk adverse in the everyday routine when dealing with uncertainty she is used to, but when it comes to the new and unfamiliar situation of risking an innovation, she is less inclined to bear the risk. Finally, the risk aversion might just be influenced by some event of the exact day when she has to take the decision of implementing the innovation.

Furthermore and relating to our overall question, it is important for the decision of an individual to engage in a new uncertain endeavor to qualify the risks and uncertainty she already bears. So we incorporate into the risk propensity the state of the model – individual or governmental. An agent who is rather risk averse[295] will be more inclined to risk an innovation in the governmental model where her existential risks are secured through a social insurance scheme. An agent who is more risk seeking[296] will focus more on the incentive to innovating which is higher in the individual model because her innovation rent is not subject to the redistributive system of contribution in the social insurance setup. Therefore, the state of the model can induce the risk taking if the individual feels comfortable with the public setup of existential risks.

Additionally, we include her innovation experience into the risk propensity equation. The more innovations she has successfully carried out, the more she will be willing and ready to bear the risk of a new innovation since she can better judge the challenges awaiting her and the difficulties which can arise. Furthermore, those innovations which have been attempted but failed will not reduce her inclination towards starting a new innovation endeavor on her own. Neither will those inventions where she could not finance the realization or where she could not find an investor influence her risk decision.

It could also be argued to include those experiences in the opposite way, namely that a successful innovation reduces her willingness to carry out another one and that the failure of an innovation will have an influence on her willingness to realize an innovation in the next situation. We have chosen to implement it as described for two reasons. On the one hand, we follow Schumpeter’s observation that an entrepreneur does not stop when he successfully secured his standard of living but that there are many reasons why he continues to try to be successful.[297] When he therefore has the opportunity to carry out another innovation, he will see the opening as a chance and not as a burden linked to additional work and implementation obstacles.

On the other hand, there are two opposite strands of argumentation in the case of a failed innovation endeavor. The first strand argues that we could make the agent more risk averse because a burnt child dreads the fire. So, only if her risk aversion has decreased since the last approach, she would dare assuming the risk again. The second strand goes as follows: from the failed approach, she has learned to avoid some mistakes and has grown more aware of the difficulties awaiting her during the process of implementing the innovation. So, when she is faced with the decision about risking

[295] This means that she has a value for her risk aversion characteristic between 6 and 10.
[296] This means that she has a value for her risk aversion characteristic between 0 and 4.
[297] [Schu34b], pp. 135f

a new endeavor she might feel more secure and therefore be even more inclined to try the realization. Besides, she could just feel all the more so the urge to make the project succeed.[298] "The striking thing about the innovators who succeeded in making our modern world is how often they failed. [...] No one likes failure, but the smart innovators learn from it."[299] Consequently, we could argue in both directions which influence outweighs the other, but for reasons of simplicity we decided to leave the failed innovations out of the risk decision.

Furthermore, having people in the environment who have realized an innovation certainly has a positive impact on the individual, since she can experience the difficulties as well as the success related to the implementation of an innovation. Furthermore, it might make her more confident to pursue her own innovation. "Not only provides the social network the opportunity to have access to additional and complementary endowment factors, networks have a crucial influence on the actual entrepreneurial decision to start a venture itself."[300] This means that if she can see others in her environment successfully implement an innovation, she may feel less fear to misjudge the overall economic situation or the difficulties related to an innovation.

Once again, we have to take a closer look at the cost of the implementation of the innovation. Independent of the achieved state of the innovation – if it is successful or if it failed – we model them as a certain amount of money the capitalist has to pay and do not differentiate how far into the process the carrying out of the innovation came when the inventor realized that it was not feasible. We could discuss if the amount lost by carrying out the innovation should correspond to a certain fraction of the innovation's cost. Since we do not specify the nature of the invention, this process would not add the slightest insight. We can always consider the money invested into a successful innovation endeavor as the full cost of the project which arises as a consequence of the implementation and we can consider the money lost in an unsuccessful innovation project as the amount of funds spent up until the moment when the venture is abandoned. Since the same invention cannot be successful and unsuccessful at the same time, interpreting the situation in such a way does in no way introduce a contradiction into the simulation.

Besides, we did not take the rent of the invention as a factor for her decision into any of the equations. This is due to the fact that the rent is inherently uncertain and not

[298] cf. [Witt87], p. 163
[299] [Evan04], p. 1
[300] [GrPH01], p. 12

foreseeable. Certainly, an agent will have a certain idea of the amount she can gain through implementing an innovation, but there is no guarantee that this expectation is close to the amount actually realized. It could be that the innovation will not work on the market even though the prospects are fantastic because someone else has independently worked on the same idea and implemented it before our innovator. Then the rent could drop to zero. On the other hand, some innovations develop a potential which was unexpected because users find a different utilization and attribute it a higher value.[301] This means that if we included an expected rent of the innovation into her decision matrix, then this value would randomly bias the agent's behavior and not necessarily add much insight. Therefore, we have chosen not to integrate this value into the agent's decision process.

Finally, an agent who has found an invention, who holds the financial means to finance its realization, and who is willing to assume the uncertainty connected to the implementation, will then carry out the innovation. The success of the project then depends on his ratio of successfully implemented innovations to implemented innovations as well as chance. There are random effects which will make an innovation work and there are influences which may arise and destroy the innovation unexpectedly. Nevertheless, an individual who does have experience with successfully implementing innovations is supposed to have a higher chance of victoriously carrying out an innovative endeavor because she is aware of some pitfalls and possible hurdles on the way. Again, we did not include the failed innovations because they can have a supporting effect because the individual knows where to be sensible and cautious, but they can also show that the agent is not able to grasp some essential criteria necessary for successfully implementing an innovation.

At the end of this rule, a successful innovation will lower the risk aversion of the individual because she has just found her decision on taking a risk to be right ex-post and since she can be certain of reaping a benefit from the innovation she might feel less adverse to other risk. A failed innovation on the other hand, will increase risk aversion in an individual since she lost the money invested in the project and since her risk assessment proved to be wrong from an ex-post perspective. So she will be more cautious in subsequent risk decisions.

[301] An example underlining this argument is the use of text messages on cell phones where the users made the service a surprising, yet tremendous success for the mobile phone companies. [Lead05] The author goes on to argue that the patent system requires the patentee to know the use of the invention even though this might change dramatically once the users figure out a different utilization. This adds to the argument that it is not reasonable to evaluate the rent from an innovation ex-ante.

7.3.3.7 Variable update and environmental stimuli

After having modeled the revenue generation, the risk provision behavior, the savings and consumption decision as well as the innovative activity, we have to update some variables related to the agent as well as to incorporate the environmental stimuli which she receives from her network and her surroundings. This is done in the rule "Update Variables".

Update Variables	Human	(1) Set new values for age, health, risk aversion, experience (2) *if age is above DeathAge then* be reborn (3) Update environmental influences a. friends network b. financing of inventions (4) *if we are in the governmental model then* set voting behavior

Table 7-12: Human rule "Update Variables"

The first step in this rule is to update those values which increase due to the time elapsing. This means that we increase age by one and we increase the working experience by one if the agent has been employed in the relevant period.

Furthermore, we update the health level of the agent as well as her risk aversion. The health level is autoregressive meaning that the new value of the agent's health status depends on her health level in the previous period. This is included to avoid frequent jumps in the health level. We include a random value as well, however, which is once again Poisson-distributed[302], so that the health level is allowed to vary from period to period. It is possible for an individual to see a sharp increase or decrease in her level of health, but the probability is higher for small variations since the expected value for the new health level is once again 95%. For reasons of simplicity, we did not include an age component in the variation of the health level. Besides, there is evidence suggesting that major changes in the life of senior citizens, such as the start into retirement, do not infer a significant change in the health level of the person concerned.[303]

In our model, the relative health level also has repercussions on the risk aversion of the individual. If the health has decreased since the previous period, then the risk aversion of the Human will increase. If she is doing better than before, then she will also be more willing to bear risks.

[302] The reasons why we have chosen a Poisson distribution are explained in section 7.3.2.1.
[303] cf. [JoLe09]

We have to revisit the age increase at this point, because it can have certain repercussions on the life of the agent. If the agent reaches her pre-set age of retirement, then she will not be able to generate her work income anymore and will have to live the subsequent years off her saved resources or public support.

Whenever an agent reaches her "Death Age" or if she is not capable of procuring for her living, she will die and be replaced by her offspring. We assume this method of reproducing since it allows us to hold the population size constant. This means that an extinction of a society is not possible, but we can observe the different dynamics unfolding. The largest problem for the simulation is that behavior would change radically if we admitted agents to mate and reproduce. We would have to specify their meeting strategies and their behavior in relationships. This would require us to include a variety of cultural and societal characteristics as well as behavioral aspects into the simulation which might make the results more insightful. The model would gain enormously in complexity, however, if the simulation of the reproduction process is supposed to be reasonable. This includes the definition of gender for the agents and distinct manners of conducting between female and male agents. Besides, we would have to include behavioral differences due to the marital status and many other aspects. Implementing such an alternative could be a rewarding project, even though there seem to be major shortfalls which may limit the reasonable feasibility of such an approach.

Therefore, we have decided to design the model such that an agent who will reach her death age or who is incapable of providing her subsistence minimum will die and is reborn as an infant. The child is considered a relative of the preceding agent since she will have similar characteristics and will inherit half of the legal estate of her ancestor. There is a critical implication in this decision to model reproduction in the society in such a way. The infant will grow up by herself and will have to provide for herself from the first day. She will have access to the credit market and will not be treated more cautiously than other customers. This setup is more feasible, simple and transparent. Furthermore, it respects that the time spent to learn and become educated is linked to low or inexistent revenue and that it has to be financed in some way.

It was argued[304] that such a method would reward the individuals who abuse the system and accrue more and more debt until they would be reborn and reset to a debt of zero, because all offspring can inherit wealth but not debt. While there is an easy

[304] This critique is from a presentation of this concept in the Economics Department at the University of Augsburg

rebuttal in the modeling framework which we will present in this section, there is also a more reality focused explanation. Almost all western countries offer the possibility for individuals to file for personal bankruptcy and can then restart into life as if there had not been this excessive debt. It is even explicitly the interest of the law to give individuals the possibility of starting anew and to "relieve the honest debtor from the weight of oppressive indebtedness"[305]. Restoring an individual to a debt of 0 in the case of having accumulated a too high burden is therefore not far from actual implementations.

Nevertheless, there is a much easier response to this critique if we remember how such a model works. The agents have a set of behavioral rules and environmental stimuli which generate their actual behavior and interaction. Since the sum they will leave for their offspring is not relevant for decisions during the course of an agent's life nor will the individual request unlimited credit for the sake of not working, those simplifications may blur the amounts in some aggregate variables but they will not bias the behavior. Since it is the behavioral interaction which is pivotal in this model, this critique is a priori no reason to refuse the model.

As mentioned earlier, the offspring's characterization depends on the parent's traits. This means that the new born agent inherits the values of her ancestor but it is possible that these values vary slightly. In the case of her age, it is reset to zero. Concerning the educational level of the child, it is possible to either have a child who will obtain a higher level, a lower level or the same as the parent agent. We have implemented a different likelihood of having the child more or less educated depending on the educational level of the parent. Any newborn agent will have an educational level which is raised by one, lowered by one or the same as the parent. Nevertheless, the level will have to remain between 1 and 3. Consequently, it is not possible for an agent of educational level 1 that her offspring has an educational level of 3. The strong barrier to jump a level is certainly not realistic, but it allows keeping a certain persistence in education levels in the simulation.

Independently of the question if they are reincarnated, all individuals also react to influences from the people in their surroundings. Nevertheless, not every person who is close in space to another agent is similarly influential. So, there are differences in how close people are and how much contact they will have. We have therefore defined a network called friends which includes all those agents who are within the field of

[305] [USSupremeCourt15], 236 US 549

vision of the agent at a certain point in time and who have not moved away further than a certain distance.[306]

An individual is influenced by the people in her environment with respect to her risk aversion, her time preference as well as her happiness. In all three dimensions, she will assimilate with the people in her network. This means that her characteristics will approach those of her neighbors. If an agent has a very high risk aversion and all the people around her are less risk averse, then she will also lose part of her shyness towards uncertain situations. The reason for that is that social interaction will lead to discussions, talks, exchanges on various grounds and in various forms and humans are influenced by the opinions and positions of their neighbors. "When individuals make choices, they are often influenced by the behavior and opinions of people in their immediate environment."[307] The great advantage in agent-based modeling is that we can integrate the influences for each individual agent into the simulation and therefore gain a much more individualistic picture of the emergent phenomena. This means that the simulation will analyze the specific environment for every agent and calculate the influences she is exposed to as well as the effects on her time preference, her risk aversion as well as her happiness.

Nevertheless, we have to respect that not every neighbor will have the same influence on the agent but that there are differences. Therefore, the simulation differentiates between simple friends who happen to live in the neighborhood of an agent and so called 'cool friends' with whom she has closer ties.

The friends who are said to be 'cool friends' are those who share certain traits with the agent in question. Similarity creates closer ties[308] and can lead to a stronger influence of those agents on each other[309], which will then have repercussions on the lives of the individuals. Consequently, an agent will choose those agents in his 'cool friends'-network who are similar and with whom she shares certain characteristics. This will create clusters and groups of people who are similarly successful. "This law, which applies universally to dynamic networks, accounts for the fact that nodes will

[306] This means that any agent, who is within a distance of say 10 at a certain time, will be included in the friends-network of an agent. If she moves further away, then she stays a member of the friends-network as long as she is not too far away, say at a distance of 25. Therefore it is possible to have agents in one's friends-network who are further away than others who do not belong to the group of friends. For a discussion on cultural transmission and friends networks in agent-based models, see [EpAx96], pp. 78f

[307] [Case92], p. 491

[308] see for example [Duck75] or [PoCHCDS97]

[309] see for example [BrDe80]

preferentially attach to other nodes or hubs that they relate to in terms of fitness."[310] Therefore, we have modeled the subset of the friends-network as the network of cool friends who relate to their peers by certain characteristics.

Since it is common in agent-based modeling to simulate characteristic traits as values inherent to the agent and then compare those values to other agent's sets in order to determine the cultural similarity[311], we have chosen exactly this approach and defined a friend to be a cool friend if she has three out of five traits which are appreciated by the agent looking for friends. The five characteristics an agent looks for in a cool friend are a comparable age group, similar educational level, a comparable degree of happiness, a higher amount of implemented innovations, and a comparable wealth. In all categories we demand that the cool friend has to be somewhat similar following the argumentation above, which means that the value of the corresponding characteristic of a cool friend may not be considerably lower or higher than that of the agent in question. Only with respect to the innovative criterion do we look for the more successful individuals. This is due to the following reason.

From intuition, we could derive two different assumptions concerning the influence of successful innovators in our surroundings. On the one hand, we could model the behavior of agents as looking only at best-practice innovative strategies and therefore only look for the most innovative agent in her environment. This asymmetric behavior will lead to a directionality that every agent is searching for the most innovative agent she can find and will try to profit from her experiences.

Yet, there is evidence that spillovers are not only asymmetric, but that economic actors can benefit from all those participants in the market who are ahead of them.[312] They will not only copy the best practice agent, but will be able to gain inputs from many more actors they perceive as interesting. "As people see more and more successful entrepreneurs in their area or in the media, this may enhance their perception of their own capabilities without enhancing actual capabilities"[313]. In an evolutionary economics context, these results match very well with the search for a 'successful practice' instead of a possible 'best practice' as well as satisficing behavior aiming at finding a way to achieve one's own ends with a reasonable degree of efficiency. It is this market observation that enables agents to find innovations and profit from the

[310] [Ogle07a], chapter 5. The law which is mentioned in the quote is the "Law of the fit get rich" which is formulated in the book [Ogle07b], p. 105 as "In an open, dynamic network, the fit get rich."
[311] see for example [EpAx96], [Axel97] or [Dwye07]
[312] cf. [KnPW09], pp. 386 f
[313] [BoLe10], p. 15

spillovers of other actors, and that can spur innovation in a certain environment. In the simulation, we take this fact into consideration when an individual divides her friends-network into 'cool friends' and others. An individual who has successfully implemented more innovations than the agent herself makes her more likely to be considered a 'cool friend'.

It is important to note, that the friends-network does not have a directionality component implemented. This means that if agent B is part of the friends-network of agent A then the opposite is also true. Therefore, the influence on the two is reciprocal. It is important to note however, that the classification of a 'cool friend' is directional meaning that if agent A thinks of agent B as a cool friend, agent B does not necessarily consider agent A a cool friend. This reflects the idea that role models can have an influence on an individual's behavior while her behavior has no repercussion on the role model. The effect cool friends have on the agent are twice as strong as those 'regular' friends have. Furthermore, the agent will try to move close towards the cool friends. This will create the clustering dynamics within the network.[314]

Additionally, an agent might consider moving if she sees no opportunity to find an investor for her invention in her surroundings. Since she has no perfect vision across the entire 'world' she can only find an investor in her neighborhood. If she realizes that most of her inventions are unfinanced, she will look further for a promising fund and move closer towards it. A fund is considered to be interesting if it has more capital and a higher rent from innovations than the fund she is invested in so far. In case she has not invested any money at a fund then any fund with positive capital which receives a rent from innovations is considered to be attractive.

Finally, if we are in the governmental model then an agent will value her happiness with the current social insurance scheme. She can take three different positions saying either that the guaranteed subsistence minimum is too low, that it is too high, or that it should remain like that. In order to take that decision, the individual assesses the contribution she had to pay or the amount she received in the previous period and her risk aversion. The more money she had to pay into the system, the more she is inclined to consider the subsistence minimum procured for by the state too high. Consequently, the more she received from the state as payment, the less she is ready to vote for a reduction in subsistence.

[314] Note that we have not implemented a routine where agents try to get away from agents whose presence they dislike, comparable to Schelling's Segregation Game. [Sche78]

Furthermore, the risk aversion is important. The more risk averse an individual is, the stronger she feels about securing a minimum lifestyle. This means that an agent with a high risk aversion will rather vote to increase than to decrease social insurance spending by setting a high subsistence minimum. Agents who are less risk averse will rather vote for a decrease. How the elections work is explained in section 7.3.3.9 since this is a rule implemented for the Public Sector.

Those were the five rules, which every agent is following in her interaction in the simulation. We will now present the rules for the other agents before we turn to the results of the model runs.

7.3.3.8 Contribution to Social Insurance

The Public Sector has two rules which govern the functioning of the welfare state. All other functions which a government usually has to fulfill are assumed to be identical in both simulation setups and have therefore not been modeled. This implies that the Public Sector agent only interferes in the simulation in the governmental model.

The first rule is where the percentage for the contribution is set. The government follows the directive that the receipts should in the long run cover the expenses, but that the social contribution should not be used to finance other governmental tasks.

Consequently, we formulate the following rule:

Calculate Contribution	Public Sector	(1) Compare the payments to the receipts from contributions (2) *if all payments are covered then* record good year a. *if receipts are more than twice the payments then* record excessive year (3) *else if payments are larger than receipts then* record bad year (4) *if there were four bad periods in a row then* raise percentage of contribution *(5) if there were four excessive periods or ten good or excessive periods in a row then* lower percentage of contribution

Table 7-13: Public Sector rule "Calculate Contribution"

The behavior of the Public Sector is very straight forward because it tries to balance its accounts by looking at the receipts it collects from those members of the society who had a revenue above the subsistence minimum and at the amount she had to spend on those individuals who were not able to secure their own standard of living.

The government will then keep track of the record concerning the receipts and expenses. Each period can then be qualified as either a bad year in case the expenses were higher than the receipts, as a good year if the state achieved a surplus or as an excessive year if the receipts are more than twice as large as the sum paid out to the receivers of social contribution.

The only value the government can change without asking the people is the percentage of their revenue which those individuals who live above the subsistence minimum have to contribute to the social insurance program. So, if the government needs more money to fulfill its obligation to secure the poorest members of the society, then it will raise the percentage. This is very straight forward and is comparable to the real world situation where a raise in the contribution to social insurances is not uncommon.[315] In our simulation, the government will also consider the balance of the inheritance tax account where it receives money when a wealthy agent dies and where it has to pay the debts if an agent dies indebted and the successor has not accepted the inheritance. Consequently, the Public Sector will compare the expenses for social insurance to the receipts of it increased by the balance of the inheritance account.

In the case where the government takes in more money than it has to spend it is less predictable if the consequence is a decrease in the percentage to be contributed. The government could also decide that it will increase the services offered to those who receive the social insurance benefits. Politically, it may be beneficial to be able to implement such ‘good deeds’. In this simulation, however, we have set the fixed rule that the Public Sector has to use excess money to reduce the contribution rate and that the level of security offered to the citizens is defined only through elections.

Furthermore, the government will not react in panic and increase or lower the rates as soon as there is a good or a bad year for the public budget. On the contrary, it will only react if there were four bad years in a row or if there were four excessive years in a row. Additionally, it will also lower the rate if the previous ten years were all good or excessive. In those cases, the government will consider the rate inadequate and will lower or increase it accordingly by two percentage points per correction.

[315] see for example [Welt09]

7.3.3.9 Vote on subsistence minimum

The second rule which is relevant for the Public Sector is that it has to hold elections where the citizens may decide on the magnitude of the social insurance. It is impossible for them to fully abolish the system of social security, but they can decide on a reduction or an increase of the subsistence minimum which is the underlying factor influencing the amount of care offered by the state as well as the amount an agent has to pay to keep up the welfare state.

The election rule is as follows:

Set Subsistence Minimum	Public Sector	(1) *if we are in an election period then* find the median voter a. *if median voter wants more social insurance then* increase subsistence minimum by 10% b. *if median voter wants less social insurance then* lower subsistence minimum by 10%

Table 7-14: Public Sector rule "Set Subsistence Minimum"

The rule is very straight forward and integrates the median voter which we introduced in section 5.4. Since the election is one-dimensional and there are only three different states possible with one being exactly in between the two others, the median voter setup is especially suited for this constellation. The Public Sector will therefore record the votes of every individual and then follow the majority which means that the median voter is the one who decides.

If the vote is such that the median voter is in favor of an increase in the subsistence minimum then it is raised by ten percent. If he votes for a decrease, it is reduced by ten percent. In a real election, there would probably be more parties with different levels which an individual can choose and the election would run on more criteria. Note that in our simulation it is not even important who is governing the society since the government only has to follow the rules aforementioned. Consequently, it is sufficient to include the public vote and make sure that the governmental budget is balanced.

7.3.3.10 The banks and investment funds

When modeling the interactions with the financial sector, we try to limit the complexity to a reasonable degree. Even though we could define the financial behavior of the economic actors to be perfectly rational – this could be possible since we as programmers can control all chances and risks – it is not sensible to use such a hypothesis. “No credible theory of investment can be built on the assumption of perfect foresight and arbitrage over time.”[316]

In this simulation, we define a very simple behavior for the banks and the investment funds. It is certainly possible to design this financial sector in a much more detailed way, but the model would grow much more complex without adding to the understanding. We only differentiate between banks and investment funds and have a very clear line of separation between their fields of activity. The banks can lend money for consumption wants and take low-risk and low-rent savings from their customers. The funds, however, take the money from their investors and finance inventions with the hope of realizing successful innovations. This division reflects the strong differentiation between the funding of an uncertain innovation project which is able to generate future profits and the foreseeable grant of credit for certain projects or to fulfill consumption wants and needs.[317]

The important thing for banks in this model is that they are not allowed to fail. Any bank will get back its credits at the beginning of a period since each agent will pay back its debt in her “Generate Revenue”-rule. So, the only case when money is actually missing is when an individual is no longer able to receive a credit to pay for her subsistence minimum and will die of starvation. But since she will have paid her debt in the beginning of her last period, it can be thought of as the state absorbing her debt in case of her passing. This means that an individual can at any time take her money out of the bank without risking it not being there. On the other hand, the banks do not “know” that they cannot fail in the sense that their behavior is not influenced by this fact. They will still only lend out money up to the amount they have collected.

The investment funds face a very different situation. They do not lend out the money, but they invest it, so the initial amount is gone as sunk costs in an innovation project, which may or may not be successful and give the investor a certain return in the years to come. This means that an individual who would like to withdraw her invested

[316] [Solo56], p. 93

[317] Schumpeter makes this very clear by arguing that there is a fundamental difference between those credits which are part of the regular activities in the business cycle and those which are only handed out on the idea of an invention which could work out as an innovation. cf. [Schu34b], pp. 146f

money cannot necessarily just take this from an amount which is directly available. Her original amount has been invested and is – hopefully from her point of view – giving a sufficient return to the investment fund. The difficulty is then how to model the input-output relationship between the fund and the individual.

In the following sections, we will present the rules which govern the behavior of the banks and the funds in the simulation.

7.3.3.11 Bank's rules

Since the bank is not facing the risk of defaulting, it follows two fairly simple rules designed to guarantee that the credit market is balanced and that the interest rate corresponds to the amounts requested.

Award credit	Bank	(1) Consider the credit request from Human agent (2) Award credit to the individual if money available
Calculate interest rate	Bank	(1) *if money requested > money saved then* increase rate (2) *else* lower rate by 1% but not below 0%

Table 7-15: Bank rules

Whenever a Human requests a credit, the bank will verify if it possesses sufficient financial resources and if so, will award the credit to the individual. The process is modeled in such a simple way, because the bank does not have to do any security checks on the creditor for it can be sure to be paid back at the beginning of the subsequent period.

This simplification limits considerably the space of action for banks and it certainly diverts largely from reality here. But it depends on the role attributed to the financial sector to argue if it should be more elaborate in this simulation. We follow the logic that "[i]ts task is not – as it just happened – a short-term decoupling from the real economy spurred by speculation, but quite the opposite, the medium- and long-term oriented sustainable financial accompaniment and encouragement of innovative and successful companies and sectors"[318]. Then it is perfectly fine to implement the financial sector with its supportive role. The banking sector takes the low risk and low return activities while the investment sector is able and required to finance innovative activities.[319]

[318] [Hanu10], p. 94

[319] cf. [Schu34b], pp. 107f

The second rule governing the behavior of banks is the calculation of the interest rate. Again, we follow a very easy and dynamic approach which takes the interest rate from the previous period into consideration and increases or decreases it according to the credit demands and the debit volume. This is the simplest form of giving the bank the ability to influence its conditions. The agents who will save money at the bank will receive this percentage of credit and the agents who borrowed money from this bank will have to pay a rate one point above this percentage. So, if Humans can save at a rate of 3% at the bank then credits are awarded at a rate of 4%.

There are some network and competition effects included in this rule, since a lower rate is more likely to raise the demand for credit and since a bank in a region with many competitors is likely to have a low credit demand, but we have decided not to complicate the matter further by including additional influences. Consequently, there is also no reaction to expectations in the bank's behavior. Since the banks are only active in the low risk market, the integration of expectations could be beneficial for them especially if they analyze the market around them and its dynamics. Yet, this would increase complexity in the banking sector even though it is not central to the analysis. Therefore, we stuck closely to the goal of keeping the banks as simple as possibly justifiable.

7.3.3.12 Fund's rules

The funds complement the financial sector by offering individuals the possibility to invest in high risk-high return activities, namely the innovative endeavors. This is the creative function of the financial sector which is crucial in the process of implementing innovations. "The banker [...] stands between those, who wish to realize new combinations, and the owners of the means of production."[320]

[320] [Schu34b], p. 110: "Der Bankier [...] steht zwischen jenen, die neue Kombinationen durchsetzen wollen, und den Besitzern von Produktionsmitteln."

Invest Money	Fund	(1) Considering all unfinanced inventions, find the most attractive one (2) finance the innovation (3) repeat as long as there are funds available
Calculate interest rate	Fund	(1) keep half of the rent from innovations to increase capital stock (2) set interest rate as return from left over rent from innovations to money invested at fund
Relocate	Fund	(1) analyze new interest rate offer to see if it has been a good year (2) *if it has been the fifth consecutive year without return then* look out as far as vision permits (3) considering all Humans, move closer to wealthy Humans
Is Successful	Fund	(1) analyze capital stock to see if it is negative showing a potentially dangerous drain of resources (2) *if it has been the fifteenth consecutive year with a negative capital stock then* close fund

Table 7-16: Fund rules

In this model, we have chosen the following approach: An individual who invests money at a fund will do so by adding the money to the account called "Client's savings" as well as "Cumulated Client's Savings". The latter is only there to calculate how much money investors have given to this fund and this amount will be used to calculate the interest rate which the fund will offer in the subsequent period.

The amount in "Client's savings" is added to the capital stock of the fund. When faced with a new investment decision, the fund will screen all inventions which need an investor and will finance as many as possible with his capital stock. This means that it will invest as much money from its capital base as possible. Only when invested, can money give a return. The order in which the fund will invest the money is that it prefers those inventions where the rent to cost ratio is highest (rule "Invest Money"). As we have argued earlier, it is impossible for the investor to accurately estimate the expected rent of an innovation. But since there is still the risk of the innovation failing, the investor cannot be sure of his choice. In the real world, he would probably take many more factors into consideration, and could still not overcome all uncertainty linked to the investment. Therefore we feel that the limitation of using the expected rent to cost ratio as the criterion for ordering the different investment opportunities is not overly simplistic.

From the investment setup, we can infer on the other hand, that if a customer would like to withdraw her money, the capital stock may not have sufficient funds to repay her. If the fund has sufficient money in its capital stock, the investor is refunded her initial amount and the investment is finished for both parties. In the case that the bank does not possess sufficient money, the agent will be able to withdraw her money as long as the capital market has not realized the peculiarities of the fund. Maybe the fund does receive substantial rent from its innovations and is therefore able to restore its capital stock in the subsequent periods. So, there is no need for the capital market to doubt the fund because of a single under-financed period.

There are, however, two mechanisms within the financial sector which will monitor the funds. The first (rule “Relocate”) will make the fund consider changing environment if it was unsuccessful in investing money over the last five years. A fund will always consider her investment unsuccessful if it was unable to offer its customers any interest on their investments. In such a case, it will screen its environment as far as it can see and try to move closer towards affluent individuals. This is implemented in regional terms but can also be understood as a reaction to certain investment fields which are more appreciated by the customers. For example, an investment funds specialized on emerging markets yet unable to acquire any funds or investment projects, might consider changing its strategy and focus on the biotech sector in order to find both investing opportunities as well as investors.

If even the relocation fails to bring any success, then there is the more consequential rule “Is Successful”, which strictly monitors the solvency of an investment fund. This means that a fund will be liquidated if it has a negative capital stock for fifteen subsequent periods. At this time, the fund will be closed and all invested agents lose their savings. All possible future rents of the innovations this fund had financed will be used to satisfy the creditors who financed the last years of capital needs of the fund.[321]

Those strong abstractions and simplifications in the design of the financial market can be accepted for two reasons. On the one hand, we will stick to the ideal of keeping the model simple and not adding too much complexity. The transparency and understandability of the model would suffer considerably if the financial market had been designed in a more detailed form. On the other hand, the innovative activity is only accompanied by the financial markets who give some entrepreneurs the ability to

[321] This is modeled in a way such that neither the creditors for the fund nor the cash flows from the innovations are accounted for anymore. In the case of the failing of the fund, the creditors will most likely not receive the full amount. Since it is not important for the simulation, to what degree they are repaid, since this has no influence on their behavior, we have left out an explicit model of this event. All that is modeled is that a failing fund looses all its innovations and that its remaining customers lose their savings.

realize their innovative ideas. While the role of a supportive banker who is willing to finance new ideas is important, the reasons and considerations behind his decision and the circumstances and issues he will have to consider are not central to this work. It would require an entire new model to include a “real” financial market into such a simulation. For our work, it will be sufficient to have a financial sector which is balanced and which can finance both consumption credits and investment projects.

7.3.3.13 Inventions

The inventions are the most abstract agent in the model since it is always possible to imagine humans, banks, funds or the government to be actors and to react to their environment. Inventions are modeled as agents in order to implement them as independent objects visible to investors and with specific characteristics.

There is only activity which is autonomously executed by the invention:

Depreciate	Invention	(1) reduce weight by five percentage points

Table 7-17: Invention rule "Depreciate"

The idea is that the value of the invention will decrease over time. Since we reduce the weight of the invention every period by five percentage points, it will have a weight of zero after twenty periods[322]. The rent the innovation returns in every period is weighted by this factor, so that it decreases over time. This may not be realistic in all cases and there may be situations, where the value of an invention should rather increase. Nevertheless, since we have no specification what the invention is all about, we have chosen the general rule of depreciating the invention. Once an invention is successfully turned into an innovation, it will still depreciate. There is no reason why the implemented invention should not face competitors, decreasing interest from the users or other factors which will erode the profit for the entrepreneur. [323]

All the inventions found during the course of the simulation are independent of each other. While this may seem trivial, it implies quite a lot on the content of the invention. A marginal invention may render a previous innovation worthless because it can better serve a certain end. Or one invention might add value to a different invention because with the help of the former the latter can achieve a considerably

[322] This value has been chosen since it is the duration of a patent when granted from the German Patent and Trade Mark Office [DPMA09] or from the US Patent and Trademark Office [USPTO08]

[323] This is comparable to Schumpeter’s elaboration that the profit the entrepreneur can reap from his innovations is only temporary and that it will vanish once the new combination is integrated into the regular flow of the economy. Cf. [Schu34b], pp. 218f

larger rent[324]. We could randomly add the functionality that an invention's rent could increase or decrease in the course of the simulation, but this would not serve any purpose. Since the rent expectations are not part of the behavioral determinants for the inventor and since the investor cannot compare different scenarios and therefore only takes the one reasonable value into account[325], there is no considerable explanatory power lost by creating independent inventions.

7.3.4 Justification for simplifications

In this section we will present some major simplifications which stretch over larger parts of the simulation and explain why we have chosen to implement them in this sense.

7.3.4.1 The Quest for a utility function

An important question within this work was if a utility function should be included in the agent's decision heuristics. Undoubtedly, whenever a human has a choice between two or more alternatives, she will opt for the one that she values highest. By using a utility function, we could have the individual take decisions and evaluate her degree of overall utility, which could be described as happiness or satisfaction. In order to establish such a measure for her well-being, we need a certain basis to evaluate the different utility gains or losses connected to every decision. This valuation scheme can not necessarily be reduced to a monetary amount which implies that even if the individual knows exactly all parameters of a choice and the outcomes of each alternative, we cannot simply add the utility of a first decision – say should I save 100 € or consume it? – to the utility of a second decision – say should I invest money into an innovative project or not? – since there is no unique scale by which to compare the changes in utility. Even though there are approaches where a weighting function is applied to all utility levels reachable and then those levels are added[326], it is theoretically controversial to simply add utility levels as if they were measured on an

[324] This is for example true for some services offered for mobile devices which have largely benefitted from the broadband capabilities of new smartphones.

[325] As argued above, we can always consider the investor to take all information and expectations to which he has access into account when he compares the rent-to-cost ratio of the different available inventions. Since he cannot know that the rent he presumes is necessarily the correct one, it is not important which reasons lead to his estimation.

[326] cf. for example [BlSZ09], p. 870. The weighting function serves in the first place to account for differences in the level of satisfaction taken from different products. That means that a loss of one unit of product A will have a different effect on utility than a gain of one unit of this product. Similarly, a gain of two units of this product will not have double the effect of a gain of one unit. Nevertheless, using a suited weighting function, adding different utility variations could be a valid calculation. This is discussed with respect to different attributes in the choice of overall packages.

ordinal scale.[327] The problem is that any weighting function would have to be based on the same underlying idea of utility for a single individual in order to make different levels of utility comparable. If a weighting function took reference to the amount of utility an individual would gain or lose with each choice and if this utility could somehow be measured on an ordinal scale, then a utility function could be an interesting addition to the simulation in order to model the happiness and satisfaction of the agents. Since this approach is not very practical and it is impossible to reasonably define for an individual the amount of utility of a certain additional unit of product A versus an additional unit of product B, this approach is no longer pursued.

There is however a way in which utility of different outcomes is supposed to be comparable and additively combinable. The von Neumann-Morgenstern utility is based on the idea of a lottery where the individual has a choice between different options and where we would like to find out how much more she likes the chosen alternative over one of the rejected ones. Then we could imagine offering the person a lottery where she will either receive the rejected option for sure or she will have to gamble over the chosen option with the probability of p of receiving it. The value of p at the time when she is indifferent between the lottery for the desired option or the sure gain of the rejected option then hints at the amount to which the one option is preferred over the other.[328]

The problem with this solution however lies in the static approach of the von Neumann-Morgenstern utility function. It is difficult or even impossible to compare the outcomes of the same decision matrix in two distinct time periods because other factors will be relevant for the individual. For this reason, we will not pursue this approach any further. Another argument for avoiding such a utility function stems from the discussion that preferences should be allowed to change over the lifetime.[329] There has been a lot of debate over whether preferences of individuals can change. If we suppose that they do, then any utility function used would have to incorporate those changes during the course of the simulation. This means that there is not only a definition of individual utility bases, an individual weighting function but also an individual function of change of utility over time.

In our case, however, the problem is even more complex. We not only cannot add the utility of different choices taken sequentially in order to define an overall utility level,

[327] [Arro63], pp. 9f
[328] See for example [Econport06]
[329] See for example [JaJa01]

the individual already fails at fully evaluating each option. The savings decision for the risk provision funds is a good example. The individual can only learn from her experience how often she suffered from income reducing risk realization, but she can in no way know the exact outcomes of her future income. Here, she is faced with true uncertainty as it was introduced earlier. We could now add a utility function that tries to model the level of satisfaction she takes from every decision, but this would not add any positive explanatory power. There are two reasons why there is no additional value in introducing a utility function in this situation in the simulation where the agent would calculate her expected utility level depending on the options she can choose.

The first reason is that "[a]bundant evidence exists, however, that (subjective) expected utility is not valid as a descriptive theory of decision under (uncertainty) risk."[330] Any measure of expected utility will fall short of a situation where the environmental variables change and where the actually eventually realized utilities may deviate substantially from the expected values. For this reason, individuals take decisions often following simplified approaches and rules of thumbs.[331] They are satisfied with a successful and working option and do not strive for the optimal solution since there may very well be unknown factors which limit her from ever reaching such a state.

The second reason why the simulation does not include a utility function and calculation procedure is now a very practical one. If we cannot add up the "utils" an individual gains from every decision, then there is no interest in calculating an accumulated utility for each individual. This means that we are only interested in a utility function in every single decision problem which an agent is facing. In this situation, however, she will see different aspects of each option and will be aware of her own preferences for each attribute. Based on this information, she will make her decision which will presumably lead to the highest utility. The absolute level of utility is of no interest, since it cannot be combined with other utility gains and the relative level will be determined from exactly the pieces of information used for the decision-making. So, adding a utility function into the decision process will only serve as a detour without any analytical benefit.

For those reasons, all decision problems included in the model are designed such that the individual takes all relevant and available information into account and chooses

[330] cf. [BlSZ09], p. 863
[331] See for example [OpSe89]

accordingly based on the set of rules presented in this chapter. An uninformed observer of the model runs could then analytically derive possible utility functions that may lie behind the actions of the agents. This would precisely be the task of analytical economists who try to conceptualize the human behavior and search for regularities. In this sense, in our simulation, the utility function is internal to the agent without it being revealed other than implicitly in the decision rules.

7.3.4.2 The savings account and the account for risk provision

In the governmental model, there is only one savings account per agent. Whenever an individual chooses not to consume all the money and to save part of it, it is placed into this account. The agent also decides on the investment strategy for this money and can choose between the risky and the less risky investment. The risky investment includes financing innovations where there is no certain payout. In the more secure option, the individual places her money at banks who lend money to agents who will use the money for consumption credits. In a situation where the government does not pay for the entire subsistence minimum, individuals could also take out loans from those banks to secure their existence.

The agent chooses the investment strategy depending on her risk aversion and the risk aversion varies with the environmental influences. In any case, it is not possible for an individual to split her savings between the low-risk and the high-risk options. Introducing split strategies would add unnecessary complexity to the model, since it is not the goal of the simulation to explain the financial market, but we need a functioning financial market to model the innovative activity.

In the individual model, however, the agent has two different accounts. One is used for the risk provision where she will put the money she wants to save to protect herself against external risks. The money she is saving for all other purposes is placed into the savings account. Since the former is used to protect her against other risks, she will invest this money in a more risk adverse form. The other savings account, on the other hand, will be invested in a more risky way.

The agent is free to choose if she prefers to invest both her accounts at funds, both at banks or the risk provision at a bank and the savings at a fund. The only option which is unavailable to her is that she would invest her risk provision at funds and deposit her savings at a bank, since the risk provision is meant to always be invested in the less risky alternative. The agent will choose her preferred portfolio strategy depending on the interest spread which she can observe between funds and banks and depending on her risk aversion. The higher the risk aversion the higher has to be the interest spread between funds and banks to incite her to move her money into the risky alternative. Once again, she can only observe the interest offers of financial institutions in her environment, and therefore, we may find comparable agents follow different investment strategies, because they do not know of certain options and offers.

7.4 Possible expansions

It is always possible to enlarge a model and there are some additions we already mentioned in the discussion above. In this section, we will point to some more structural issues which could be integrated in future models or which should be kept in mind when trying to relate the model to specific problems.

We have modeled offspring to replace the parent agent once the latter dies. This is certainly an assumption which could be relaxed. It is possible to define some behavior which leads to offspring. A major challenge in the implementation will be to decide on the integration of gender in the simulation. This will introduce a score of new behavioral patterns both for the parent agents as well as the children and their potential siblings but as long as they are included in a comprehensible way, it can be realized.

Another aspect which might change some of the simulations' results is that we have not modeled any loyalty or hesitation for the agents to their banks. This means that once an agent finds a bank or a fund offering a higher interest rate, then she will change her entire savings or risk provision account to this bank or fund. In the real world, such a change would certainly not be as fast and we would expect to see some loyalty to the "house bank".

As an overall argument, it is always possible to find additional characteristic traits which could be implemented in order to become more realistic or to be able to model certain situations and events. An idea which points in this direction is that maybe the difference in innovativeness observed in the real world is linked to other factors such as for example the religiousness of the members of a society which might incite people to strive even more. Adding those factors would complicate the model to a degree which we felt inadequate.

Furthermore, the effort an individual puts into the increase in her income by inventing and innovating is not deductible for her contribution payment. Consequently, an agent would have a higher incentive to invest the effort of trying to implement her invention since the financial risk would be reduced. This would most likely have an influence on her willingness to bear the risk of the innovation. Therefore, it can now be thought of being included in the risk propensity procedure in the simulation. Future research might try to split this issue and reduce the financial risk by allowing an individual to deduct her investments.[332]

Diffusion is not taken into account in the model. This could be added fairly easily since the model already includes spatial factors. It would only require to define and to program the underlying assumptions which have to be added. It is not included for reasons of simplicity. This includes hypotheses on the demand effects for innovation. If a customer does not accept the transaction cost he incurs when checking if a new product is better suited, then the innovation will not be successful. In our simulation we have abstracted from this point by attributing the success or failure of an innovation to a random process without any recursion to different mindsets in the underlying population.[333] Adding diffusion should also include a focus on the demand side and its implications on innovation.

[332] In the model presented in section 5.2 such deductibility is clearly postulated. Cf. [Sinn96], p. 276
[333] see for example [Wegn09], p. 81

8 The model's results

When talking about the outcome which emerges from the simulation, we will first explain the verification effort we have undertaken. Afterwards, we will present the results and link it to the previous discussions.

8.1 Verification

As we have discussed in section 6.1.3.5, it is important to make sure that the model does what it is supposed to do. Therefore, we can use the possibilities which the software Repast is offering in debugging and checking for consistency, and we can implement a monitoring routine which allows us to understand the behavior of the individual agents.

First of all, we have made sure that the simulation will lead to the same results on subsequent runs with identical starting conditions. When a simulation uses random numbers then these have to be created by the computer. Since the computer cannot randomly decide on choosing certain values, there are elaborate algorithms which will create values in an apparently random order. There is an extensive statistical literature on creating useable and reliable sets of random numbers.[334] Each random number generator relies on a certain starting value – called random seed – from which it will derive the next "random" number. By choosing this starting value it is possible to recreate the same list of random values. In order for the simulation to be reproducible, it has to return the same results if we use the same random numbers. This condition is met for the vast majority of the results reported in the next section.[335]

The next step to verify the proper running of the model consisted in our case in the incremental implementation of different functionalities. Since the behavior of the Human agents is the most complex of the different agents used in the simulation, we have chosen to create it in a step-by-step structure. This means that we first programmed the revenue generation process and checked for its consistency by monitoring each step which a limited number of agents will take. Then we added the possibility to choose the risk provision behavior and we checked again the behavior. The third step was to add the "consumption and saving"-method allowing the agent to use her money.

[334] see for example the websites of the National Institute of Standards and Technology [NIST08] or by [Hell10] at the pLab of the University of Salzburg

[335] Single runs out of each set of 100 runs will vary slightly at changing intervals when they are recreated. Since the final conclusions did not change with those values, we chose to keep them in the analysis in order to keep the set of random seeds constant over all runs from 1,000,001 to 1,000,100.

We implemented the innovation rule twice – first independent of the rest of the simulation in an own environment and then within the final model in the way we explained above. The reason for this strategy is that this rule is introduced in an already complex environment where many interactions exist and where it is hardly feasible to check each step of every agent once we allow for a larger number of agents. Besides, since innovation is at the heart of the research questions we put special care into making sure that the routine would work flawless and in the intended manner. This can be more easily tested in a situation where we can run both isolated tests on only this rule and integrated checks in the complete model.

Moreover, we have programmed a very tight set of information which the Human agents, the Fund agents and the Public Sector agent can communicate during the simulation. This helps track the behavior of each individual agent and therefore single out emergent developments against programming errors. Sample protocols of such information each agent will furnish during one period are presented in appendix C.

Furthermore, we have tested the simulation using very few agents which enables us to follow the interactions between them and to check almost each calculation which is done during the simulation.

Finally, we have checked the proper execution of the model on different computers and using different operating systems[336]. It is important to make sure that the same results can be reproduced independently of a specific computer. After extensive testing and debugging, we turned to the evaluation process.

8.2 Results

Before discussing the results which we can derive from the different simulation runs, we will present the general setup and the method we used to run the model.

Every simulation is run for 60 periods. Since every period is understood to represent one year, we consider the development in our simulated population during the course of 60 years. While it is very easily possible to increase this amount considerably, we feel that trying to model the development of a society over a too long period is difficult because of the changing environment.[337] Furthermore, we have run the

[336] We used two different computers which used Windows XP and Windows Vista. We ran Repast Simphony in the version 1.2 on both.

[337] In order to extend the time horizon in a sensible way would require us to better specify how some environmental variables such as population size may change during the time span considered.

simulation 100 times with each individual configuration meaning that the only difference in the starting values was the different random seed.[338]

Each simulation starts with the initialization of the Human agents, the Bank agents, the Fund agents and the Public Sector agent. They are randomly placed in a "world" with a size of 50x50. The space is defined to be continuous, however, which means that an agent can stand at any location within this space and not only at integer numbered fields. This means that agents do not have to move on a specific field comparable to a chess board but that they can occupy any position in between. A typical presentation of an initial situation can be found below:

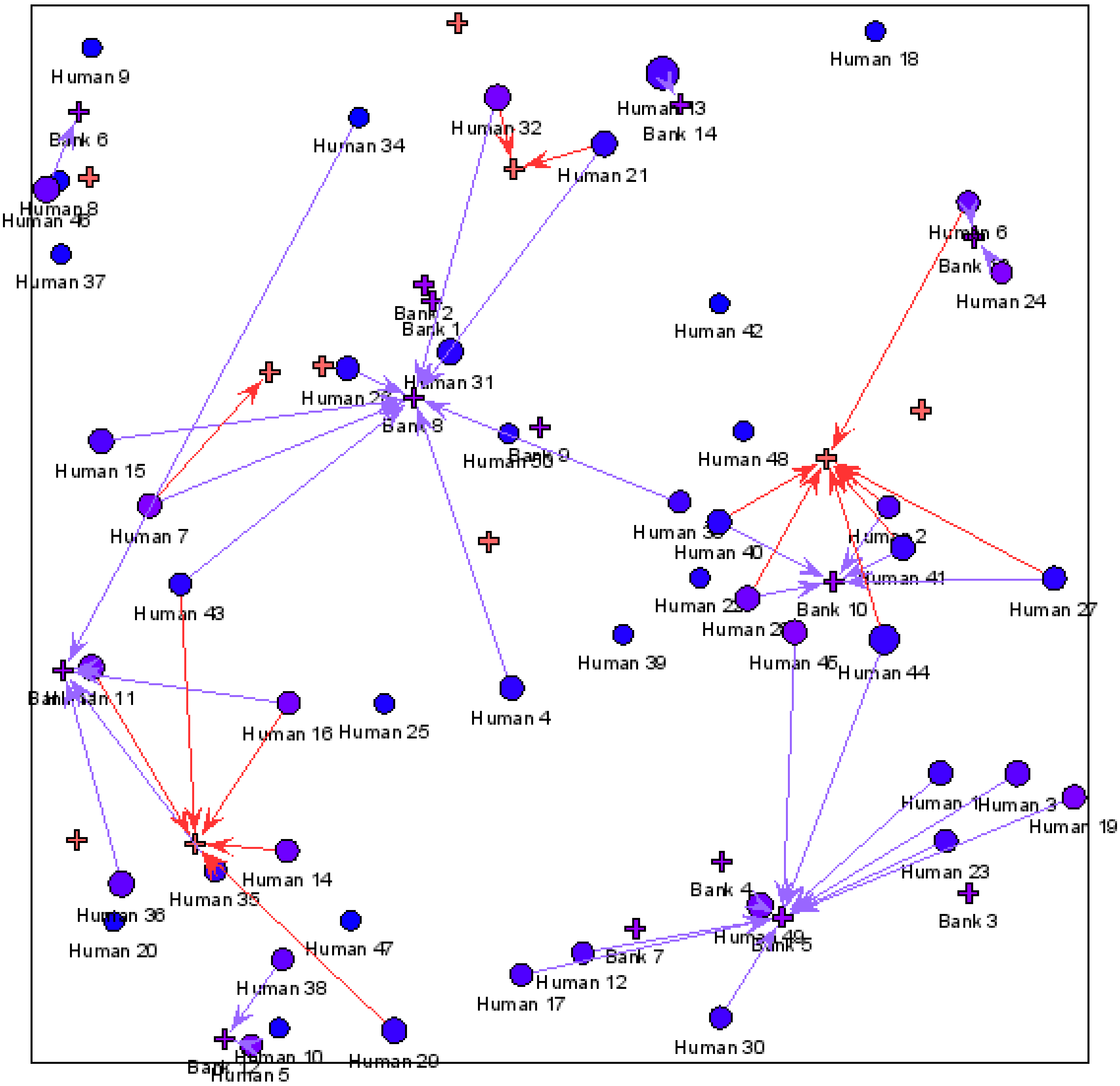

Figure 8-1: Exemplary situation after one time step - finance

[338] [Axel97] used ten runs per configuration setting. Therefore, we feel that using ten times as many will be suited to consider the results fairly robust to the choice of random seeds. Furthermore, we chose the random seeds between 1,000,001 and 1,000,100.

In the picture, each blue dot corresponds to a Human agent. The red cross symbols represent Funds and the purple crosses correspond to the Banks. An arrow from a Human to a Bank or a Fund signifies that the Human holds an account there. The different sizes of the Humans correspond to their revenue. The larger a blue circle, the greater the agent's revenue.

The corresponding view in the friends' network in this case looks as follows:

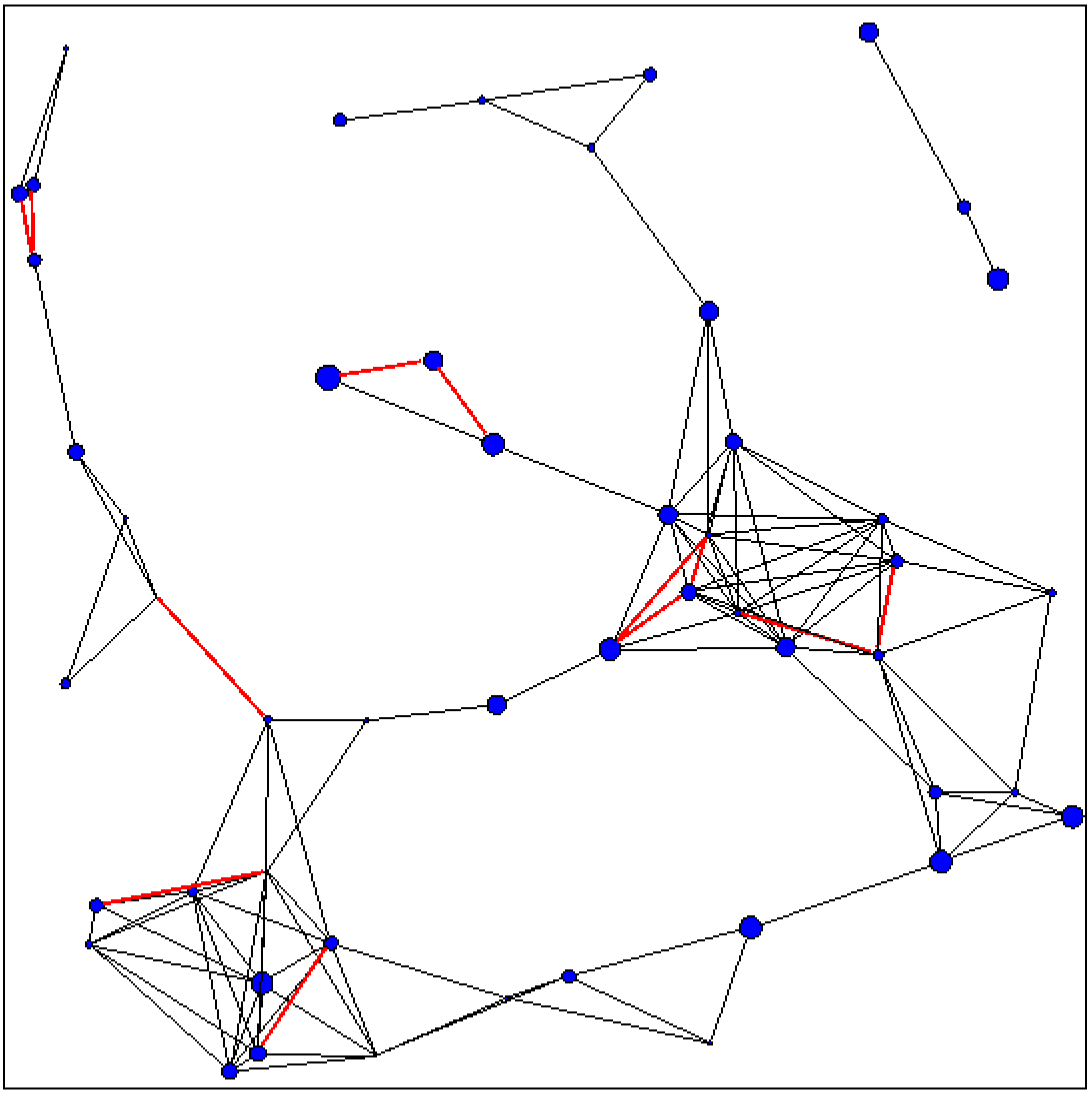

Figure 8-2: Exemplary situation after one time step – friends-network

Here, the blue dots are once again the Human agents, but this time the size of the dot corresponds to the risk aversion which ranges between 0 and 10. The black lines between the agents represent the neighborhood relation between two agents. This means that all Humans which are within a certain distance are in the agent's friends' network. The red line shows that two agents consider each other 'cool friends' and share an even more pronounced interaction pattern. In any case, two things can be easily shown when looking at the initial configuration: on the one hand, we can have two situations with identical agents which will lead to different outcomes only because they are placed at different locations in the environment and therefore interact differently. Furthermore, the interaction patterns are not complete in the sense that an agent is comparably well connected to every other agent. This means that even though the network spreads almost across the entire 'country', there is a difference in interaction between agents which are close and those which are at opposing borders. Nevertheless, we see that allowing local interaction for the agent can lead to a situation where almost the whole population is connected.

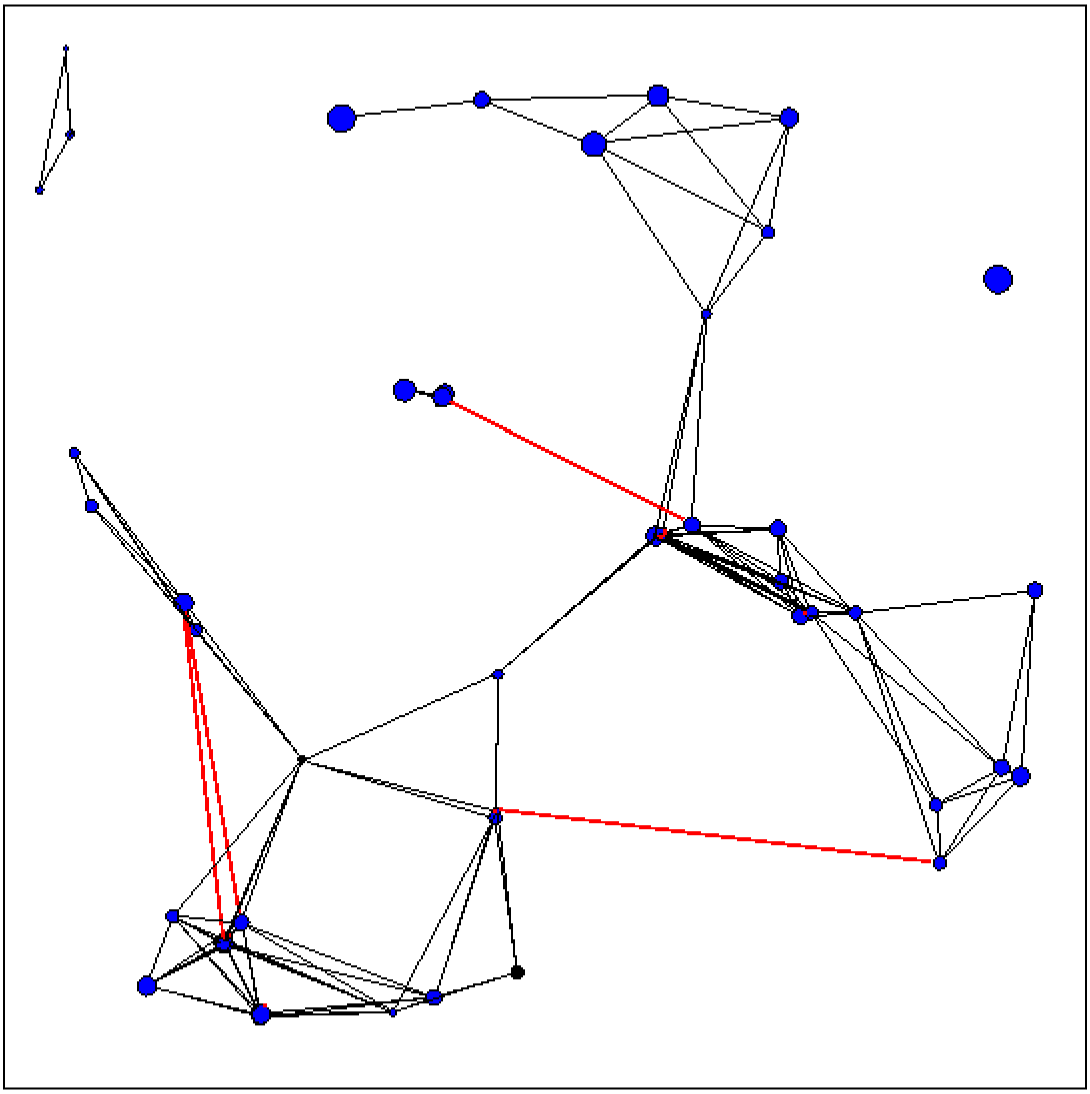

Figure 8-3: Exemplary situation at the end of the simulation – friends-network

In this situation at the first time step, every agent will receive its initial endowment as explained in section 7.3.2 and then the agents will be allowed to interact according to the rules specified in section 7.3.3. Accordingly, we find ourselves in a situation after 60 periods, where the spatial distribution will have changed. The situation in the friends' network may now look as shown in Figure 8-3.

We can see that integration and clustering can take place, since for example the group in the north-east has been integrated and since we find densely populated areas in the south-west as well as in the center of our field. On the other hand, it is also possible that groups get separated and disintegrate from others such as for example the group in the north-west, which had been connected to the majority but lost this connection.

During the run, we can track individual characteristics of the agents or aggregate variables of interest. For example, we can look at the development of the amount of inventions and innovations which are generated by all agents at every time step as an example of an aggregate variable or we can monitor the risk aversion of the individual agents:

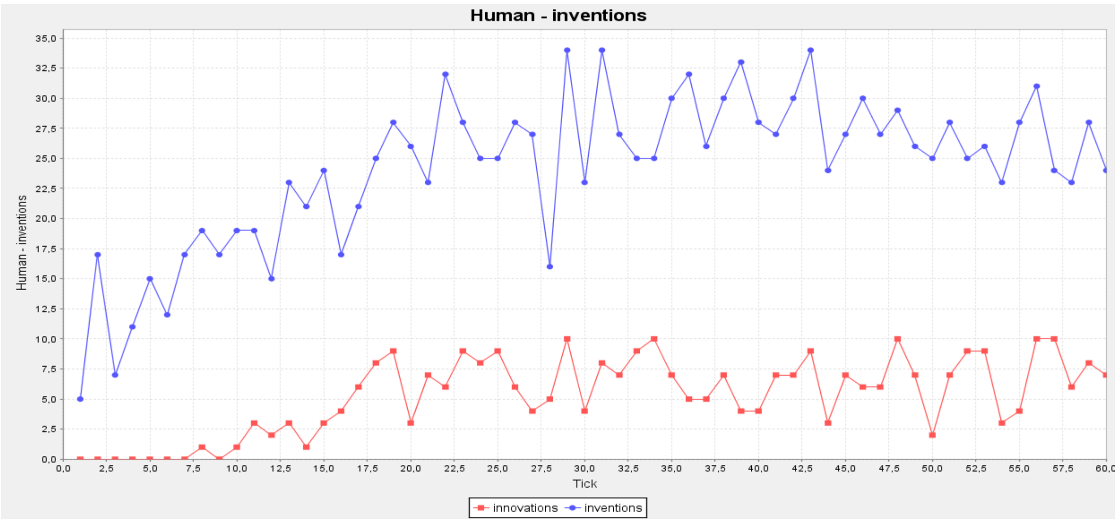

Figure 8-4: Invention and innovation development in an exemplary run

The distribution of risk aversion in this case looks as follows. We can see the change and alteration in every individual's value for risk aversion. It is also visible that some agents become more risk averse or more risk seeking as time goes by.

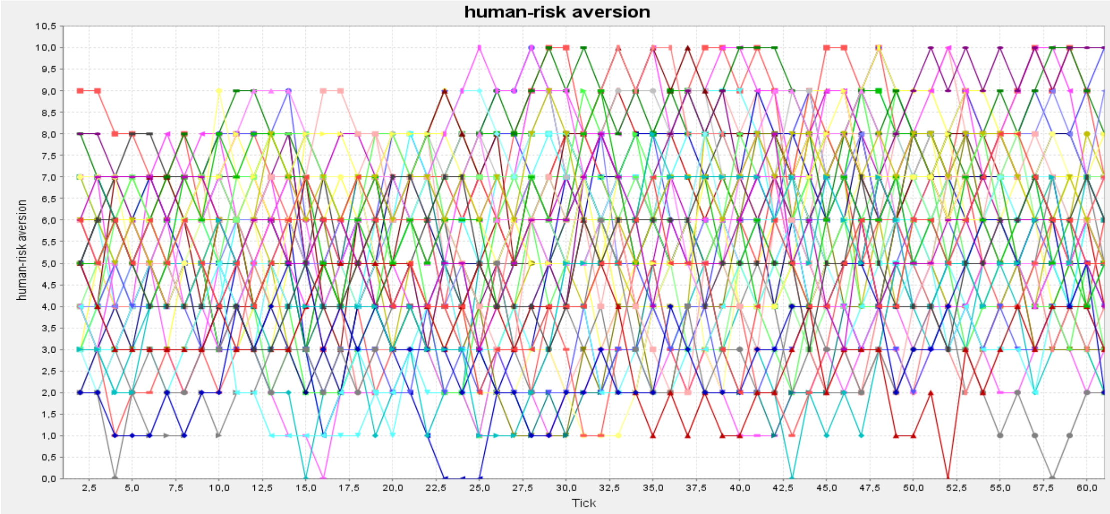

Figure 8-5: Risk aversion of the simulated agents during the course of an exemplary run

Since each run relies on several random influences which only depend on the random seed chosen in the beginning, we cannot just analyze a single run because it may rely on some extraordinary influences.

The great advantage of the simulation environment is that we can run the model a large number of times and see which structures emerge. The main variables where we checked for an influence on the outcome are the following:

Variable	Used values		
		Standard	
Merit goods	0	1	
Subsistence minimum	2	8	12
Invention threshold	40	60	80
Average risk provision	10%	20%	

Table 8-1: Influential variables

Table 8-1 shows that the standard run will use the default values which we explained in section 7.3.1. We have used the idea that governmental influence will not only be exerted in monetary terms, but that there are services which have an effect on the inventiveness of the individuals not linked to public expenditures. In order to test if this influence of merit goods has a decisive effect on the ability of a society to be inventive and innovative, we also let the simulation run with this value set to zero.

The subsistence minimum is supposed to be 8 in the standard setup and we will increase it to 12 and reduce it to 2 in order to see if the amount of welfare offered by the state makes a difference to the innovative behavior of the agents. Furthermore, using two as the subsistence minimum helps verifying if the simulation is able to reproduce the results which had been found in the study by [Bird01] discussed in section 5.2.

Moreover, in the standard run we set the invention threshold to 60, which refers to the likelihood of finding an invention for each agent. In subsequent runs, we will increase it to 80 and lower it to 40 to see how the results are affected by such a variation.

Lastly, we have varied the average risk provision which is also the starting value for the social insurance contribution set by the government. This helps us determine if the amount which people will use to provide for their risks has an influential effect on the innovativeness.

Each of these setups has been run both for the individual model and for the governmental model. It generated the seven runs, which are listed in Table 8-2.

	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
Merit goods	1	0	1	1	1	1	1
Subsistence minimum	8	8	2	12	8	8	8
Invention threshold	60	60	60	60	40	80	60
Average risk provision	20%	20%	20%	20%	20%	20%	10%

Table 8-2: The seven simulation setups

We have compared the results through difference-in-means analysis. In order to be able to use this method, we need independent samples as well as normally distributed outcomes. The samples are independent since no specific execution of the simulation has an influence on any other execution and since we can exclusively and unambiguously attribute each simulation run to its group. Moreover, even though we do not know the distribution of the data in our case, we can use this test because following the central limit theorem we have a sufficiently large sample.[339] Furthermore, it is possible to use the test even though we do not know if the "true" variation of both groups is identical since this condition does not have to hold when using the same sample size for each group as in our case.[340]

The difference-in-means analysis allows us to check the hypothesis that there is no difference in the means of two groups of values. The idea is that if we can reject this

[339] cf. for example [Came09] where he explains that we need a minimum of 30 observations in order to use the Central Limit Theorem

[340] cf. for example [BaBa02], pp. 192

hypothesis then we can suppose that there is a difference between the two groups. This allows us, for example, to test if the individual model has a different effect on the innovativeness of the society than the governmental model. A sample output of the difference-in-means analysis for the amount of innovations is shown in Table 8-3.[341]

t-test: Paired Two Sample for Mean

	inno-individual	inno-governmental
Mean	272.48	325.17
Variance	23935.90869	18856.38495
Observations	100	100
Pearson Correlation	0.303317286	
Hypothesized Mean Difference	0	
df	99	
t Stat	-3.046916276	
P(T<=t) one-tail	0.001482019	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.002964039	
t Critical two-tail	2.62640545	

Table 8-3: Difference in Means Analysis: amount of innovations

In Table 8-3, we can see that the mean amount of innovations in the individual model was 272.48 and in the governmental model 325.17. This means that out of the 100 runs, the average amount of innovations which were created when social insurance was not offered was 52.37 lower than in the situation where the state provided for the subsistence minimum. The second line shows the variance which has been observed over the 100 runs in each model setup and the third line confirms the amount of runs which we have conducted in order to generate our data sets.

We do not use the Pearson Correlation coefficient in our analysis, because each run is known to be independent of every other run. The line "Hypothesized Mean Difference" refers to the hypothesis which we would like to reject. We have chosen this hypothesized mean difference to be zero in each test in order to try if we can reject the following hypothesis: "The difference between the means of the governmental

[341] A complete list of the analyses of the here presented cases can be found in Appendix D.

model against the individual model is zero". Once we can reject this hypothesis, we can be fairly certain that there is an influence exerted by social insurance.
The next lines show the degrees of freedom ("df") as well as the amount for the t-statistics. The higher the absolute value of the "t Stat", the more significant is the difference between the two models.
From the "t Stat" value, the p-value ("P(T<=t)") of the analysis is calculated. The lower the p-value, the smaller is the chance that it will be false to reject our basic hypothesis. Therefore, a p-value of 0.2964039% signifies that we are well above the 99%-significance level when we reason that there is a difference between the two models.
In the subsequent analysis, we will use the two-tail tests in order to analyze the differences between the governmental and the individual model. This helps us finding the influences where social insurance does have an effect on factors related to the innovativeness in the society.
From the 100 simulation runs in the first setup (Run1), we find that the individual model produces on average 272 innovations and 658 inventions and, consequently, has an average ratio of innovations from inventions of 40%. In the governmental model, we find on average 325 innovations and 715 inventions, which corresponds to a ratio of innovation from invention of 45%. Furthermore, we also checked for the mean income of the agents as well as the standard deviation of the income during the simulation. Corresponding to the discussion in section 5.2, we can then analyze the position of the society in the μ-σ-space. We find that, on average, the mean income in the individual model amounts to 31 with an average standard deviation of the income per period of 48.[342] In the governmental model, the average mean income is 38 with an average standard deviation of 32. The difference-in-means analysis shows that there is a statistically significant difference even at the 99%-level between the individual and the governmental model pointing to more inventions, more innovations, a higher mean income and a lower standard deviation of income in the case of social insurance. We have represented those results in Table 8-4. The first column shows the criterion for which we checked the means, the second shows the difference between the means

[342] The mean income presented here is calculated by taking the mean income in the simulation at every time-step (so the mean income of the 50 agents in the simulation) and then taking the arithmetic average of the 60 values over the entire simulation. The standard deviation is similarly calculated in every period and then we take the mean of the standard deviations which we find in the simulation. Finally, we take those two values per run and average them over the 100 simulation runs we conducted leading to an average mean income per period as well as an average standard deviation per period.

when subtracting the mean value of the individual model from the governmental model[343], and the third column shows the corresponding p-value in the t-statistics. Consequently, we can say that at the 99%-level of significance the governmental model leads to more inventions, more innovations, a higher mean income in the population and a lower standard deviation of income in the society.

Criterion	Δ Means	p-value[344]
Inventions	57.08	0.000
Innovations	52.69	0.003
Ratio of innos from inventions	0.05	0.038
Mean income of agents	6.36	0.000
Mean standard deviation of income	-16.26	0.000
Mean risk aversion	-0.08	0.256

Table 8-4: Results from Run 1: Difference in Means Analysis between Individual and Governmental Model

Furthermore, we checked for a difference in the mean risk aversion. The p-value of 0.256 suggests that we cannot reject the hypothesis that the two means are the same at a sensible level. This means that even though the mean risk aversion after 100 simulation runs was slightly higher in the individual model with a value of 6.11 against 6.03 in the governmental model, we cannot say that there is a statistically significant difference in the risk aversion in the two models. Consequently, the difference in the innovative behavior has to stem from other factors such as, for example, the stability introduced through the public sector's social insurance.

[343] To avoid misunderstandings, the value of 57.08 for the difference in the means of inventions shows that there were on average over the 100 runs 57 inventions more in the governmental model than in the individual model after 60 periods.
[344] The p-values in the table are from the two-tailed test of the paired two sample for mean t-test.

We have used the six variations in initial setups to check for the robustness of the results. From the difference-in-means analysis for the second setup ("Run 2"), we get the following results:

Criterion	Δ Means	p-value
Inventions	34.88	0.000
Innovations	11.79	0.563
Ratio of innos from inventions	0.01	0.746
Mean income of agents	4.97	0.000
Mean standard deviation of income	-17.74	0.000
Mean risk aversion	0.02	0.842

Table 8-5: Results from Run 2: Difference in Means Analysis between Individual and Governmental Model

Run 2 is marked by the fact that we chose to ignore any non-monetary influence of the public sector on the inventiveness of the agents. This means that the value for the variable "Merit Goods" was zero. On the individual agents' level, this variable influenced exclusively her inventiveness. Consequently, we find that now the governmental model only leads to, on average, 35 inventions more than the individual model. We find, however, that this still suggests that there is a statistically significant difference between the inventiveness in the governmental against the individual model. Nevertheless, even though we cannot perceive a changed picture concerning the inventions, there is a marked difference when looking at innovations. With a p-value of 0.56 we can no longer say that there is a higher innovativeness in the governmental model. Consequently, it seems that the higher amount of inventions in the first run of the governmental model has also enabled more of the individuals to become innovative. As we can see from the now almost identical ratios of innovations from inventions, the advantage in the governmental model in the first run probably stemmed from the self-enforcing effects of innovations on the environment. So, even though we cannot decide anymore if one of the models leads to more innovations in this case, we can still look at the mean income and its variance. We find that the difference between the two models is significant and that the governmental model still has a higher mean income and a lower standard deviation. This means that even though it cannot produce more innovations, social insurance still can have an income increasing effect on the economy as a whole. Once again, the difference in the risk aversion is not significant.[345] So, we find that even when we restrict the government to providing social insurance only in a monetary form to those in need, there is a beneficial influence on the society what concerns the distribution of income. Furthermore, there is no evidence for a negative effect on the future orientation in such a way that the insurance offering might block innovation.

The next influence for which we checked the model was the subsistence minimum. We had fixed it to 8 corresponding to a value of 8,000 €. Following Bird's argument in section 5.2, it is not necessarily important how much social protection a government offers, but only that it does offer some. Therefore we have checked the model with a subsistence minimum of 2 (Run 3) and with a larger value of 12 (Run 4). The results can be found in Table 8-6.

Criterion	Run 3		Run 4	
	Δ Means	p-value	Δ Means	p-value
Inventions	74.56	0.000	72.07	0.000
Innovations	47.78	0.011	35.04	0.049
Ratio of innos from inventions	0.02	0.369	0.01	0.591
Mean income of agents	0.89	0.332	14.29	0.000
Mean standard deviation of income	-3.36	0.005	-33.33	0.000

Table 8-6: Results from Run 3 and 4: Difference in Means Analysis between Individual and Governmental Model

Looking at the p-values, we find that we can no longer say that the ratio of innovations from inventions is different between the two models. Both for a larger as well as a smaller subsistence minimum, the difference is not marked enough to allow us to be sure of a difference between the models. This implies that the one which can generate more inventions will also produce more innovations. While the difference in the mean amount of inventions in the standard model (Run 1) was 57, it is now above 70 in both situations. In both Run 3 and Run 4 we find a slight decrease in the number of inventions in the individual models and an increase in the number of inventions in the governmental model. This suggests that the more pronounced values for the subsistence minimum work in favor of the stabilizing system with the governmental

[345] The difference in the mean risk aversion turns out not to be significant at the 90% level or above in any of the seven cases. Therefore we will leave it out of the tables for the subsequent runs, but the results can still be found in Appendix D.

insurance scheme. Similarly, we find that we can reject the hypothesis that the two models are equivalently innovative at the 95% level. Especially in the case of Run 3, we can reproduce the result which Bird mentioned in his paper that even a small insurance scheme may lead to a welfare increasing effect by stimulating innovations. Nevertheless, even though we find the significantly larger innovativeness, we do not have a statistically significant difference in the income distribution. The income variation is statistically significantly lower, but we cannot say that the mean income is higher in the governmental model. This is not very surprising since this time the public sector only raises people to a very low income level and therefore, the amount of people who are better off in the governmental than in the individual system is reduced. So, at a low level of social insurance, the main effect of the public sector seems to be the creation of a stable environment which allows the people to develop their creative abilities.

Still, the graph in Figure 8-6 showing the average percentage of contribution to the social services as well as the corresponding average subsistence minimum per period after 100 simulation runs shows clearly that in the governmental model, the people will use the possibility to vote for an increase in the services of the welfare state.

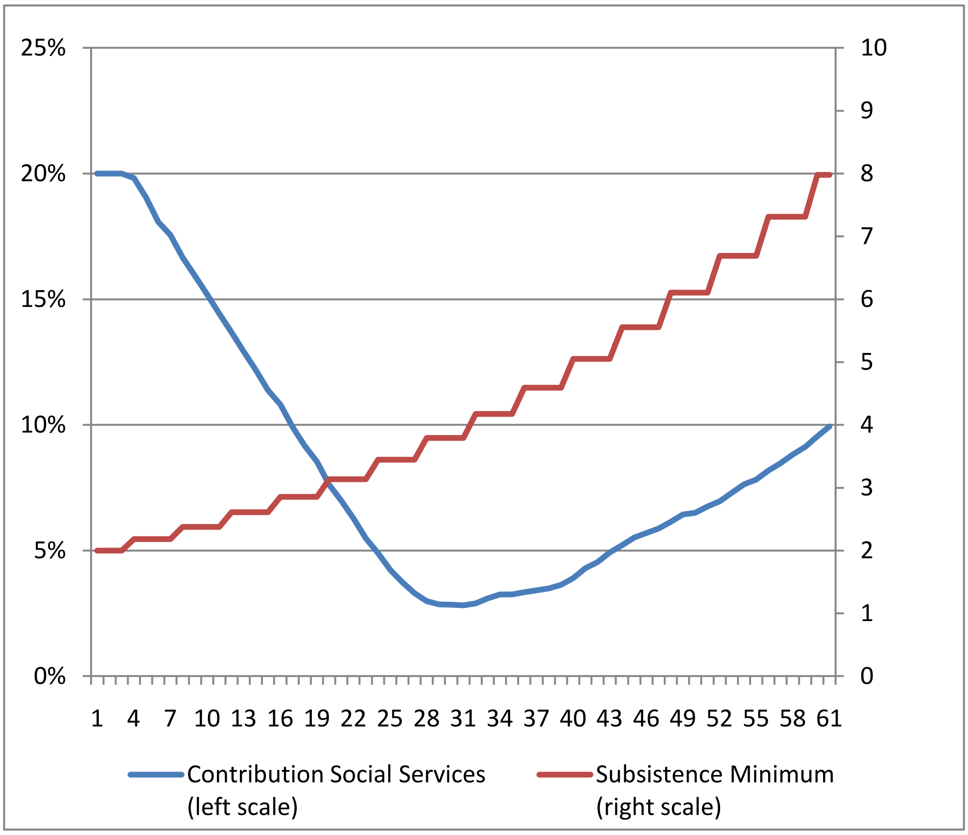

Figure 8-6: Development of social insurance in the governmental model in Run 3

Therefore, even though in the individual model each agent is free to choose her preferred strategy of dealing with the risk she faces in her life, the combined strategy in the governmental model appears to be more successful when it comes to generating innovations.

In Run 4, however, we find that there are not only more innovations and more inventions, but the society in the governmental model also has a higher average income with a lower standard deviation. Consequently, we find a situation where the governmental model is again robustly superior to the individual model. In order to be able to compare the three situations, we looked at some of the developments. Figure 8-7 shows the development of the percentage rate for the social contribution and the average subsistence minimum in our standard setup Run 1 as well as in Run 4. Compared to Run 3 both values in both setups are always larger. But when we plot Run 1 against Run 4 we find that even though the latter starts with a higher subsistence minimum and consequently first sees the contribution rate climb even higher, in the end it is Run 1 which shows the largest subsistence minimum and the highest contribution rate. This means that the members of the society voted either for a decrease or an increase in public services.

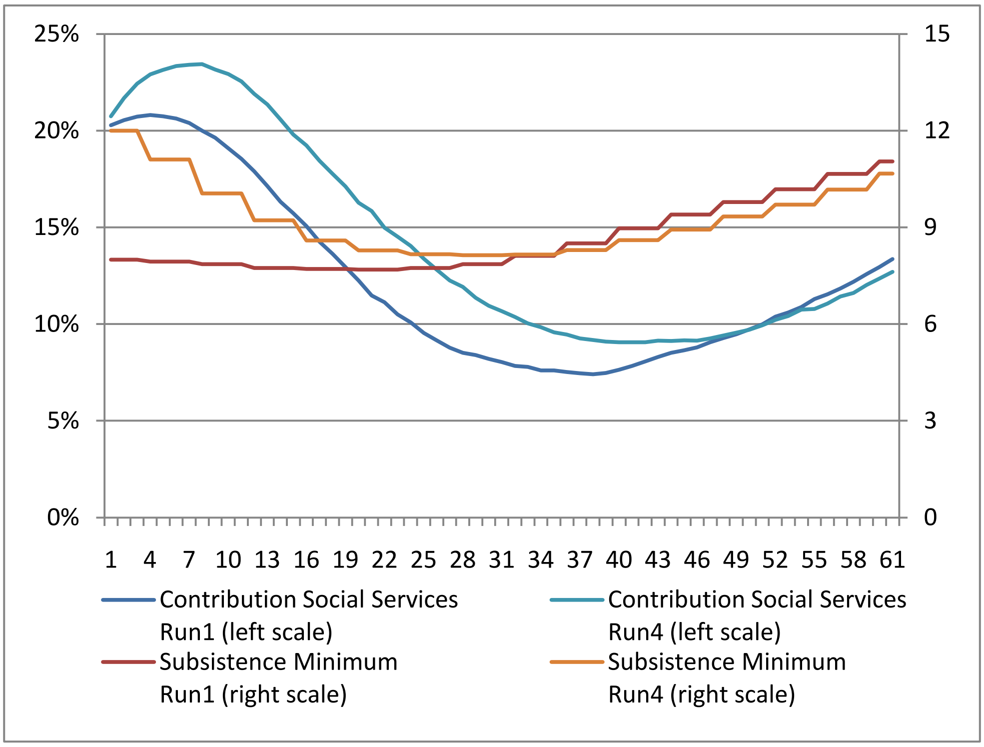

Figure 8-7: Comparison of Run1 to Run4 in the Governmental Model

In order to see if any of the three governmental models is superior to the others, we also conducted difference in means analysis from Run1 against Run3 and against Run4. The results are shown in Table 8-7.

Criterion	Run1 vs Run3		Run1 vs Run4	
	Δ Means	p-value	Δ Means	p-value
Inventions	-13.29	0.056	-8.62	0.152
Innovations	-0.59	0.967	8.27	0.497
Ratio of innos from inventions	0.01	0.750	0.02	0.289
Mean income of agents	2.67	0.000	-1.39	0.010
Mean standard deviation of income	-1.53	0.095	0.16	0.835
Mean subsistence minimum	4.35	0.000	-0.62	0.000
Mean contribution to social insurance	0.04	0.000	-0.02	0.000

Table 8-7: Difference in Means Analysis of Run1 against Run3 and Run4 in the Governmental Model

We find that for most variables we cannot reject the hypothesis that their means are the same even at the 95% level of confidence. While it is not surprising that the differences in both the subsistence minimum and the rate of contribution to the social insurance are significant, we also find that mean income of the agents is significantly higher, the higher the subsistence minimum is at the time the simulation is started. This implies that the strategy which emerged for the population in Run 4 proved to be the most successful. They started with a high social standard and reduced it over time, which apparently lead to the most successful situation in terms of economic welfare. In any case, even though it is true that any level of social insurance is better than the individual model, we find that different levels do have an effect on the welfare of the society. Further research in this direction might help find a better design for the optimal amount of social insurance.

Furthermore, we tested our model for robustness in the invention threshold parameter. The lower the value, the easier it is for an individual to find an invention. This parameter has, however, no influence on the innovativeness or any other aspect in the agents' life. In the default setting it is chosen to be at 60 and we lower it to 40 (Run5) and raise it to 80 (Run6). The results of the two runs can be found in Table 8-8.

Criterion	Run 5		Run 6	
	Δ Means	p-value	Δ Means	p-value
Inventions	45.58	0.000	70.49	0.000
Innovations	36.45	0.064	40.58	0.000
Ratio of innos from inventions	0.01	0.408	0.10	0.002
Mean income of agents	-1.39	0.286	11.78	0.000
Mean standard deviation of income	-11.00	0.000	-20.20	0.000

Table 8-8: Results from Run 5 and 6: Difference in Means Analysis between Individual and Governmental Model

Just looking at the means will already suggest that in both runs the governmental model is once again more future oriented and welfare enhancing. There are, however, marked differences between the two cases. In run 6, the situation is as clear cut as it presents itself. From the p-value we can see that all values are different between the models well above the 99% level of significance. This means that once it is very difficult to find an invention, the governmental model offers a huge advantage over the individual model by generating on average 41 innovations more and securing a higher and less widespread income for the citizens.

The case is less clear when looking at Run 5 where invention has been facilitated compared to our standard setup. We find that the governmental model still is able to generate more inventions than the individual model, but we can only reject the hypothesis of equality for innovations at a 90%-level[346]. This means that there is much evidence that the innovativeness is still higher in the governmental model when inventions are easy to be found, but it is less clearly pronounced.

Furthermore, this simulation setup does not lead to a higher average income in the governmental model. We find that in our sample the opposite is true where the mean income in the individual model is higher, but we cannot even say that there is a

[346] The exact value would be 93.6%-level of confidence.

difference in the means at a confidence level of 75%. Still, we do find that the governmental model has once again contributed to a smoothing in the distribution meaning that the standard deviation is significantly lower than in the individual model. Consequently, we find that the more difficult it is to be innovative, the stronger is the advantage of the governmental model and the better it is to have the social insurance scheme. Nevertheless, the mean income is more than twice as large in Run 5 as in Run 6, which means that for social welfare it is best, if inventions and innovations are easily found. The easier it is to be creative and inventive, the less we need a public sector securing the citizens against their life risks because they can provide for their own. The more difficult it will be to find an invention, the more important the role of the government.

Lastly we checked for a situation where the role of risk provision is less important for the population and so we reduced average risk provision in the individual model to 10% and lowered the starting value for the contribution to the social services to 10%. The situation in the governmental model improves slightly with higher rates of inventions, innovations and a higher mean income. In the individual model, however, we see a different picture. While the number of inventions is relatively stable, the number of innovation decreased slightly pointing at the difficulties to finance an innovation. We find a sharp drop, however, in the mean income of the population which falls to 25 compared to 31 in Run 1. Consequently, we find the comparison as follows:

Criterion	Δ Means	p-value
Inventions	57.83	0.000
Innovations	56.16	0.000
Ratio of innos from inventions	0.05	0.019
Mean income of agents	14.55	0.001
Mean standard deviation of income	-21.97	0.000

Table 8-9: Results from Run 7: Difference in Means Analysis between Individual and Governmental Model

In this situation we find statistically significantly more inventions and more innovations in the governmental model – each time even well beyond the 99%-level. Similarly, the mean income of the agents as well as the standard deviation are statistically significantly different in both models and as in the runs before we find a higher and less widespread income in the governmental model.

From those analyses, we can see that this simple agent-based model is able to reproduce the insights from the studies by Sinn and Bird. Furthermore, the results are fairly robust to changes in the parameter setup. Only in Run2, where we supposed that there is no effect from merit goods derived from the social insurance services provided by the government, is the society not capable of producing a statistically significantly higher amount of innovation compared to the individual model. In all other cases, the governmental model turned out to foster innovation in the society and led to a higher average income of the agents. Consequently, it suggests that social insurance can indeed spur innovation in a society.

Further research can and should investigate into expanding the model and testing for other influences. We will point to some limitations of the simulation in the subsequent section.

8.3 Limitations of the results

At this point we can ask if the model and its implementation have fulfilled the expectations and met the desired goals. Before we dismiss it for having too strong assumptions or too weak results, we may look at what a model is able to achieve and what it cannot realize: "As in so many areas of economic research, we are forced to estimate 'false models' that do not provide a complete or correct picture of reality. As a consequence, no single study can be regarded as a definitive test of a theory in the way that studies are in the experimental sciences. Instead, inferences must be made by weighing the results of different studies and by under-standing the basic data and the relevant institutions."[347]

One aspect which makes agent-based simulations difficult to interpret is the considerable amount of specific definitions of variables and dependencies. For a precise model which is supposed to be calculated, it is not sufficient to define that the derivative of a certain variable on a characteristic is positive. We need specific values and we need to clearly define the mathematical equations underlying those relationships. Such a definition is always unique, but it may not be uniquely definable. Consequently, each model can only give insight on the emergent structure in the precise system.

[347] [Feld82], p. 460

Still, it is not useless if it cannot mirror exactly a set of data found in the real world. It is necessary to require the interior consistency as well as to argue over the assumptions and hypotheses taken during the modeling. Furthermore, it is certainly valuable to explore more models on a similar question with different setups and compare the emerging structure of those in order to find similarities in the dynamics which allow inferring certain causalities from the assumptions.

In the analysis presented here, we have almost exclusively focused on the final states of the simulation after the 60 periods, since the main goal was to gain insight on the ability of social insurance to spur innovation. Nevertheless, further analysis could look more closely at the development of the characteristics of the society during the simulation in order to find key influences which drive creativity, innovation or income generation.

We also did not discuss the absolute values found in the simulation, such as amount of innovations or the average income of the individuals. Since the model could never exactly reproduce reality, the values it generates will not be comparable to anything outside the simulation. This means that it is not important if the amount of innovation corresponds to the mean amount of granted patents in a certain country. As long as the model is built on sound assumptions and it is interiorly consistent, then we can compare the results of different runs and draw conclusions from the variation.

Additionally, the individual model which we discussed here is certainly not comparable to any real world implementation of any country. At least for reasons of fairness and justice, there is some system in any country which prevents that people have to starve to death. This means that our individual system, which does not offer any support to those who are unable to provide for themselves, cannot be found in any country. Nevertheless, in almost any system we will find some members who argue that the protection of the poorest and weakest is still too generous. In such a situation it may be useful to have a model as the one we presented here showing that a certain degree of social protection is desirable. Furthermore, the model also allows us to compare different setups of social insurance with each other so that we can see if some design of the public sector is more beneficial than others.

Moreover, agents can decide if they are willing or not to be innovative. In this aspect we see the moral hazard which a system of social insurance can introduce. Agents with a low risk aversion might rather shy away from innovating in the governmental system, because they lack the incentive. Nevertheless, we did not include such a behavior in the search for work or the working behavior. It can be argued that some people will adapt their living in order to lead their life off of public support. Such individuals may have a strong effect on others in their environment or their larger network. Some of them may also choose to offer their work in the black market, therefore forgoing contributing to the system as well as receiving support. The behavioral consequences on the environment could be strong depending on the interaction between the agents. Including such a behavior is certainly a central idea for a future extension of this simulation.

Even though the current state of complexity of the model may blur the results and it is not always easy to find the underlying mechanisms leading to certain emergent structures, our model can provide additional insight on the implications which a social security scheme and a welfare state can have on an economy. Although referring to recessions in the current economic crisis, we find Nobel Prize laureates calling for more diverse approaches: "economists need to abandon the neat but wrong solution of assuming that everyone is rational and markets work perfectly. The vision that emerges as the profession rethinks its foundations may not be all that clear; it certainly won't be neat; but we can hope that it will have the virtue of being at least partly right."[348] Agent-based models offer a viewpoint and a methodological approach, which allows us to tackle research questions from a different, more comprehensive perspective which may shed light on formerly unexplored facets of an issue.

[348] [Krug09], p. 8

9 Conclusion

The question we started off with was if social insurance was able to spur innovation and therefore secure the future-orientation for a region or if it limited the incentives to innovate for the members of the society and would lead to a tradeoff between income maximization and social cohesion.

As we have seen in section 5.3, a definite solution to this question is hardly possible. Consequently, we cannot derive from our study that social insurance can stimulate innovative behavior and therefore create the dynamic environment necessary for economic development and the future optimism in a society. Nevertheless, our model has added a new perspective and is able to add to the arguments pointing in the direction that social insurance is indeed able to foster innovation.

In a more general view, this study started from the theoretical base of CNSE which means that it is situated in an evolutionary context focusing on the dynamics of a system, and that it takes the interactions which exist in and between the three pillars – real sector, financial sector and public sector – into account. It builds on the idea that it is important to include all three sectors into the analysis when trying to understand the cause-effect relationships in an economy. All economic actors are part of larger systems both on a meso- as well as on a macro-level and they will influence others just as they are influenced by other agents and by the environment.

Furthermore, we concentrate on the innovativeness of a society as the key criterion of its future orientation. While there may be other political measures possible which improve the current state of an economy, it is crucial for a society to ensure the well-being in the future. Without innovation it is difficult – if not impossible - to maintain the current standard of living because of unexpected and unforeseeable events such as shortages in supply, changes in preferences or even natural influences like for example the climate change or on a short term scale an ash-throwing volcano. In all those cases, a society needs innovation and entrepreneurs who assume the risk of failing and try to implement novelty. Only through an ongoing creative destruction is it possible to sustain a certain lifestyle. Consequently, from a welfare perspective, maximizing today's welfare should not be the primary goal of a political measure but rather maximizing the potential for future welfare, so that the economy is well prepared for the uncertainties and the changing and varying influences of the future.

Social insurance is such a political measure which is introduced in an economy in order to provide for those who are unable to look out for themselves. It serves as a safety net for the entire population securing that everybody will be supported to a certain level deemed to be the subsistence minimum. Grown through history, most western countries offer their citizens a more or less densely knit social system designed to help them overcome periods of distress or to balance bad fate by social support. This social system is often justified against a free-market logic by arguing that there is a moral value of fairness and equality, as well as the political goal of social peace. On the other hand, it is often attacked for being too generous and for limiting the incentive for people to get active. Therefore, we have taken the two ideas – the more integrated CNSE-approach and the dilemma of social insurance – and modeled them in an agent-based simulation designed to provide insights on the cause-effect relationship between social insurance and the innovativeness of the society.

The model which we have presented here can certainly only be a step in the direction to better understand the different inter-sector and intra-sector relations and how changes in the parameters – such as the introduction of social insurance – affect the system's state. Nevertheless, it offers direct insight at the influences of some aspects.

We have found that the governmental model offering social insurance shows in no case a trend to fewer innovations than the individual model. In the standard setup, we even find that the ratio of how many of the inventions will be implemented into innovations is significantly higher once social insurance is offered. We have checked the robustness of those results to several parameter changes and found in most cases that social insurance will improve the future-orientation of an economy by increasing the amount of innovations and that there is no case at all, when it will have negative effects on the future orientation. This effect is even stronger, once it becomes difficult for an individual to find an invention or once we reduce the average risk provision making individuals bolder towards their own life strategy. The overall picture shows that social insurance is not only a means of securing social peace and cohesion in a country, but that it can also add to the future orientation.

While policy and political decisions always work on a different basis than economics, it is important for economists to offer ideas and their welfare implications in order to enable politicians to find the best solution. Innovation is not only about the cool gadgets which made us the star in the schoolyard. For an economy and a society, they are much rather the best insurance and guarantee for a prosperous future. From our model, we infer that social insurance is a good means of reaching just this goal. We argue that social insurance can indeed spur innovation.

Table of Contents - Appendix

Appendix A: Source Code of the Model

1) File model.score

```
<?xml version="1.0" encoding="UTF-8" ?>
- <score:SContext xmlns:xsi="http://www.w3.org/2001/XMLSchema-
    instance" xmlns:score="http://scoreabm.org/score" label="InnoEasy"
    ID="innoEasy" pluralLabel="InnoEasies">
  <attributes label="initial Number Of Humans" ID="initialNumberOfHumans"
    pluralLabel="initial Number Of Humanss" sType="INTEGER"
    defaultValue="50" />
  <attributes label="initial Number Of Banks" ID="initialNumberOfBanks"
    pluralLabel="initial Number Of Bankss" sType="INTEGER"
    defaultValue="10" />
  <attributes label="initial Number Of Funds" ID="initialNumberOfFunds"
    pluralLabel="initial Number Of Fundss" sType="INTEGER"
    defaultValue="10" />
  <attributes label="individual Model" ID="individualModel"
    pluralLabel="individual Models" defaultValue="true" />
  <attributes label="subsistence Minimum" ID="subsistenceMinimum"
    pluralLabel="subsistence Minimums" sType="FLOAT" defaultValue="8.0" />
  <attributes label="influence Merit Goods" ID="influenceMeritGoods"
    pluralLabel="influence Merit Goodss" sType="INTEGER" defaultValue="1"
    />
  <attributes label="invention Threshold" ID="inventionThreshold"
    pluralLabel="invention Thresholds" sType="INTEGER" defaultValue="60"
    />
  <attributes label="minWorkAge" ID="minWorkAge"
    pluralLabel="minWorkAges" sType="INTEGER" defaultValue="16" />
  <attributes label="max Initial Age" ID="maxInitialAge" pluralLabel="max
    Initial Ages" sType="INTEGER" defaultValue="50" />
  <attributes label="avgRetirementAge" ID="avgRetirementAge"
    pluralLabel="avgRetirementAges" sType="INTEGER" defaultValue="67" />
  <attributes label="minDeathAge" ID="minDeathAge"
    pluralLabel="minDeathAges" sType="INTEGER" defaultValue="60" />
  <attributes label="maxDeathAge" ID="maxDeathAge"
    pluralLabel="maxDeathAges" sType="INTEGER" defaultValue="100" />
```

```
<attributes label="maxEducation" ID="maxEducation"
   pluralLabel="maxEducations" sType="INTEGER" defaultValue="3" />

<attributes label="yearForEdu" ID="yearForEdu" pluralLabel="yearForEdus"
   description="how many years it takes to get to the next higher level of
   education" sType="INTEGER" defaultValue="3" />

<attributes label="avgUnempment" ID="avgUnempment"
   pluralLabel="avgUnempments" sType="INTEGER" defaultValue="8" />

<attributes label="healthProbability" ID="healthProbability"
   pluralLabel="healthProbabilities" sType="INTEGER" defaultValue="95" />

<attributes label="avgRiskProvision" ID="avgRiskProvision"
   pluralLabel="avgRiskProvisions" description="" sType="FLOAT"
   defaultValue="0.2" />

<attributes label="avgConsumptionRatio" ID="avgConsumptionRatio"
   pluralLabel="avgConsumptionRatios" sType="FLOAT" defaultValue="0.9"
   />

<attributes label="highEduIncFactor" ID="highEduIncFactor"
   pluralLabel="highEduIncFactors" description="Factor how high education
   influences the average income" sType="FLOAT" defaultValue="1.62" />

<attributes label="midEduIncFactor" ID="midEduIncFactor"
   pluralLabel="midEduIncFactors" description="Factor how middle
   education influences the average income" sType="FLOAT"
   defaultValue="1.07" />

<attributes label="lowEduIncFactor" ID="lowEduIncFactor"
   pluralLabel="lowEduIncFactors" description="Factor how low education
   influences the average income" sType="FLOAT" defaultValue="0.91" />

<attributes label="num Periods" ID="numPeriods" pluralLabel="num
   Periodss" sType="INTEGER" defaultValue="60" />

<attributes label="boolDebug" ID="boolDebug" pluralLabel="boolDebugs"
   defaultValue="false" />

<implementation package="innoeasy" className="" basePath="../InnoEasy"
   mode="AUTO" />

- <agents label="ModelInitializer" ID="modelInitializer"
   pluralLabel="ModelInitializers">

<implementation className="ModelInitializer" />

  </agents>

- <agents label="Human" ID="human" pluralLabel="Humans">

<implementation className="Human" />
```

```
    </agents>
- <agents label="Bank" ID="bank" pluralLabel="Banks">
  <implementation className="Bank" />
    </agents>
- <agents label="Fund" ID="fund" pluralLabel="Funds">
  <implementation className="Fund" />
    </agents>
- <agents label="PublicSector" ID="publicSector"
    pluralLabel="PublicSectors">
  <implementation className="PublicSector" basePath="" />
    </agents>
- <agents label="Invention" ID="invention" pluralLabel="Inventions">
  <implementation className="Invention" />
    </agents>
- <projections xsi:type="score:SContinuousSpace" label="Space" ID="space"
    pluralLabel="Spaces" dimensionality="2">
  <attributes xsi:type="score:SAttributeArray" label="Dimensions"
    ID="dimensions" pluralLabel="Dimensionss" description="The size of each
    dimension." sType="INTEGER" size="2" />
  <attributes label="Width" ID="width" pluralLabel="Widths" description="The
    horizontal extent of the space." sType="INTEGER" defaultValue="50" />
  <attributes label="Height" ID="height" pluralLabel="Heights" description="The
    vertical extent of the space." sType="INTEGER" defaultValue="50" />
    </projections>
  <projections xsi:type="score:SNetwork" label="Inventor" ID="inventor"
    pluralLabel="Inventors" />
  <projections xsi:type="score:SNetwork" label="Innovator" ID="innovator"
    pluralLabel="Innovators" directed="true" />
  <projections xsi:type="score:SNetwork" label="Financier" ID="financier"
    pluralLabel="Financiers" directed="true" />
  <projections xsi:type="score:SNetwork" label="Banking" ID="banking"
    pluralLabel="Bankings" directed="true" />
```

```
<projections xsi:type="score:SNetwork" label="Investing" ID="investing"
   pluralLabel="Investings" directed="true" />

<projections xsi:type="score:SNetwork" label="ProvisionNet"
   ID="provisionNet" pluralLabel="ProvisionNets" directed="true" />

<projections xsi:type="score:SNetwork" label="SavingNet" ID="savingNet"
   pluralLabel="SavingNets" directed="true" />

<projections xsi:type="score:SNetwork" label="Friends" ID="friends"
   pluralLabel="Friendss" />

<projections xsi:type="score:SNetwork" label="Community" ID="community"
   pluralLabel="Communities" directed="true" />

   </score:SContext>
```

2) File ModelInitializer.groovy

```
/**
 *
 * This file was automatically generated by the Repast Simphony
Agent Editor.
 * Please see http://repast.sourceforge.net/ for details.
 *
 */

/**
 *
 * Set the package name.
 *
 */
package innoeasy

/**
 *
 * Import the needed packages.
 *
 */
import java.io.*
import java.math.*
import java.util.*
import javax.measure.unit.*
import org.jscience.mathematics.number.*
import org.jscience.mathematics.vector.*
import org.jscience.physics.amount.*
import repast.simphony.adaptation.neural.*
import repast.simphony.adaptation.regression.*
import repast.simphony.context.*
import repast.simphony.context.space.continuous.*
import repast.simphony.context.space.gis.*
import repast.simphony.context.space.graph.*
import repast.simphony.context.space.grid.*
import repast.simphony.engine.environment.*
import repast.simphony.engine.schedule.*
import repast.simphony.engine.watcher.*
import repast.simphony.groovy.math.*
import repast.simphony.integration.*
import repast.simphony.matlab.link.*
import repast.simphony.query.*
import repast.simphony.query.space.continuous.*
import repast.simphony.query.space.gis.*
import repast.simphony.query.space.graph.*
import repast.simphony.query.space.grid.*
import repast.simphony.query.space.projection.*
import repast.simphony.parameter.*
import repast.simphony.random.*
import repast.simphony.space.continuous.*
import repast.simphony.space.gis.*
import repast.simphony.space.graph.*
import repast.simphony.space.grid.*
import repast.simphony.space.projection.*
import repast.simphony.ui.probe.*
import repast.simphony.util.*
import simphony.util.messages.*
import static java.lang.Math.*
import static repast.simphony.essentials.RepastEssentials.*
```

```
/**
 *
 * This is an agent.
 *
 */
public class ModelInitializer  {

    /**
     *
     * This value is used to automatically generate agent
identifiers.
     * @field serialVersionUID
     *
     */
    private static final long serialVersionUID = 1L

    /**
     *
     * This value is used to automatically generate agent
identifiers.
     * @field agentIDCounter
     *
     */
    protected static long agentIDCounter = 1

    /**
     *
     * This value is the agent's identifier.
     * @field agentID
     *
     */
    protected String agentID = "ModelInitializer " +
(agentIDCounter++)

    /**
     *
     * This is the user model builder
     * @method initializeModel
     *
     */
    @ScheduledMethod(
        start = 0d,
        shuffle = true
    )
    public static def initializeModel() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        RandomHelper.createNormal(0, 1)
        RandomHelper.createPoisson(5)
        // This is a task.
        PublicSector state = new PublicSector()
        AddAgentToContext("InnoEasy", state)
        state.initialize()

        // This is a loop.
```

```
        for (i in 1..GetParameter("initialNumberOfHumans")) {

            // This is a task.
            Human human = new Human()
            AddAgentToContext("InnoEasy", human)
            human.initializeHuman()

        }


        // This is a loop.
        for (i in 1..GetParameter("initialNumberOfBanks")) {

            // This is a task.
            Bank bank = new Bank()
            bank.dblInterest = RandomHelper.nextDoubleFromTo(0.0,
0.07)
            AddAgentToContext("InnoEasy", bank)

        }


        // This is a loop.
        for (i in 1..GetParameter("initialNumberOfFunds")) {

            // This is a task.
            Fund fund = new Fund()
            fund.dblInterest = RandomHelper.nextDoubleFromTo(0.0,
0.07)
            AddAgentToContext("InnoEasy", fund)

        }

        // Return the results.
        return returnValue

    }

    /**
     *
     * This method provides a human-readable name for the agent.
     * @method toString
     *
     */
    @ProbeID()
    public String toString() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // Set the default agent identifier.
        returnValue = this.agentID
        // Return the results.
        return returnValue

    }


}
```

3) File Human.groovy

```
/**
 *
 * This file was automatically generated by the Repast Simphony
Agent Editor.
 * Please see http://repast.sourceforge.net/ for details.
 *
 */

/**
 *
 * Set the package name.
 *
 */
package innoeasy

/**
 *
 * Import the needed packages.
 *
 */
import java.io.*
import java.math.*
import java.util.*
import javax.measure.unit.*
import org.jscience.mathematics.number.*
import org.jscience.mathematics.vector.*
import org.jscience.physics.amount.*
import repast.simphony.adaptation.neural.*
import repast.simphony.adaptation.regression.*
import repast.simphony.context.*
import repast.simphony.context.space.continuous.*
import repast.simphony.context.space.gis.*
import repast.simphony.context.space.graph.*
import repast.simphony.context.space.grid.*
import repast.simphony.engine.environment.*
import repast.simphony.engine.schedule.*
import repast.simphony.engine.watcher.*
import repast.simphony.groovy.math.*
import repast.simphony.integration.*
import repast.simphony.matlab.link.*
import repast.simphony.query.*
import repast.simphony.query.space.continuous.*
import repast.simphony.query.space.gis.*
import repast.simphony.query.space.graph.*
import repast.simphony.query.space.grid.*
import repast.simphony.query.space.projection.*
import repast.simphony.parameter.*
import repast.simphony.random.*
import repast.simphony.space.continuous.*
import repast.simphony.space.gis.*
import repast.simphony.space.graph.*
import repast.simphony.space.grid.*
import repast.simphony.space.projection.*
import repast.simphony.ui.probe.*
import repast.simphony.util.*
import simphony.util.messages.*
import static java.lang.Math.*
import static repast.simphony.essentials.RepastEssentials.*
```

```
/**
 *
 * This is an agent.
 *
 */
public class Human  {

    /**
     *
     * This is an agent property.
     * @field intAge
     *
     */
    @Parameter (displayName = "Age", usageName = "intAge")
    public int getIntAge() {
        return intAge
    }
    public void setIntAge(int newValue) {
        intAge = newValue
    }
    public int intAge = 0

    /**
     *
     * This is an agent property.
     * @field intExperience
     *
     */
    @Parameter (displayName = "Experience", usageName =
"intExperience")
    public int getIntExperience() {
        return intExperience
    }
    public void setIntExperience(int newValue) {
        intExperience = newValue
    }
    public int intExperience = 0

    /**
     *
     * This is an agent property.
     * @field intEducation
     *
     */
    @Parameter (displayName = "Education", usageName =
"intEducation")
    public int getIntEducation() {
        return intEducation
    }
    public void setIntEducation(int newValue) {
        intEducation = newValue
    }
    public int intEducation = 0

    /**
     *
     * This is an agent property.
     * @field intRiskAversion
     *
     */
```

```
    @Parameter (displayName = "Risk Aversion", usageName =
"intRiskAversion")
    public int getIntRiskAversion() {
        return intRiskAversion
    }
    public void setIntRiskAversion(int newValue) {
        intRiskAversion = newValue
    }
    public int intRiskAversion = 0

    /**
     *
     * This is an agent property.
     * @field dblRiskProvision
     *
     */
    @Parameter (displayName = "Risk Prov", usageName =
"dblRiskProvision")
    public double getDblRiskProvision() {
        return dblRiskProvision
    }
    public void setDblRiskProvision(double newValue) {
        dblRiskProvision = newValue
    }
    public double dblRiskProvision = 0

    /**
     *
     * This is an agent property.
     * @field dblSavings
     *
     */
    @Parameter (displayName = "Savings", usageName = "dblSavings")
    public double getDblSavings() {
        return dblSavings
    }
    public void setDblSavings(double newValue) {
        dblSavings = newValue
    }
    public double dblSavings = 0

    /**
     *
     * This is an agent property.
     * @field blnRetired
     *
     */
    @Parameter (displayName = "Retired?", usageName = "blnRetired")
    public boolean getBlnRetired() {
        return blnRetired
    }
    public void setBlnRetired(boolean newValue) {
        blnRetired = newValue
    }
    public boolean blnRetired = 0

    /**
     *
     * This is the Health field.
     * @field dblHealth
     *
     */
```

```
    @Parameter (displayName = "Health", usageName = "dblHealth")
    public double getDblHealth() {
        return dblHealth
    }
    public void setDblHealth(double newValue) {
        dblHealth = newValue
    }
    public double dblHealth = 1

    /**
     *
     * Shows if the person has a job or not. 1:= employed; 0 :=
unemployed
     * @field blnEmployed
     *
     */
    @Parameter (displayName = "Employed?", usageName =
"blnEmployed")
    public boolean getBlnEmployed() {
        return blnEmployed
    }
    public void setBlnEmployed(boolean newValue) {
        blnEmployed = newValue
    }
    public boolean blnEmployed = 0

    /**
     *
     * This is an agent property.
     * @field dblHappiness
     *
     */
    @Parameter (displayName = "Happiness", usageName =
"dblHappiness")
    public double getDblHappiness() {
        return dblHappiness
    }
    public void setDblHappiness(double newValue) {
        dblHappiness = newValue
    }
    public double dblHappiness = 0

    /**
     *
     * This is an agent property.
     * @field intRetiringAge
     *
     */
    @Parameter (displayName = "Retiring Age", usageName =
"intRetiringAge")
    public int getIntRetiringAge() {
        return intRetiringAge
    }
    public void setIntRetiringAge(int newValue) {
        intRetiringAge = newValue
    }
    public int intRetiringAge = 0

    /**
     *
     * This is an agent property.
     * @field intDeathAge
```

```
     *
     */
    @Parameter (displayName = "Death Age", usageName =
"intDeathAge")
    public int getIntDeathAge() {
        return intDeathAge
    }
    public void setIntDeathAge(int newValue) {
        intDeathAge = newValue
    }
    public int intDeathAge = 0

    /**
     *
     * This is an agent property.
     * @field dblWorkIncome
     *
     */
    @Parameter (displayName = "Work Income", usageName =
"dblWorkIncome")
    public double getDblWorkIncome() {
        return dblWorkIncome
    }
    public void setDblWorkIncome(double newValue) {
        dblWorkIncome = newValue
    }
    public double dblWorkIncome = 0

    /**
     *
     * This is an agent property.
     * @field dblRevenue
     *
     */
    @Parameter (displayName = "Revenue", usageName = "dblRevenue")
    public double getDblRevenue() {
        return dblRevenue
    }
    public void setDblRevenue(double newValue) {
        dblRevenue = newValue
    }
    public double dblRevenue = 0

    /**
     *
     * This is an agent property.
     * @field dblBankingI
     *
     */
    @Parameter (displayName = "i% Banking", usageName =
"dblBankingI")
    public double getDblBankingI() {
        return dblBankingI
    }
    public void setDblBankingI(double newValue) {
        dblBankingI = newValue
    }
    public double dblBankingI = 0

    /**
     *
     * This is an agent property.
```

```
     * @field dblInvestingI
     *
     */
    @Parameter (displayName = "i% Investing", usageName =
"dblInvestingI")
    public double getDblInvestingI() {
        return dblInvestingI
    }
    public void setDblInvestingI(double newValue) {
        dblInvestingI = newValue
    }
    public double dblInvestingI = 0

    /**
     *
     * This is an agent property.
     * @field dblMoneyLeftAvailable
     *
     */
    @Parameter (displayName = "Money Left", usageName =
"dblMoneyLeftAvailable")
    public double getDblMoneyLeftAvailable() {
        return dblMoneyLeftAvailable
    }
    public void setDblMoneyLeftAvailable(double newValue) {
        dblMoneyLeftAvailable = newValue
    }
    public double dblMoneyLeftAvailable = 0

    /**
     *
     * This is the Happy w/ I% field.
     * @field blnHappyWInterests
     *
     */
    @Parameter (displayName = "Happy w/ I%", usageName =
"blnHappyWInterests")
    public boolean getBlnHappyWInterests() {
        return blnHappyWInterests
    }
    public void setBlnHappyWInterests(boolean newValue) {
        blnHappyWInterests = newValue
    }
    public boolean blnHappyWInterests = true

    /**
     *
     * This is an agent property.
     * @field intTimePreference
     *
     */
    @Parameter (displayName = "Time Pref", usageName =
"intTimePreference")
    public int getIntTimePreference() {
        return intTimePreference
    }
    public void setIntTimePreference(int newValue) {
        intTimePreference = newValue
    }
    public int intTimePreference = 0

    /**
```

```
     *
     * This is an agent property.
     * @field dblConsumption
     *
     */
    @Parameter (displayName = "Consumption", usageName =
"dblConsumption")
    public double getDblConsumption() {
        return dblConsumption
    }
    public void setDblConsumption(double newValue) {
        dblConsumption = newValue
    }
    public double dblConsumption = 0

    /**
     *
     * This is an agent property.
     * @field dblConsumptionRatio
     *
     */
    @Parameter (displayName = "... Ratio", usageName =
"dblConsumptionRatio")
    public double getDblConsumptionRatio() {
        return dblConsumptionRatio
    }
    public void setDblConsumptionRatio(double newValue) {
        dblConsumptionRatio = newValue
    }
    public double dblConsumptionRatio = 0

    /**
     *
     * This is an agent property.
     * @field dblAvgInterestRate
     *
     */
    @Parameter (displayName = "Avg i% Rate", usageName =
"dblAvgInterestRate")
    public double getDblAvgInterestRate() {
        return dblAvgInterestRate
    }
    public void setDblAvgInterestRate(double newValue) {
        dblAvgInterestRate = newValue
    }
    public double dblAvgInterestRate = 0

    /**
     *
     * This is an agent property.
     * @field dblDebt
     *
     */
    @Parameter (displayName = "Debt", usageName = "dblDebt")
    public double getDblDebt() {
        return dblDebt
    }
    public void setDblDebt(double newValue) {
        dblDebt = newValue
    }
    public double dblDebt = 0
```

```
    /**
     *
     * This is an agent property.
     * @field blnInsolvent
     *
     */
    @Parameter (displayName = "Insolvent?", usageName =
"blnInsolvent")
    public boolean getBlnInsolvent() {
        return blnInsolvent
    }
    public void setBlnInsolvent(boolean newValue) {
        blnInsolvent = newValue
    }
    public boolean blnInsolvent = false

    /**
     *
     * This is an agent property.
     * @field blnDebugAgent
     *
     */
    @Parameter (displayName = "Debugger", usageName =
"blnDebugAgent")
    public boolean getBlnDebugAgent() {
        return blnDebugAgent
    }
    public void setBlnDebugAgent(boolean newValue) {
        blnDebugAgent = newValue
    }
    public boolean blnDebugAgent = false

    /**
     *
     * This is an agent property.
     * @field dblMyCoords
     *
     */
    @Parameter (displayName = "Coords", usageName = "dblMyCoords")
    public double[] getDblMyCoords() {
        return dblMyCoords
    }
    public void setDblMyCoords(double[] newValue) {
        dblMyCoords = newValue
    }
    public double[] dblMyCoords = new double[2]

    /**
     *
     * This is an agent property.
     * @field intInvented
     *
     */
    @Parameter (displayName = "# Inventions", usageName =
"intInvented")
    public int getIntInvented() {
        return intInvented
    }
    public void setIntInvented(int newValue) {
        intInvented = newValue
    }
    public int intInvented = 0
```

```
    /**
     *
     * This is an agent property.
     * @field intTinkerer
     *
     */
    @Parameter (displayName = "Tinkerer", usageName =
"intTinkerer")
    public int getIntTinkerer() {
        return intTinkerer
    }
    public void setIntTinkerer(int newValue) {
        intTinkerer = newValue
    }
    public int intTinkerer = 0

    /**
     *
     * This is an agent property.
     * @field intInnovated
     *
     */
    @Parameter (displayName = "# Innovations", usageName =
"intInnovated")
    public int getIntInnovated() {
        return intInnovated
    }
    public void setIntInnovated(int newValue) {
        intInnovated = newValue
    }
    public int intInnovated = 0

    /**
     *
     * This is an agent property.
     * @field dblInnoRent
     *
     */
    @Parameter (displayName = "Inno rent", usageName =
"dblInnoRent")
    public double getDblInnoRent() {
        return dblInnoRent
    }
    public void setDblInnoRent(double newValue) {
        dblInnoRent = newValue
    }
    public double dblInnoRent = 0

    /**
     *
     * This is an agent property.
     * @field intFailedInnos
     *
     */
    @Parameter (displayName = "failed innos", usageName =
"intFailedInnos")
    public int getIntFailedInnos() {
        return intFailedInnos
    }
    public void setIntFailedInnos(int newValue) {
        intFailedInnos = newValue
```

```
    }
    public int intFailedInnos = 0

    /**
     *
     * This is an agent property.
     * @field intExpensiveInvention
     *
     */
    @Parameter (displayName = "costly invent", usageName =
"intExpensiveInvention")
    public int getIntExpensiveInvention() {
        return intExpensiveInvention
    }
    public void setIntExpensiveInvention(int newValue) {
        intExpensiveInvention = newValue
    }
    public int intExpensiveInvention = 0

    /**
     *
     * This is an agent property.
     * @field intScaredInvention
     *
     */
    @Parameter (displayName = "scared", usageName =
"intScaredInvention")
    public int getIntScaredInvention() {
        return intScaredInvention
    }
    public void setIntScaredInvention(int newValue) {
        intScaredInvention = newValue
    }
    public int intScaredInvention = 0

    /**
     *
     * This is an agent property.
     * @field intNewInno
     *
     */
    @Parameter (displayName = "new Inno", usageName = "intNewInno")
    public int getIntNewInno() {
        return intNewInno
    }
    public void setIntNewInno(int newValue) {
        intNewInno = newValue
    }
    public int intNewInno = 0

    /**
     *
     * This is an agent property.
     * @field intNewInvention
     *
     */
    @Parameter (displayName = "new Invent", usageName =
"intNewInvention")
    public int getIntNewInvention() {
        return intNewInvention
    }
    public void setIntNewInvention(int newValue) {
```

```
        intNewInvention = newValue
    }
    public int intNewInvention = 0

    /**
     *
     * This is an agent property.
     * @field intNewExpensive
     *
     */
    @Parameter (displayName = "new costly", usageName =
"intNewExpensive")
    public int getIntNewExpensive() {
        return intNewExpensive
    }
    public void setIntNewExpensive(int newValue) {
        intNewExpensive = newValue
    }
    public int intNewExpensive = 0

    /**
     *
     * This is an agent property.
     * @field intNewScared
     *
     */
    @Parameter (displayName = "new scared", usageName =
"intNewScared")
    public int getIntNewScared() {
        return intNewScared
    }
    public void setIntNewScared(int newValue) {
        intNewScared = newValue
    }
    public int intNewScared = 0

    /**
     *
     * This is an agent property.
     * @field intNewFailed
     *
     */
    @Parameter (displayName = "new Failed", usageName =
"intNewFailed")
    public int getIntNewFailed() {
        return intNewFailed
    }
    public void setIntNewFailed(int newValue) {
        intNewFailed = newValue
    }
    public int intNewFailed = 0

    /**
     *
     * This is an agent property.
     * @field dblSocialContribution
     *
     */
    @Parameter (displayName = "Social Contribution", usageName =
"dblSocialContribution")
    public double getDblSocialContribution() {
        return dblSocialContribution
```

```
    }
    public void setDblSocialContribution(double newValue) {
        dblSocialContribution = newValue
    }
    public double dblSocialContribution = 0

    /**
     *
     * This is an agent property.
     * @field blnMoreWelfare
     *
     */
    @Parameter (displayName = "More Welfare", usageName =
"blnMoreWelfare")
    public boolean getBlnMoreWelfare() {
        return blnMoreWelfare
    }
    public void setBlnMoreWelfare(boolean newValue) {
        blnMoreWelfare = newValue
    }
    public boolean blnMoreWelfare = false

    /**
     *
     * This is an agent property.
     * @field blnLessWelfare
     *
     */
    @Parameter (displayName = "Less Welfare", usageName =
"blnLessWelfare")
    public boolean getBlnLessWelfare() {
        return blnLessWelfare
    }
    public void setBlnLessWelfare(boolean newValue) {
        blnLessWelfare = newValue
    }
    public boolean blnLessWelfare = false

    /**
     *
     * This is an agent property.
     * @field blnSavingsAtBank
     *
     */
    @Parameter (displayName = "Savings at bank?", usageName =
"blnSavingsAtBank")
    public boolean getBlnSavingsAtBank() {
        return blnSavingsAtBank
    }
    public void setBlnSavingsAtBank(boolean newValue) {
        blnSavingsAtBank = newValue
    }
    public boolean blnSavingsAtBank = false

    /**
     *
     * This is an agent property.
     * @field blnProvisionAtBank
     *
     */
    @Parameter (displayName = "Provision at bank?", usageName =
"blnProvisionAtBank")
```

```
    public boolean getBlnProvisionAtBank() {
        return blnProvisionAtBank
    }
    public void setBlnProvisionAtBank(boolean newValue) {
        blnProvisionAtBank = newValue
    }
    public boolean blnProvisionAtBank = true

    /**
     *
     * This is an agent property.
     * @field dblSavingI
     *
     */
    @Parameter (displayName = "i% Saving", usageName =
"dblSavingI")
    public double getDblSavingI() {
        return dblSavingI
    }
    public void setDblSavingI(double newValue) {
        dblSavingI = newValue
    }
    public double dblSavingI = 0

    /**
     *
     * This is an agent property.
     * @field dblProvisionI
     *
     */
    @Parameter (displayName = "i% Provision", usageName =
"dblProvisionI")
    public double getDblProvisionI() {
        return dblProvisionI
    }
    public void setDblProvisionI(double newValue) {
        dblProvisionI = newValue
    }
    public double dblProvisionI = 0

    /**
     *
     * This is an agent property.
     * @field intCoolFriends
     *
     */
    @Parameter (displayName = "# of friends", usageName =
"intCoolFriends")
    public int getIntCoolFriends() {
        return intCoolFriends
    }
    public void setIntCoolFriends(int newValue) {
        intCoolFriends = newValue
    }
    public int intCoolFriends = 0

    /**
     *
     * This is an agent property.
     * @field dblIncBeforeRedistribution
     *
     */
```

```
    @Parameter (displayName = "inc before redistrib", usageName =
"dblIncBeforeRedistribution")
    public double getDblIncBeforeRedistribution() {
        return dblIncBeforeRedistribution
    }
    public void setDblIncBeforeRedistribution(double newValue) {
        dblIncBeforeRedistribution = newValue
    }
    public double dblIncBeforeRedistribution = 0

    /**
     *
     * This is an agent property.
     * @field dblIncAfterRedistribution
     *
     */
    @Parameter (displayName = "inc after redistrib", usageName =
"dblIncAfterRedistribution")
    public double getDblIncAfterRedistribution() {
        return dblIncAfterRedistribution
    }
    public void setDblIncAfterRedistribution(double newValue) {
        dblIncAfterRedistribution = newValue
    }
    public double dblIncAfterRedistribution = 0

    /**
     *
     * Here are the inventions of this agent and her predecessors
     * @field intFamilyInventions
     *
     */
    @Parameter (displayName = "Family Inv", usageName =
"intFamilyInventions")
    public int getIntFamilyInventions() {
        return intFamilyInventions
    }
    public void setIntFamilyInventions(int newValue) {
        intFamilyInventions = newValue
    }
    public int intFamilyInventions = 0

    /**
     *
     * Here are the innovations of the individual and her
predecessors
     * @field intFamilyInnovations
     *
     */
    @Parameter (displayName = "Family Innos", usageName =
"intFamilyInnovations")
    public int getIntFamilyInnovations() {
        return intFamilyInnovations
    }
    public void setIntFamilyInnovations(int newValue) {
        intFamilyInnovations = newValue
    }
    public int intFamilyInnovations = 0

    /**
     *
     * This is an agent property.
```

```
     * @field intInnosAround
     *
     */
    @Parameter (displayName = "Innos Around", usageName =
"intInnosAround")
    public int getIntInnosAround() {
        return intInnosAround
    }
    public void setIntInnosAround(int newValue) {
        intInnosAround = newValue
    }
    public int intInnosAround = 0

    /**
     *
     * This value is used to automatically generate agent
identifiers.
     * @field serialVersionUID
     *
     */
    private static final long serialVersionUID = 1L

    /**
     *
     * This value is used to automatically generate agent
identifiers.
     * @field agentIDCounter
     *
     */
    protected static long agentIDCounter = 1

    /**
     *
     * This value is the agent's identifier.
     * @field agentID
     *
     */
    protected String agentID = "Human " + (agentIDCounter++)

    /**
     *
     * This is the step behavior.
     * @method liveOneYear
     *
     */
    @ScheduledMethod(
        start = 1d,
        interval = 1d,
        shuffle = true
    )
    public def liveOneYear() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        if (blnDebugAgent == true) {System.out.println("We'll start
a new year, I'm updating my variables")}
        updateVariables()
```

```
        // This is a task.
        if (blnDebugAgent == true) {System.out.println("I'll see
what revenue I can generate")}
        generateRevenue()
        // This is a task.
        if (blnDebugAgent == true) {System.out.println("I have to
look for my risk")}
        riskProvision()
        // This is a task.
        if (blnDebugAgent == true) {System.out.println("Now, I'll
save or consume!")}
        saveConsume()
        // This is a task.
        invent()
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method initializeHuman
     *
     */
    public def initializeHuman() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        def maxInitialAge = GetParameter("maxInitialAge")
        def maxEducation = GetParameter("maxEducation")
        def minDeathAge = GetParameter("minDeathAge")
        def maxDeathAge = GetParameter("maxDeathAge")
        def avgRetirementAge = GetParameter("avgRetirementAge")
        // This is a task.
        def subsistenceMinimum = GetParameter("subsistenceMinimum")
//it is no problem that we get the value here from the parameter
group, since there has not been any need yet for the state to
change it. From now on (i.e. when an agent is reborn) this value
will be read from the state.
        def lowEduIncFactor = GetParameter("lowEduIncFactor")
        def midEduIncFactor = GetParameter("midEduIncFactor")
        def highEduIncFactor = GetParameter("highEduIncFactor")
        def minWorkAge = GetParameter("minWorkAge")
        // This is a task.
        def healthParameter = 100 -
GetParameter("healthProbability")
        // This is a task.
        setIntRiskAversion(RandomHelper.nextIntFromTo(0, 10))
        setDblHappiness(RandomHelper.nextIntFromTo(0, 100))
        setIntTimePreference(RandomHelper.nextIntFromTo(0,10))
        def educationLevel = RandomHelper.nextIntFromTo(0,100)
        if (educationLevel < 30)
        { intEducation = 1}
        else
        {
          if (educationLevel < 74)
```

```
            { intEducation = 2}
            else
            { intEducation = 3}
        }
        // This is a task.
        setIntAge(RandomHelper.nextIntFromTo(0, maxInitialAge))
        if (intAge < minWorkAge) {dblSavings =
RandomHelper.nextDoubleFromTo(0, ((minWorkAge -
intAge)*subsistenceMinimum))}
        setIntDeathAge(RandomHelper.nextIntFromTo(minDeathAge,
maxDeathAge))

setIntRetiringAge(RandomHelper.nextIntFromTo(avgRetirementAge - 10,
avgRetirementAge + 10))
        if (intRetiringAge > intDeathAge) {intRetiringAge =
intDeathAge}  //this helps avoid an error in "update Variables"
        // This is a task.
        def eduIncFactor = 0.0
        if (intEducation == 1) {eduIncFactor = lowEduIncFactor}
        if (intEducation == 2) {eduIncFactor = midEduIncFactor}
        if (intEducation == 3) {eduIncFactor = highEduIncFactor}
        // This is a task.
        RandomHelper.createNormal(0, 1)
        def incomeVariable =
(double)RandomHelper.getNormal().nextDouble()
        setDblWorkIncome((int)(exp(3.35 + 0.47 * incomeVariable) *
eduIncFactor + subsistenceMinimum))
        // This is a task.
        RandomHelper.createPoisson(healthParameter)
        setDblHealth(100 - RandomHelper.getPoisson().nextInt())
        // This is a task.
        initializeNetwork()
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method generateRevenue
     *
     */
    public def generateRevenue() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        def individualModel = GetParameter("individualModel")

        // This is an agent decision.
        if (AmIWorking()) {

            // This is a task.
            setDblRevenue(dblWorkIncome * dblHealth / 100)
            if (blnDebugAgent == true) {System.out.println("I'm
working, I'll get an income of "+dblRevenue)}
```

```
        } else  {


        }
        // This is a task.
        if (blnDebugAgent == true) {System.out.println("And I get
the rent from my innovations")}
        dblRevenue += RentFromInnovations()
        // This is a task.
        InterestPayment(true)  //the true refers to the savings
account
        setDblSavingI(dblBankingI + dblInvestingI)
        dblRevenue += dblBankingI + dblInvestingI
        if (blnDebugAgent == true)
{System.out.println("Furthermore, I get interest: From my bank,
it's "+dblBankingI+" and from my fund it's "+dblInvestingI)}
        setDblBankingI(dblInvestingI = 0)
        // This is a task.
        if (individualModel) {InterestPayment(false)} //the false
refers to the risk provision account if we have the individual
model
        setDblProvisionI(dblBankingI + dblInvestingI)
        dblRevenue += dblBankingI + dblInvestingI
        if (blnDebugAgent == true)
{System.out.println("Furthermore, I get interest: From my bank,
it's "+dblBankingI+" and from my fund it's "+dblInvestingI)}
        setDblBankingI(dblInvestingI = 0)
        // This is a task.
        if ((dblSavingI <= 0.0) || (dblProvisionI <=0.0))
{blnHappyWInterests = false}
        dblRevenue -= RepayCredit()
        if (blnDebugAgent == true) {System.out.println("Ok, and I
just repaid my credit")}
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method AmIWorking
     *
     */
    public boolean AmIWorking() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        def minWorkAge = GetParameter("minWorkAge")
        def yearForEdu = GetParameter("yearForEdu")
        // This is a task.
        def intWorkAge = minWorkAge + (intEducation - 1)*yearForEdu
        if ((blnRetired == false)  && (intAge >= intRetiringAge))
        { blnRetired = true}


        // This is an agent decision.
```

```
        if ((intAge < minWorkAge) || blnRetired || !(IsEmployed()))
{

            // This is a task.
            setBlnEmployed(false)
            returnValue = false
            if (blnDebugAgent == true) {System.out.println("Either
I'm too young ("+intAge+") or I'm retired ("+blnRetired+") or I'm
just unemployed")}

        } else  {

            // This is a task.
            returnValue = true
            if (blnDebugAgent == true) {System.out.println("I'm
working!")}

        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method updateVariables
     *
     */
    public def updateVariables() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        def healthProbability = GetParameter("healthProbability")
        def individualModel = GetParameter("individualModel")
        // This is a task.
        def oldHealth = dblHealth
        dblHealth += RandomHelper.nextIntFromTo(0, 20) - 10
        setDblHealth((oldHealth + dblHealth) / 2)
        if (dblHealth > 100) {dblHealth = 100}
        if (dblHealth < 0) {dblHealth = 0}
        // This is a task.
        if (dblHealth > oldHealth) {intRiskAversion --}
        if (dblHealth < oldHealth) {intRiskAversion ++}
        if (intRiskAversion > 10) {intRiskAversion  = 10}
        if (intRiskAversion < 0) {intRiskAversion = 0}
        // This is a task.
        intAge++
        if (blnEmployed == true) {intExperience++}
        setDblRevenue(dblBankingI = dblInvestingI = 0)
        //if (RandomHelper.nextIntFromTo(0,100) < intAge)
{intTimePreference--}
        if (intTimePreference < 0) {intTimePreference = 0}
        //if (RandomHelper.nextIntFromTo(intRetiringAge-10,
intDeathAge) < intAge) {intTimePreference++}
        if (intTimePreference > 10) {intTimePreference = 10}
```

```
        //here we follow Fisher's theories of decreasing then
increasing time preference
        // This is a task.
        //intInnovated += intNewInno
        //intInvented += intNewInvention    -> this is taken care
of in the inventive process
        setIntNewInno(intNewInvention = 0)
        setIntNewExpensive(intNewScared = intNewFailed = 0)
        // This is a task.
        if (intAge > intDeathAge) {beReborn()}
        // This is a task.
        environmentalInfluence()
        if (RandomHelper.nextDoubleFromTo(0.0, 1.0) > 0.5)
{blnHappyWInterests = true} else {blnHappyWInterests = false}
        if ((dblBankingI + dblInvestingI <= 0) && (dblSavings +
dblRiskProvision >= 0)) {blnHappyWInterests = false}
        if (individualModel == false) {publicSectorInfluence()}
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method RentFromInnovations
     *
     */
    public double RentFromInnovations() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        Context context = FindContext("InnoEasy")
        ContinuousSpace space =
(ContinuousSpace)context.getProjection("Space")
        // This is a task.
        Network innovativeness =
(Network)context.getProjection("Innovator")
        Network financing =
(Network)context.getProjection("Financier")
        // This is a task.
        def rent = 0

        // This is a loop.
        for (partInnovation in (new NetPathWithin(innovativeness,
this, 1).query())) {

            // This is a task.
            def particularRent
            particularRent = partInnovation.dblRent *
partInnovation.dblWeight / 2
            rent += particularRent
            if (blnDebugAgent == true) {System.out.println("The
innovation brings me "+particularRent+".")}

        }
```

```
        // This is a loop.
        for (partFinanced in (new NetPathWithin(financing, this,
1).query())) {

            // This is an agent decision.
            if (partFinanced.blnSuccess == true) {

                // This is a task.
                def particularRentFinanced
                particularRentFinanced = partFinanced.dblRent *
partFinanced.dblWeight / 2
                rent += particularRentFinanced
                if (blnDebugAgent == true) {System.out.println("The
innovation which I financed brings me
"+particularRentFinanced+".")}

            } else  {


            }

        }

        // This is a task.
        setDblInnoRent(rent)
        if (blnDebugAgent == true) {System.out.println("Ok, so in
total I get "+rent+" EUR from my innovations.")}
        returnValue = rent
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method InterestPayment
     *
     */
    public void InterestPayment(boolean blnOnSavings) {

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        Context context = FindContext("InnoEasy")
        Network banking = (Network)context.getProjection("Banking")
        Network investing =
(Network)context.getProjection("Investing")
        Network savingNet =
(Network)context.getProjection("SavingNet")
        Network provisionNet =
(Network)context.getProjection("ProvisionNet")
        // This is a task.
        def AmountForInterest = 0.0
        def individualModel = GetParameter("individualModel")
        def additionalPoint = 0.0
        Iterator list = new NetworkSuccessor(savingNet,
this).query().iterator()
        def WhichNetwork = ""
```

```
        // This is an agent decision.
        if (blnOnSavings) {

            // This is a task.
            WhichNetwork = "InnoEasy/SavingNet"
            if (dblSavings < 0) {additionalPoint = 0.01}
            AmountForInterest = dblSavings

        } else  {

            // This is a task.
            list = new NetworkSuccessor(provisionNet,
this).query().iterator()
            WhichNetwork = "InnoEasy/ProvisionNet"
            AmountForInterest = dblRiskProvision
            //here we don't have to set the additional percentage
point in case risk provision is negative, because risk provision
can never be negative.

        }

        // This is an agent decision.
        if (list.hasNext()) {

            // This is a task.
            Object institution = list.next()

            // This is an agent decision.
            if (institution instanceof Bank) {

                // This is a task.
                setDblBankingI(AmountForInterest *
(institution.dblInterest + additionalPoint))
                //if (dblBankingI > AmountForInterest * 10)
{dblBankingI = 0}
                if (dblBankingI > 0)
{institution.dblInterestPayments += dblBankingI}
                if (dblBankingI < 0)
{institution.dblInterestReceipts -= dblBankingI}
                if (blnDebugAgent == true) {System.out.println("I
received or paid "+dblBankingI+" EUR interest from or to my bank
corresponding to an invested amount of "+AmountForInterest+".")}

            } else  {

                // This is a task.
                setDblInvestingI(AmountForInterest *
institution.dblInterest)
                //if (dblInvestingI > AmountForInterest * 10)
{dblInvestingI = 0}
                if (dblInvestingI <=0) {dblInvestingI = 0} // we
can only invest money at funds but not borrow from them
                if (dblInvestingI > 0)
{institution.dblInterestPayments += dblInvestingI}
                if (blnDebugAgent == true) {System.out.println("I
received "+dblInvestingI+" EUR interest from my fund.")}

            }

        } else  {
```

```
        }
        // End the method.
        return

    }

    /**
     *
     * This is the step behavior.
     * @method RepayCredit
     *
     */
    public double RepayCredit() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        Context context = FindContext("InnoEasy")
        ContinuousSpace space =
(ContinuousSpace)context.getProjection("Space")
        // This is a task.
        Network savingNet =
(Network)context.getProjection("SavingNet")
        // This is a task.
        def individualModel = GetParameter("individualModel")
        returnValue = 0.0

        // This is a loop.
        for (bank in (new NetworkAdjacent(savingNet,
this).query())) {


            // This is an agent decision.
            if ((dblSavings < 0) && (bank instanceof Bank)) {

                // This is a task.
                bank.dblClientsCredits = bank.dblClientsCredits +
dblSavings
                RepastEdge removedEdge =
RemoveEdge("InnoEasy/Banking", this, bank)
                RepastEdge removedEdge2 =
RemoveEdge("InnoEasy/SavingNet", this, bank)
                // This is a task.
                returnValue = -dblSavings
                if (!(individualModel)) {dblDebt = -dblSavings}
                setDblSavings(0)
                if (blnDebugAgent == true) {System.out.println("I
payed back my credit and closed my banking account")}

            } else  {

                // This is a task.
                returnValue = 0
                if (blnDebugAgent == true) {System.out.println("I
had no credit and just keep my savings account.")}

            }
```

```
        }

        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method IsEmployed
     *
     */
    public boolean IsEmployed() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        def avgUnempment = GetParameter("avgUnempment")

        // This is an agent decision.
        if (blnEmployed == true) {


            // This is an agent decision.
            if (RandomHelper.nextIntFromTo(0,100) > avgUnempment) {

                // This is a task.
                setBlnEmployed(true)
                returnValue = true
                if (blnDebugAgent == true) {System.out.println("I'm
employed!")}

            } else  {

                // This is a task.
                setBlnEmployed(false)
                returnValue = false
                if (blnDebugAgent == true) {System.out.println("I'm
unemployed")}

            }

        } else  {


            // This is an agent decision.
            if (RandomHelper.nextIntFromTo(0,100) > avgUnempment *
2) {

                // This is a task.
                setBlnEmployed(true)
                returnValue = true
                if (blnDebugAgent == true) {System.out.println("I'm
employed!")}

            } else  {
```

```
                    // This is a task.
                    setBlnEmployed(false)
                    returnValue = false
                    if (blnDebugAgent == true) {System.out.println("I'm unemployed")}

                }

            }
            // Return the results.
            return returnValue

        }

        /**
         *
         * This is the step behavior.
         * @method riskProvision
         *
         */
        public def riskProvision() {

            // Define the return value variable.
            def returnValue

            // Note the simulation time.
            def time = GetTickCountInTimeUnits()

            // This is a task.
            def individualModel = GetParameter("individualModel")

            // This is an agent decision.
            if (individualModel == true) {

                // This is a task.
                if (blnDebugAgent == true) {System.out.println("Let's go for individual risk provision")}
                individualRiskProvision()

            } else  {

                // This is a task.
                if (blnDebugAgent == true) {System.out.println("Let's go for social risk provision")}
                socialRiskProvision()

            }
            // Return the results.
            return returnValue

        }

        /**
         *
         * This is the step behavior.
         * @method individualRiskProvision
         *
         */
        public def individualRiskProvision() {

            // Define the return value variable.
```

```
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        Context context = FindContext("InnoEasy")
        Network community =
(Network)context.getProjection("Community")
        Iterator list = new NetworkAdjacent(community,
this).query().iterator()
        PublicSector state = list.next()
        def subsistenceMinimum = state.dblSubsistenceMinimum
        // This is a task.
        def avgRiskProvision = GetParameter("avgRiskProvision")
        setDblMoneyLeftAvailable(dblRevenue)
        setDblIncBeforeRedistribution(dblIncAfterRedistribution =
dblRevenue)

        // This is an agent decision.
        if (dblRevenue >= subsistenceMinimum) {


            // This is an agent decision.
            if (blnHappyWInterests) {


            } else  {

                // This is a task.
                deleteAccount(blnProvisionAtBank, false)
                //the true refers to banks and the false to the
Risk Provision account
                // This is a task.
                searchNewFinInst(takeBankOrFund(false), false)
                //the true refers to banks and the false to the
Risk Provision account
                //if (intRiskAversion <= 3)
{searchNewFinInst(false, false)}
                //the false refers to funds and the false to the
Risk Provision account

            }
            // This is a task.
            dblMoneyLeftAvailable -= subsistenceMinimum
            // This is a task.
            def Percentage = avgRiskProvision + (intRiskAversion -
intTimePreference) / 10 * 0.2
            if (Percentage < 0) {Percentage = 0}
            // This is a task.
            def AmountToSave = Percentage * dblMoneyLeftAvailable
            saveAmount(blnProvisionAtBank, false, AmountToSave)
            dblMoneyLeftAvailable -= AmountToSave
            dblRiskProvision += AmountToSave
            if (blnDebugAgent == true) {System.out.println("I had
enough money for the subsistence minimum and I put "+Percentage+" %
as savings into my account, that's "+AmountToSave+" EUR. Now I have
"+dblMoneyLeftAvailable+" EUR left over for saving and consuming."
)}

        } else  {
```

```
            // This is a task.
            def AllMoneyAvailable = dblRevenue + dblSavings + 
dblRiskProvision
            if (blnDebugAgent == true) {System.out.println("I don't 
have enough revenue to cover my subsistence minimum. The funds I 
have are "+AllMoneyAvailable)}

            // This is an agent decision.
            if (AllMoneyAvailable > subsistenceMinimum) {


                // This is an agent decision.
                if (dblSavings > subsistenceMinimum - dblRevenue) {

                    // This is a task.
                    emptyAccount(blnSavingsAtBank, true)
                    setDblSavings(dblSavings - subsistenceMinimum + 
dblRevenue)
                    saveAmount(blnSavingsAtBank, true, dblSavings)
                    setDblMoneyLeftAvailable(0)
                    if (blnDebugAgent == true) 
{System.out.println("I had enough savings and so I used those to 
cover my subsistence minimum.")}

                } else  {

                    // This is a task.
                    if (blnDebugAgent == true) 
{System.out.println("My savings of "+dblSavings+" are not enough. 
So I take from my risk Provision of "+dblRiskProvision+" the 
remaining amount of "+(subsistenceMinimum - dblSavings - 
dblRevenue)+".")}
                    // This is a task.
                    emptyAccount(blnSavingsAtBank, true)  //savings 
account at funds
                    emptyAccount(blnProvisionAtBank, false)  //risk 
provision account at banks
                    setDblRiskProvision(dblRiskProvision - 
subsistenceMinimum + dblRevenue + dblSavings)
                    saveAmount(blnProvisionAtBank, false, 
dblRiskProvision)  //if there is a remainder, we'll put it into the 
risk provision account. That means we first take the savings and 
then the needed extra from the risk provision
                    setDblMoneyLeftAvailable(dblSavings = 0)

                }

            } else  {

                // This is a task.
                def AmountNeeded = subsistenceMinimum - dblRevenue 
- dblSavings - dblRiskProvision
                emptyAccount(blnProvisionAtBank, false)  //get all 
the money she has
                emptyAccount(blnSavingsAtBank, true)  //get all the 
money she has
                if (blnDebugAgent == true) {System.out.println("Oh 
my gosh, I need "+AmountNeeded+" to cover my subsistence 
minimum.")}

                // This is an agent decision.
                if (getCredit(AmountNeeded)) {
```

```
                        // This is a task.
                        setDblMoneyLeftAvailable(dblRiskProvision = 0)
                        setDblSavings(-(AmountNeeded))
                        if (blnDebugAgent == true)
{System.out.println("Ok, cool, I received a credit!")}

                    } else  {

                        // This is a task.
                        //death()
                        if (blnDebugAgent == true)
{System.out.println("Well, I guess, I'm starviiiiiinn.....")}
                        beReborn()

                    }

                }

            }
            // Return the results.
            return returnValue

        }

        /**
         *
         * This is the step behavior.
         * @method socialRiskProvision
         *
         */
        public def socialRiskProvision(innoeasy.PublicSector
watchedAgent) {

            // Define the return value variable.
            def returnValue

            // Note the simulation time.
            def time = GetTickCountInTimeUnits()

            // This is a task.
            Context context = FindContext("InnoEasy")
            ContinuousSpace space =
(ContinuousSpace)context.getProjection("Space")
            // This is a task.
            Network community =
(Network)context.getProjection("Community")
            Iterator list = new NetworkAdjacent(community,
this).query().iterator()
            PublicSector state = list.next()
            // This is a task.
            def subsistenceMinimum = state.dblSubsistenceMinimum
            def percentSocContribution =
state.dblPercentSocContribution
            setDblMoneyLeftAvailable(dblRevenue)
            setDblIncBeforeRedistribution(dblRevenue + dblDebt)

            // This is an agent decision.
            if (dblRevenue + dblDebt >= subsistenceMinimum) {

                // This is a task.
```

```
            if (blnDebugAgent == true) {System.out.println("I have
enough funds ("+dblMoneyLeftAvailable+") to cover my own
subsistence minimum. So, I'll contribute to the social security
fund.")}
            setDblMoneyLeftAvailable(dblMoneyLeftAvailable -
subsistenceMinimum)
            def double contributionPayment
            contributionPayment = (dblMoneyLeftAvailable + dblDebt)
* percentSocContribution
            // In the second step, we have to add dblDebt to the
amount of money we have to pay taxes on because this money has been
subtracted in the GenerateRevenue-method. But the money I use to
repay my debt is certainly not tax exempt therefore we have to add
it here.
            state.dblCurrentSocialReceipts += contributionPayment
            dblMoneyLeftAvailable -= contributionPayment
            dblSocialContribution += contributionPayment
            setDblIncAfterRedistribution(dblIncBeforeRedistribution
- contributionPayment)

        } else  {

            // Here we have to subtract dblDebt from the
subsistenceMinimum as well, since this money does not really lack
in the revenue but is a consequence of extensive consumption in
previous periods. Therefore, the social system should not be used
to repay the debts of the individual.
            def double socialReceipts
            socialReceipts = subsistenceMinimum -
dblMoneyLeftAvailable - dblDebt
            state.dblCurrentSocialExpenses += socialReceipts
            if (blnDebugAgent == true) {System.out.println("I don't
have enough funds "+dblMoneyLeftAvailable+" including the debt of
"+dblDebt+" to cover my own subsistence minimum. I will need the
government to help me.")}
            dblSocialContribution -= socialReceipts
            // This is a task.
            setDblMoneyLeftAvailable(-dblDebt)
            //I don't have any money available, but I still have my
debt to cover.
            setDblIncAfterRedistribution(dblIncBeforeRedistribution
+ socialReceipts)

        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method initializeNetwork
     *
     */
    public def initializeNetwork() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()
```

```
        // This is a task.
        Context context = FindContext("InnoEasy")
        ContinuousSpace space =
(ContinuousSpace)context.getProjection("Space")
        Network savingNet =
(Network)context.getProjection("SavingNet")
        Network provisionNet =
(Network)context.getProjection("ProvisionNet")
        // This is a task.
        Network community =
(Network)context.getProjection("Community")
        Network friends = (Network)context.getProjection("Friends")
        Network banking = (Network)context.getProjection("Banking")
        Network investing =
(Network)context.getProjection("Investing")

        // This is important when an individual is reborn. It
should not know all the people his ancestor used to know
        for (friend in (new NetPathWithin(friends, this,
1).query())) {

            // This is a task.
            RemoveEdge("InnoEasy/Friends", this, friend)

        }


        // This is a loop.
        for (state in (GetObjects("InnoEasy",
"innoeasy.PublicSector"))) {


            // Make a decision.
            if (state instanceof PublicSector) {

                // This is a task.
                CreateEdge("InnoEasy/Community", this, state, 1.0)
                //IndexedIterable iter = GetObjects("root",
"anl.example.MyAgent")

            } else  {


            }

        }


        // This is important when an individual is reborn. It
should not know all the people his ancestor used to know
        for (bank in (new NetPathWithin(banking, this, 1).query()))
{

            // This is a task.
            RemoveEdge("InnoEasy/Banking", this, bank)

        }


        // This is important when an individual is reborn. It
should not know all the people his ancestor used to know
```

```
        for (fund in (new NetPathWithin(investing, this,
1).query())) {

            // This is a task.
            RemoveEdge("InnoEasy/Investing", this, fund)

        }

        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method emptyAccount
     *
     */
    public def emptyAccount(boolean atBanks, boolean fromSavings) {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        Context context = FindContext("InnoEasy")
        Network banking = (Network)context.getProjection("Banking")
        Network investing =
(Network)context.getProjection("Investing")
        Network savingNet =
(Network)context.getProjection("SavingNet")
        Network provisionNet =
(Network)context.getProjection("ProvisionNet")
        // This is a task.
        def AmountToWithdraw = 0.0
        Iterator list = new NetworkSuccessor(savingNet,
this).query().iterator()
        def WhichNetwork = ""

        // This is an agent decision.
        if (fromSavings) {

            // This is a task.
            AmountToWithdraw = dblSavings
            WhichNetwork = "InnoEasy/SavingNet"

        } else  {

            // This is a task.
            AmountToWithdraw = dblRiskProvision
            list = new NetworkSuccessor(provisionNet,
this).query().iterator()
            WhichNetwork = "InnoEasy/ProvisionNet"

        }

        // This is an agent decision.
        if (list.hasNext()) {
```

```
            // This is a task.
            Object institution = list.next()

            // This is an agent decision.
            if (institution instanceof Bank) {

                // This is a task.
                institution.dblClientsSavings -= AmountToWithdraw
                if (blnDebugAgent == true) {System.out.println("Ok,
I just emptied my bank account")}

            } else  {

                // This is a task.
                institution.dblCapitalStock -= AmountToWithdraw
                institution.dblCumClientsSavings -=
AmountToWithdraw
                if (blnDebugAgent == true)
{System.out.println("Well, I'm out of all my investments")}

            }

        } else  {


        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method searchNewFinInst
     *
     */
    public def searchNewFinInst(boolean atBanks, boolean
fromSavings) {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        def AmountToSave = 0
        def WhichNetwork = ""

        // This is an agent decision.
        if (fromSavings) {

            // This is a task.
            AmountToSave = dblSavings
            WhichNetwork = "InnoEasy/SavingNet"

        } else  {

            // This is a task.
            AmountToSave = dblRiskProvision
            WhichNetwork = "InnoEasy/ProvisionNet"
```

```
        }
        // This is a task.
        def maxInterest = 0
        def bestInstitution = ""
        def blnFound = false
        // This is a task.
        Context context = FindContext("InnoEasy")
        ContinuousSpace space =
(ContinuousSpace)context.getProjection("Space")

        // This is a loop.
        for (institution in (new ContinuousWithin(space, this,
15).query())) {

            // Make a decision.
            if (atBanks) {

                // Make a decision.
                if (institution instanceof Bank) {

                    // This is an agent decision.
                    if (institution.dblInterest >= maxInterest) {

                        // This is a task.
                        //bestInstitution = institution.name
                        maxInterest = institution.dblInterest

                    } else  {


                    }

                } else  {


                }

            } else  {

                // Make a decision.
                if (institution instanceof Fund) {

                    // This is an agent decision.
                    if (institution.dblInterest >= maxInterest) {

                        // This is a task.
                        //bestInstitution = institution.name
                        maxInterest = institution.dblInterest

                    } else  {


                    }

                } else  {
```

```
                }

            }

        }

        // This is a loop.
        for (institution in (new ContinuousWithin(space, this,
15).query())) {

            // Make a decision.
            if (atBanks) {

                // Make a decision.
                if (institution instanceof Bank) {

                    // This is an agent decision.
                    if ((institution.dblInterest == maxInterest) &&
(blnFound == false)) {

                        // This is a task.
                        RepastEdge newEdge =
CreateEdge("InnoEasy/Banking", this, institution, 1.0)
                        RepastEdge newEdge2 =
CreateEdge(WhichNetwork, this, institution, AmountToSave)
                        institution.dblClientsSavings +=
AmountToSave
                        blnFound = true
                        if (blnDebugAgent == true)
{System.out.println("Ok, so I found a new bank and will save my
money here")}

                    } else  {


                    }

                } else  {


                }

            } else  {

                // Make a decision.
                if (institution instanceof Fund) {

                    // This is an agent decision.
                    if ((institution.dblInterest == maxInterest) &&
(blnFound == false)) {

                        // This is a task.
                        RepastEdge newEdge =
CreateEdge("InnoEasy/Investing", this, institution, 1.0)
```

```
                        RepastEdge newEdge2 =
CreateEdge(WhichNetwork, this, institution, AmountToSave)
                        institution.dblCumClientsSavings +=
AmountToSave
                        institution.dblClientsSavings +=
AmountToSave
                        blnFound = true
                        // This is a task.
                        if (blnDebugAgent == true)
{System.out.println("Ok, so I found a new fund and will invest my
money here")}

                    } else {


                    }

                } else {


                }

            }

        }

        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method saveAmount
     *
     */
    public def saveAmount(boolean atBanks, boolean inSavings,
double AmountToSave) {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        Context context = FindContext("InnoEasy")
        Network banking = (Network)context.getProjection("Banking")
        Network investing =
(Network)context.getProjection("Investing")
        Network savingNet =
(Network)context.getProjection("SavingNet")
        Network provisionNet =
(Network)context.getProjection("ProvisionNet")
        // This is a task.
        Iterator list = new NetworkSuccessor(savingNet,
this).query().iterator()
        def WhichNetwork = ""
        def NewTotal = 0.0

        // This is an agent decision.
```

```
        if (inSavings) {

            // This is a task.
            NewTotal = dblSavings + AmountToSave
            WhichNetwork="InnoEasy/SavingNet"

        } else  {

            // This is a task.
            NewTotal = dblRiskProvision + AmountToSave
            list = new NetworkSuccessor(provisionNet,
this).query().iterator()
            WhichNetwork="InnoEasy/ProvisionNet"

        }

        // This is an agent decision.
        if (list.hasNext()) {

            // This is a task.
            Object institution = list.next()

            // This is an agent decision.
            if (institution instanceof Bank) {

                // This is a task.
                institution.dblClientsSavings += AmountToSave
                RepastEdge edge = SetEdgeWeight(WhichNetwork, this,
institution, NewTotal)
                if (blnDebugAgent == true) {System.out.println("I
just saved "+AmountToSave+" in my bank account.")}

            } else  {

                // This is a task.
                institution.dblClientsSavings += AmountToSave
                institution.dblCumClientsSavings += AmountToSave
                RepastEdge edge = SetEdgeWeight(WhichNetwork, this,
institution, NewTotal)
                if (blnDebugAgent == true) {System.out.println("I
just invested "+AmountToSave+" in my fund.")}

            }

        } else  {


        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method deleteAccount
     *
     */
    public def deleteAccount(boolean atBanks, boolean fromSavings)
{
```

```
        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        Context context = FindContext("InnoEasy")
        Network banking = (Network)context.getProjection("Banking")
        Network investing =
(Network)context.getProjection("Investing")
        Network savingNet =
(Network)context.getProjection("SavingNet")
        Network provisionNet =
(Network)context.getProjection("ProvisionNet")
        // This is a task.
        emptyAccount(atBanks, fromSavings)
        Iterator list = new NetworkSuccessor(savingNet,
this).query().iterator()
        def WhichNetwork = ""

        // This is an agent decision.
        if (fromSavings) {

            // This is a task.
            WhichNetwork = "InnoEasy/SavingNet"

        } else  {

            // This is a task.
            list = new NetworkSuccessor(provisionNet,
this).query().iterator()
            WhichNetwork = "InnoEasy/ProvisionNet"

        }

        // This is an agent decision.
        if (list.hasNext()) {

            // This is a task.
            Object institution = list.next()

            // This is an agent decision.
            if (institution instanceof Bank) {

                // This is a task.
                RepastEdge removedEdge = RemoveEdge(WhichNetwork,
this, institution)
                if (blnDebugAgent == true) {System.out.println("Ok,
I just deleted my savings or risk provision account")}

            } else  {

                // This is a task.
                RepastEdge removedEdge4 = RemoveEdge(WhichNetwork,
this, institution)
                if (blnDebugAgent == true) {System.out.println("I
just deleted my savings or my provision account")}

            }

            // This is an agent decision.
```

```
            if (atBanks) {

                // This is a task.
                list = new NetworkAdjacent(banking,
this).query().iterator()

                // This is an agent decision.
                if (list.hasNext()) {

                    // This is a task.
                    Bank myBank = list.next()
                    RepastEdge removedEdge2 =
RemoveEdge("InnoEasy/Banking", this, myBank)
                    if (blnDebugAgent == true)
{System.out.println("I just deleted my bank account")}

                } else  {


                }

            } else  {

                // This is a task.
                list = new NetworkAdjacent(investing,
this).query().iterator()

                // This is an agent decision.
                if (list.hasNext()) {

                    // This is a task.
                    Fund myFund = list.next()
                    RepastEdge removedEdge3 =
RemoveEdge("InnoEasy/Investing", this, myFund)
                    if (blnDebugAgent == true)
{System.out.println("I just deleted my investment account")}

                } else  {


                }

            }

        } else  {


        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method getCredit
     *
     */
    public boolean getCredit(double AmountAsked) {

        // Define the return value variable.
```

```
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        Context context = FindContext("InnoEasy")
        ContinuousSpace space =
(ContinuousSpace)context.getProjection("Space")
        // This is a task.
        Network banking = (Network)context.getProjection("Banking")
        Network savingNet =
(Network)context.getProjection("SavingNet")
        // This is a task.
        boolean hasCredit = false
        def counter = 0
        //banks in (GetObjects("InnoEasy", "innoeasy.Bank"))

        // This is a loop.
        for (banks in ( FindAgentsInContext("InnoEasy", "SELECT *
FROM innoeasy.Bank ORDER BY dblInterest ASC"))) {

            // This is a task.
            counter++
            if (blnDebugAgent == true) {System.out.println("Let's
ask the "+counter+"th bank for money. It's interest rate would be
"+banks.dblInterest+" (%).")}

            // This is an agent decision.
            if (hasCredit == false) {


                // This is an agent decision.
                if (banks instanceof Bank) {


                    // This is an agent decision.
                    if (banks.creditRequest(AmountAsked)) {

                        // This is a task.
                        hasCredit = true
                        deleteAccount(blnSavingsAtBank, true)
                        RepastEdge newEdge =
CreateEdge("InnoEasy/Banking", this, banks, 10.0)
                        RepastEdge newEdge2 =
CreateEdge("InnoEasy/SavingNet", this, banks, AmountAsked)
                        if (blnDebugAgent == true)
{System.out.println("Cool, I received my credit from the
"+counter+". bank.")}

                    } else  {


                    }

                } else  {


                }

            } else  {
```

```
            }

        }


        // This is an agent decision.
        if (hasCredit) {

            // This is a task.
            setBlnSavingsAtBank(true)
            returnValue = true

        } else  {

            // This is a task.
            returnValue = false
            if (blnDebugAgent == true) {System.out.println("Oh no,
nobody wants to lend me some money")}

        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method saveConsume
     *
     */
    public def saveConsume() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        def avgConsumptionRatio =
GetParameter("avgConsumptionRatio")
        def individualModel = GetParameter("individualModel")
        def boolDebug = GetParameter("boolDebug")

        // This is an agent decision.
        if (dblSavings - dblDebt > 0) {

            // This is a task.
            setDblConsumptionRatio(avgConsumptionRatio +
(dblSavings - dblDebt)/dblRevenue / 10)

        } else  {

            // This is a task.
            setDblConsumptionRatio(avgConsumptionRatio +
(dblSavings - dblDebt)/dblRevenue / 2)

        }
        // This is a task.
        dblConsumptionRatio += ((intTimePreference - 5) *2 / 100)
```

```
        def fundsRate = getAvgInterestRate(false) //the "false"
refers to funds instead of banks
        def banksRate = getAvgInterestRate(true) + 0.01 //the
"true" refers to banks instead of funds; 0.01 is added due to the
cost of the credit
        if (boolDebug == false) {dblConsumptionRatio -=
(((fundsRate + banksRate) / 2 - 0.03)*5)}  //0.03 is subtracted to
account for a real rate of interest of 1% and an inflation rate of
2%.
        if (boolDebug == true) {dblConsumptionRatio -= ((banksRate
- 0.03)*5)}  //0.03 is subtracted to account for a real rate of
interest of 1% and an inflation rate of 2%.
        // This is a task.
        if (blnDebugAgent == true) {System.out.println("To
calculate my consumption ratio, I take the interest offers from
funds "+fundsRate+" and from banks "+banksRate+" and the time
preference "+intTimePreference+" (as "+((intTimePreference - 5) *2
/ 100)+" into account.")}
        // This is a task.
        if (dblConsumptionRatio < 0) {dblConsumptionRatio = 0}
        if (dblConsumptionRatio > 10) {dblConsumptionRatio =
avgConsumptionRatio}
        if ((dblConsumptionRatio > 1) && (blnInsolvent == true))
{dblConsumptionRatio = 1}
        if (dblRevenue + dblSavings - dblDebt < 0)
(dblConsumptionRatio = 0)
        if (blnDebugAgent == true) {System.out.println("My savings
are "+dblSavings+" and I still have "+dblMoneyLeftAvailable+". Hey,
I'd like to consume "+(dblConsumptionRatio * 100)+"% of the amount
of money I still have.")}
        // This is a task.
        setDblConsumption(dblMoneyLeftAvailable *
dblConsumptionRatio)
        dblMoneyLeftAvailable -= dblConsumption
        if (blnDebugAgent == true) {System.out.println("I just
consumed "+dblConsumption+" and so left over money is
"+dblMoneyLeftAvailable)}

        // This is an agent decision.
        if (dblMoneyLeftAvailable >= 0) {


            // This is an agent decision.
            if (dblMoneyLeftAvailable > 0.0) {

                // This is a task.
                if (blnDebugAgent == true) {System.out.println("I'm
saving the left over money")}
                consumptionSaving(individualModel,
dblMoneyLeftAvailable)

            } else  {


            }

        } else  {


            // This is an agent decision.
            if ((dblSavings < -(dblMoneyLeftAvailable))) {
```

```
                // This is an agent decision.
                if (getCredit(-(dblMoneyLeftAvailable) -
dblSavings)) {

                    // This is a task.
                    setDblSavings(dblMoneyLeftAvailable +
dblSavings)
                    setDblDebt(0)
                    if (blnDebugAgent == true)
{System.out.println("I received my credit")}

                } else  {


                    // This is an agent decision.
                    if (dblMoneyLeftAvailable + dblSavings +
dblConsumption > 0) {

                        // This is a task.
                        setDblConsumption(dblMoneyLeftAvailable +
dblConsumption + dblSavings)
                        setDblSavings(0)
                        setDblDebt(0)
                        if (blnDebugAgent == true)
{System.out.println("Unfortunately, I didn't get a credit. So, I
reduced my consumption to "+dblConsumption+" and used up all my
savings.")}

                    } else  {

                        // This is a task.
                        setDblConsumption(0)
                        setDblSavings(0)
                        setDblDebt(0)
                        setBlnInsolvent(true)
                        if (blnDebugAgent == true)
{System.out.println("Unfortunately, I didn't get a credit. So, in
the social model, I'm not allowed to take out any more debts")}

                    }

                }

            } else  {

                // This is a task.
                if (blnDebugAgent == true) {System.out.println("I
will have to take my savings to cover my consumption wants")}
                withdrawAmount(blnSavingsAtBank, true, (-
(dblMoneyLeftAvailable)))  //the first argument is "atBanks", the
second "inSavings", the third the amount
                if (blnDebugAgent == true) {System.out.println("I
just withdrew the money out of my savings which I wanted to
consume")}
                // This is a task.
                dblSavings += dblMoneyLeftAvailable
                //we add 'moneyLeftAvailable' since it contains a
negative value
                if (blnDebugAgent == true) {System.out.println("I
take the additional money to consume from my savings accounts.")}
```

```
            }

        }
        // This is a task.
        setDblMoneyLeftAvailable(0)
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method getAvgInterestRate
     *
     */
    public double getAvgInterestRate(boolean fromBanks) {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        def numInstitutions = 0
        def cumulatedInterestRate = 0.0
        def foundNewLocation = false
        // This is a task.
        Context context = FindContext("InnoEasy")
        ContinuousSpace space =
(ContinuousSpace)context.getProjection("Space")

        // This is a loop.
        for (institution in (new ContinuousWithin(space, this,
15).query())) {


            // This is an agent decision.
            if (fromBanks) {


                // Make a decision.
                if (institution instanceof Bank) {

                    // This is a task.
                    numInstitutions ++
                    cumulatedInterestRate +=
institution.dblInterest
                    if (blnDebugAgent == true)
{System.out.println("Here's a bank with "+institution.dblInterest *
100+"% interest...count for average")}

                } else  {


                }

            } else  {


                // Make a decision.
```

```
                if (institution instanceof Fund) {

                    // This is a task.
                    numInstitutions ++
                    cumulatedInterestRate +=
institution.dblInterest
                    if (blnDebugAgent == true)
{System.out.println("Here's a fund with "+institution.dblInterest *
100+"% interest...count for average.")}

                } else  {


                }

            }

        }


        // This is an agent decision.
        if ((numInstitutions > 0) || (fromBanks == false)) {

            // This is a task.
            if (numInstitutions == 0) {dblAvgInterestRate = 0.0}
            else {dblAvgInterestRate = cumulatedInterestRate /
numInstitutions}
            //we do not want to found new funds, therefore we need
to check for a value of 0
            returnValue = dblAvgInterestRate

        } else  {

            // This is a task.
            NdPoint point = space.getLocation(this)
            double myY = point.getY()
            double myX = point.getX()
            // System.out.println("My coordinates are:
"+space.getLocation(this)+" and that should be the same as: "+myX+"
and "+myY+".")
            // This is a task.
            Bank newBank = new Bank()
            context.add(newBank)
            returnValue = 0

            // This is a loop.
            while (!foundNewLocation) {

                // This is a task.
                double bankX=myX +
RandomHelper.nextDoubleFromTo(0.0, 5.0) - 2.5
                double bankY=myY +
RandomHelper.nextDoubleFromTo(0.0, 5.0) - 2.5
                if (bankX < 0) {bankX = 0}
                if (bankY < 0) {bankY = 0}
                def maxX = GetParameter("spacewidth")
                // This is a task.
                def maxY = GetParameter("spaceheight")
                if (bankX > maxX-1) {bankX = maxX-1}  //this is not
good programming style
                if (bankY > maxY-1) {bankY = maxY-1}  //dimensions
shoulb be read from ContinuousSpace
```

```
                foundNewLocation = MoveAgent("InnoEasy/Space",
newBank, bankX, bankY)
                returnValue = 0.03

            }


        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method consumptionSaving
     *
     */
    public def consumptionSaving(boolean individualModel, double
AmountToSave) {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()


        // This is an agent decision.
        if (blnHappyWInterests) {


        } else  {

            // This is a task.
            deleteAccount(blnSavingsAtBank, true)
            //the atBanks refers to banks and the true to the
Savings account
            // This is a task.
            searchNewFinInst(takeBankOrFund(true), true)
            //the atBanks refers to banks and the true to the
Savings account

        }
        // This is a task.
        saveAmount(blnSavingsAtBank, true, AmountToSave)
        dblSavings += AmountToSave
        setDblMoneyLeftAvailable(0)
        if (blnDebugAgent == true) {System.out.println("I have been
saving money which I didn't consume")}
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method withdrawAmount
     *
     */
```

```
    public def withdrawAmount(boolean atBanks, boolean inSavings,
double AmountToWithdraw) {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        Context context = FindContext("InnoEasy")
        Network banking = (Network)context.getProjection("Banking")
        Network investing =
(Network)context.getProjection("Investing")
        Network savingNet =
(Network)context.getProjection("SavingNet")
        Network provisionNet =
(Network)context.getProjection("ProvisionNet")
        // This is a task.
        Iterator list = new NetworkSuccessor(savingNet,
this).query().iterator()
        def NewTotal = 0.0
        def WhichNetwork = ""

        // This is an agent decision.
        if (inSavings) {

            // This is a task.
            NewTotal = dblSavings - AmountToWithdraw
            WhichNetwork="InnoEasy/SavingNet"

        } else  {

            // This is a task.
            NewTotal = dblRiskProvision - AmountToWithdraw
            list = new NetworkSuccessor(provisionNet,
this).query().iterator()
            WhichNetwork="InnoEasy/ProvisionNet"

        }

        // This is an agent decision.
        if (list.hasNext()) {

            // This is a task.
            Object institution = list.next()

            // This is an agent decision.
            if (institution instanceof Bank) {

                // This is a task.
                institution.dblClientsSavings -= AmountToWithdraw
                RepastEdge edge = SetEdgeWeight(WhichNetwork, this,
institution, NewTotal)
                if (blnDebugAgent == true) {System.out.println("I
just withdrew "+AmountToWithdraw+" from my bank account.")}

            } else  {

                // This is a task.
                institution.dblCapitalStock -= AmountToWithdraw
```

```
                institution.dblCumClientsSavings -=
AmountToWithdraw
                RepastEdge edge = SetEdgeWeight(WhichNetwork, this,
institution, NewTotal)
                if (blnDebugAgent == true) {System.out.println("I
just took out "+AmountToWithdraw+" from my investment fund")}

            }

        } else  {


        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This contains the invention step, the financing step as well
as the risking step
     * @method invent
     *
     */
    public def invent() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()


        // This is an agent decision.
        if (findInvention()) {

            // This is a task.
            Invention invention = new Invention()
            invention.initialize()
            AddAgentToContext("InnoEasy", invention)
            CreateEdge("InnoEasy/Inventor", this, invention, 1.0)
            // This is a task.
            intInvented++
            intNewInvention ++
            dblHappiness += 1
            intFamilyInventions ++

            // This is an agent decision.
            if (financeInvention(invention)) {

                // This is a task.
                CreateEdge("InnoEasy/Financier", this, invention,
1.0)
                invention.blnFinanced = true

                // This is an agent decision.
                if (riskInnovation(invention)) {


                    // This is an agent decision.
```

```
                    if (RandomHelper.nextDoubleFromTo(0.0, 2.0) -
1 + intInnovated / intInvented > 0.5) {

                        // This is a task.
                        intInnovated++
                        withdrawAmount(blnSavingsAtBank, true,
invention.dblCost)
                        intNewInno++
                        intRiskAversion -= 1
                        if (intRiskAversion < 0) {intRiskAversion =
0}
                        intFamilyInnovations++
                        // This is a task.
                        dblHappiness ++
                        if (dblHappiness > 100) {dblHappiness =
100}
                        CreateEdge("InnoEasy/Innovator", this,
invention, 1.0)
                        invention.blnSuccess = true
                        if (blnDebugAgent == true)
{System.out.println("Cool, the invention was a success...I did it
all by myself!.")}
                        dblSavings -= invention.dblCost

                    } else  {

                        // This is a task.
                        intFailedInnos++
                        invention.blnFailed = true
                        intRiskAversion += 1
                        if (intRiskAversion > 10) {intRiskAversion
= 10}
                        intNewFailed ++
                        // This is a task.
                        if (blnDebugAgent == true)
{System.out.println("Oh gosh...I tried to do it as a one-man-show,
but the innovation failed. ;-(")}
                        dblHappiness -=
RandomHelper.nextIntFromTo(0,2)
                        if (dblHappiness < 0) {dblHappiness = 0}
                        withdrawAmount(blnSavingsAtBank, true,
invention.dblCost)
                        dblSavings -= invention.dblCost

                    }

                } else  {

                    // This is a task.
                    intScaredInvention++
                    intNewScared++
                    dblHappiness -= RandomHelper.nextIntFromTo(0,1)
                    if (dblHappiness < 0) {dblHappiness = 0}

                }

            } else  {

                // This is a task.
                intExpensiveInvention ++
                intNewExpensive++
                invention.blnFinanced = false
```

```
                dblHappiness -= RandomHelper.nextIntFromTo(0,1)
                if (dblHappiness < 0) {dblHappiness = 0}

            }

        } else  {

            // This is a task.
            dblHappiness -= RandomHelper.nextIntFromTo(0,2)
            dblHappiness += 1
            if (dblHappiness > 100) {dblHappiness = 100}
            if (dblHappiness < 0) {dblHappiness = 0}

        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method beReborn
     *
     */
    public def beReborn() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        def maxInitialAge = GetParameter("maxInitialAge")
        def maxEducation = GetParameter("maxEducation")
        def minDeathAge = GetParameter("minDeathAge")
        def maxDeathAge = GetParameter("maxDeathAge")
        def avgRetirementAge = GetParameter("avgRetirementAge")
        // This is a task.
        //def subsistenceMinimum =
GetParameter("subsistenceMinimum")
        if (blnDebugAgent == true) {System.out.println("Good Lord,
a miracle! I'm reborn.")}
        // This is a task.
        Context context = FindContext("InnoEasy")
        Network community =
(Network)context.getProjection("Community")
        Iterator list = new NetworkAdjacent(community,
this).query().iterator()
        PublicSector state = list.next()
        def subsistenceMinimum = state.dblSubsistenceMinimum
        // This is a task.
        setIntRiskAversion(intRiskAversion +
RandomHelper.nextIntFromTo(0, 2) - 1)
        if (intRiskAversion > 10) {intRiskAversion = 10}
        if (intRiskAversion < 0) {intRiskAversion = 0}
        setDblHappiness(dblHappiness +
RandomHelper.nextIntFromTo(0, 20))
        if (dblHappiness > 100) {dblHappiness = 100}
        setIntEducation(intEducation +
RandomHelper.nextIntFromTo(0, 2) - 1)
```

```
        if (intEducation > maxEducation) {intEducation =
maxEducation}
        if (intEducation < 1) {intEducation = 1}
        setIntTimePreference(intTimePreference +
RandomHelper.nextIntFromTo(0,2) - 1)
        setIntExperience(0)
        // This is a task.
        setIntAge(0)
        intDeathAge += RandomHelper.nextIntFromTo(0,20) - 10
        if (intDeathAge > 100) {intDeathAge = 100}
        if (intDeathAge < 60) {intDeathAge = 60}
        intRetiringAge += RandomHelper.nextIntFromTo(0, 10) - 5
        if (intRetiringAge > avgRetirementAge + 15) {intRetiringAge
= avgRetirementAge + 15}
        if (intRetiringAge < avgRetirementAge - 15) {intRetiringAge
= avgRetirementAge - 15}
        intTinkerer += RandomHelper.nextIntFromTo(0, 2) - 1
        if (intTinkerer > 1) {intTinkerer = 1}
        if (intTinkerer < 0) {intTinkerer = 0}
        if (intRetiringAge > intDeathAge) {intRetiringAge =
intDeathAge}  //this helps avoid an error in "update Variables"
        // This is a task.
        def adjustmentFactor = RandomHelper.nextDoubleFromTo(0.0,
1.0) + 0.5
        setDblWorkIncome(dblWorkIncome * adjustmentFactor)
        if (dblWorkIncome < subsistenceMinimum) {dblWorkIncome =
subsistenceMinimum}
        // This is a task.
        setIntExpensiveInvention(intScaredInvention =
intFailedInnos = 0)
        setIntInvented(intInnovated = 0)
        setBlnRetired(false)
        // This is a task.
        inheritSavings()
        // This is a task.
        ContinuousSpace space =
(ContinuousSpace)context.getProjection("Space")
        Network inventiveness =
(Network)context.getProjection("Inventor")
        Network innovativeness =
(Network)context.getProjection("Innovator")
        Network financier =
(Network)context.getProjection("Financier")
        // This is a task.
        def counterInvent = 0
        def counterInno = 0
        def counterFinancedInno = 0

        // This is a loop.
        for (partInvention in (new NetPathWithin(inventiveness,
this, 1).query())) {

            // This is a task.
            partInvention.blnDeadInventor = true
            counterInvent ++
            RemoveEdge("InnoEasy/Inventor", this, partInvention)
            if (blnDebugAgent == true) {System.out.println("That's
too bad. I'm losing the "+counterInvent+"th invention of my
forefather.")}

        }
```

```
        // This is a loop.
        for (partInno in (new NetPathWithin(innovativeness, this,
1).query())) {

            // This is a task.
            counterInno ++
            RemoveEdge("InnoEasy/Innovator", this, partInno)
            if (blnDebugAgent == true) {System.out.println("That's
too bad. I'm losing the "+counterInno+"th innovation of my
forefather.")}

        }


        // This is a loop.
        for (partInno in (new NetPathWithin(financier, this,
1).query())) {

            // This is a task.
            counterFinancedInno ++
            RemoveEdge("InnoEasy/Financier", this, partInno)

        }

        // This is a task.
        initializeNetwork()
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method findInvention
     *
     */
    public boolean findInvention() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        def individualModel = GetParameter("individualModel")
        def influenceMeritGoods = 0
        if (!(individualModel)) {influenceMeritGoods =
GetParameter("influenceMeritGoods")}
        // the idea is that the public system also offers better
general conditions (i.e. job market effects or infrastructural
effects). Therefore, there is a better environment for innovation
in the public system
        // This is a task.
        def inventionPropensity = influenceMeritGoods
        inventionPropensity += (intEducation + intTinkerer)*10 +
intExperience
        inventionPropensity += intInvented
        inventionPropensity += dblHappiness / 20
        inventionPropensity += intCoolFriends
```

```
        // This is a task.
        def riskInfluence = 1.0
        riskInfluence = 0.4 * intRiskAversion - (intRiskAversion * 
intRiskAversion / 25) + 1
        //this way, the risk aversion has the highest effect on 
invention propensity when it is in a medium sector. The more extrem 
an agent feels about risk, the less likely she will invent
        inventionPropensity = inventionPropensity * riskInfluence
        if (blnDebugAgent == true) {System.out.println("My risk 
aversion is "+intRiskAversion+" and accordingly, the risk Influence 
is "+riskInfluence+".")}

        // This is an agent decision.
        if (RandomHelper.nextDoubleFromTo(0, inventionPropensity) > 
GetParameter("inventionThreshold")) {

            // This is a task.
            returnValue = true
            if (blnDebugAgent == true) {System.out.println("I 
invented something. My invention propensity was 
"+inventionPropensity+".")}

        } else  {

            // This is a task.
            returnValue = false
            if (blnDebugAgent == true) {System.out.println("I 
didn't invent anything. My invention propensity was 
"+inventionPropensity+".")}
            //System.out.println("I didn't invent anything. My 
invention propensity was "+inventionPropensity+".")

        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method financeInvention
     *
     */
    public boolean financeInvention(Invention invention) {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        def financePropensity=0
        financePropensity = dblSavings - invention.dblCost

        // This is an agent decision.
        if (financePropensity > 0) {

            // This is a task.
            returnValue = true
```

```
            if (blnDebugAgent == true) {System.out.println("I
financed the invention. My finance propensity was
"+financePropensity+".")}

        } else  {

            // This is a task.
            returnValue = false
            if (blnDebugAgent == true) {System.out.println("I
couldn't finance the invention. My finance propensity was
"+financePropensity+".")}
            //System.out.println("I couldn't finance the invention.
My finance propensity was "+financePropensity+".")

        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method riskInnovation
     *
     */
    public boolean riskInnovation(Invention invention) {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        def riskPropensity = 0.0
        riskPropensity = (10 -
RandomHelper.nextDoubleFromTo(intRiskAversion-2,
intRiskAversion+2))
        riskPropensity += intInnovated
        riskPropensity += (intInnosAround / 2)
        // This is a task.
        def individualModel = GetParameter("individualModel")
        def intIndividualModel = 0
        def influenceIndividualModel = 0
        if (individualModel) {intIndividualModel = 1}  //this
allows us to add or subtract the influence of the individual model
on the innovation propensity of the agent
        // This is a task. If the risk aversion is high, then the
public model rather makes the agent risk the innovation. If she's
rather risk seeking then she will more likely risk it in the
individual model
        if (intRiskAversion > 5) {influenceIndividualModel = 1 -
intIndividualModel}
        if (intRiskAversion < 5) {influenceIndividualModel =
intIndividualModel}
        riskPropensity += influenceIndividualModel

        // This is an agent decision.
        if (riskPropensity > 5) {

            // This is a task.
```

```
            returnValue = true
            if (blnDebugAgent == true) {System.out.println("I dared
implementing the invention. My risk propensity was
"+riskPropensity+".")}

        } else  {

            // This is a task.
            returnValue = false
            if (blnDebugAgent == true) {System.out.println("I
didn't risk implementing the invention. My risk propensity was
"+riskPropensity+".")}
            //System.out.println("I didn't risk implementing the
invention. My risk propensity was "+riskPropensity+".")

        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method inheritSavings
     *
     */
    public def inheritSavings() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        Context context = FindContext("InnoEasy")
        Network community =
(Network)context.getProjection("Community")
        Iterator list = new NetworkAdjacent(community,
this).query().iterator()
        PublicSector state = list.next()
        // This is a task.
        deleteAccount(blnSavingsAtBank, true)  //here we delete the
savings account
        deleteAccount(blnProvisionAtBank, false) //here we delete
the risk provision account

        // This is an agent decision.
        if (dblSavings + dblRiskProvision > 0) {

            // This is a task.
            setDblSavings((dblSavings + dblRiskProvision) / 2)
            state.dblInheritance += dblSavings
            setDblRiskProvision(0)

        } else  {

            // This is a task.
            state.dblInheritance = state.dblInheritance +
dblSavings + dblRiskProvision
            setDblSavings(0)
```

```
            setDblRiskProvision(0)

        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method isFriendCool
     *
     */
    public boolean isFriendCool(Human friend) {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        def counter = 0

        // This is an agent decision.
        if ((friend.intAge - intAge >= -5) && (friend.intAge -
intAge <= 5)) {

            // This is a task.
            counter ++

        } else  {


        }

        // This is an agent decision.
        if (friend.intEducation == intEducation) {

            // This is a task.
            counter ++

        } else  {


        }

        // This is an agent decision.
        if ((friend.dblHappiness - dblHappiness >= -5) &&
(friend.dblHappiness - dblHappiness <= 5)) {

            // This is a task.
            counter ++

        } else  {


        }

        // This is an agent decision.
        if (friend.intInnovated - intInnovated >= 0) {
```

```
            // This is a task.
            counter ++

        } else  {


        }

        // This is an agent decision.
        if ((friend.dblSavings + friend.dblRiskProvision -
dblSavings - dblRiskProvision >= -20) && (friend.dblSavings +
friend.dblRiskProvision - dblSavings - dblRiskProvision <= 20)) {

            // This is a task.
            counter ++

        } else  {


        }

        // This is an agent decision.
        if (counter > 3) {

            // This is a task.
            RepastEdge edge = SetEdgeWeight("InnoEasy/Friends",
this, friend, 2.5)
            returnValue = true

        } else  {

            // This is a task.
            RepastEdge edge = SetEdgeWeight("InnoEasy/Friends",
this, friend, 1.0)
            returnValue = false

        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method isInterestingFund
     *
     */
    public boolean isInterestingFund(Fund institution) {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        def counter = 0
        def ownCapitalStock = 0
        def ownInnoRent = 0
        // This is a task.
```

```
        Context context = FindContext("InnoEasy")
        ContinuousSpace space =
(ContinuousSpace)context.getProjection("Space")
        // This is a task.
        Network investing =
(Network)context.getProjection("Investing")
        Iterator list = new NetworkAdjacent(investing,
this).query().iterator()

        // This is an agent decision.
        if (list.hasNext()) {

            // This is a task.
            Fund myFund = list.next()
            ownCapitalStock = myFund.dblCapitalStock
            ownInnoRent = myFund.dblInnoRent
            if (blnDebugAgent == true) {System.out.println("My fund
has a capital stock of "+ownCapitalStock+" and an inno rent of
"+ownInnoRent+".")}

        } else  {


        }

        // This is an agent decision.
        if (institution.dblCapitalStock > ownCapitalStock) {

            // This is a task.
            counter ++

        } else  {


        }

        // This is an agent decision.
        if (institution.dblInnoRent > ownInnoRent) {

            // This is a task.
            counter ++

        } else  {


        }

        // This is an agent decision.
        if (counter >=2) {

            // This is a task.
            returnValue = true
            if (blnDebugAgent == true) {System.out.println("There
is a more interesting fund with a capital stock
of"+institution.dblCapitalStock+" and an inno rent of
"+institution.dblInnoRent+".")}

        } else  {

            // This is a task.
            returnValue = false
```

```
            if (blnDebugAgent == true) {System.out.println("This
fund is less interesting with a capital stock
of"+institution.dblCapitalStock+" and an inno rent of
"+institution.dblInnoRent+".")}

        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method environmentalInfluence
     *
     */
    public def environmentalInfluence() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        Context context = FindContext("InnoEasy")
        ContinuousSpace space =
(ContinuousSpace)context.getProjection("Space")
        Network friends = (Network)context.getProjection("Friends")
        Network inventiveness =
(Network)context.getProjection("Inventor")
        setIntInnosAround(0)
        // This is a task.
        if (blnDebugAgent == true) {System.out.println("My friends
do have an effect on me. But to start with, I have a risk aversion
of "+intRiskAversion+", a time preference of "+intTimePreference+"
and my happiness is "+dblHappiness+".")}
        // This is a task.
        def counter = 0
        def tempRiskAversion = 0
        def tempTimePreference = 0
        def tempHappiness = 0
        def tempAvgInterest = 0
        // This is a task.
        def tempXCoords = 0
        def tempYCoords = 0
        def counterCoords = 0
        def counterFinancedInventions = 0
        def counterUnfinancedInventions = 0

        // This is a loop.
        for (friend in (new AndQuery(new ContinuousWithin(space,
this, 10), new NotQuery(context, new NetPathWithin(friends, this,
1))).query())) {


            // Make a decision.
            if (friend instanceof Human) {

                // This is a task.
                CreateEdge("InnoEasy/Friends", this, friend, 1.0)
```

```
                if (blnDebugAgent == true) {System.out.println("I
have a new friend.")}

            } else  {


            }

        }


        // This is a loop.
        for (friend in (new AndQuery(new NotQuery(context, new
ContinuousWithin(space, this, 25)), new NetPathWithin(friends,
this, 1)).query())) {

            // This is a task.
            RemoveEdge("InnoEasy/Friends", this, friend)
            if (blnDebugAgent == true) {System.out.println("I lost
touch with a friend.")}

        }


        // This is a loop.
        for (friend in (new NetPathWithin(friends, this,
1).query())) {

            // This is a task.
            tempRiskAversion += friend.intRiskAversion
            tempTimePreference += friend.intTimePreference
            tempHappiness += friend.dblHappiness
            counter++
            intInnosAround += friend.intNewInno
            // This is a task.
            if (blnDebugAgent == true) {System.out.println("This
friend has a risk aversion of "+friend.intRiskAversion+", a time
preference of "+friend.intTimePreference+" and interests of
"+friend.dblBankingI+" and "+friend.dblInvestingI+".")}

            // This is an agent decision.
            if (isFriendCool(friend)) {

                // This is a task.
                NdPoint point = space.getLocation(friend)
                tempYCoords += point.getY()
                tempXCoords += point.getX()
                if (blnDebugAgent == true)
{System.out.println("This friend is cool, I'll try to move
closer.")}
                counterCoords ++
                // This is a task.
                tempRiskAversion += friend.intRiskAversion
                tempTimePreference += friend.intTimePreference
                tempHappiness += friend.dblHappiness
                counter++
                if (blnDebugAgent == true)
{System.out.println("This friend is cool, so her influence counts
double.")}

            } else  {
```

```
            }

        }


        // This is a loop.
        for (invention in (new NetPathWithin(inventiveness, this,
1).query())) {


            // This is an agent decision.
            if (invention.dblWeight > 0.25) {

                // This is a task.
                if (invention.blnFinanced == false)
{counterUnfinancedInventions ++}
                if (invention.blnFinanced == true)
{counterFinancedInventions ++}
                if (blnDebugAgent == true)
{System.out.println("Checked financing. Result:
"+invention.blnFinanced+".")}
                //The agent does not care, if he financed the
invention himself. We suppose that she just wants to see her
inventions financed and once she grows unhappy w/ the possibilities
she considers moving closer to the next fund

            } else  {


            }

        }


        // This is an agent decision.
        if ((counterUnfinancedInventions + 1) /
(counterFinancedInventions + 1) >= 1.5) {


            // This is a loop.
            for (institution in (new ContinuousWithin(space, this,
30).query())) {


                // Make a decision.
                if ((institution instanceof Fund) &&
(isInterestingFund(institution))) {

                    // This is a task.
                    NdPoint point = space.getLocation(institution)
                    tempYCoords += point.getY()
                    tempXCoords += point.getX()
                    if (blnDebugAgent == true)
{System.out.println("I found a fund and will move closer.")}
                    counterCoords ++

                } else  {


                }
```

```
            }

        } else  {

        }

        // This is an agent decision.
        if (counter > 0) {

            // This is a task.
            tempRiskAversion = tempRiskAversion / counter
            setIntRiskAversion((int)Math.round((intRiskAversion * 3
+ tempRiskAversion) / 4))
            if (intRiskAversion > 10) {intRiskAversion = 10}
            if (intRiskAversion < 0) {intRiskAversion = 0}
            // This is a task.
            tempTimePreference = tempTimePreference / counter
            setIntTimePreference((int)Math.round((intTimePreference
* 3 + tempTimePreference) / 4))
            if (intTimePreference > 10) {intTimePreference = 10}
            if (intTimePreference < 0) {intTimePreference = 0}
            // This is a task.
            tempHappiness = tempHappiness / counter
            setDblHappiness((int)Math.round((dblHappiness * 3 +
tempHappiness) / 4))
            if (blnDebugAgent == true) {System.out.println("My
friends did have an effect on me. Now I have a risk aversion of
"+intRiskAversion+", a time preference of "+intTimePreference+" and
my happiness is "+dblHappiness+".")}

            // This is an agent decision.
            if (counterCoords > 0) {

                // This is a task.
                NdPoint point = space.getLocation(this)
                def myY = point.getY()
                def myX = point.getX()
                // System.out.println("My coordinates are:
"+space.getLocation(this)+" and that should be the same as: "+myX+"
and "+myY+".")
                // This is a task.
                double newX=(myX * 9 + tempXCoords / counterCoords)
/ 10

                double newY=(myY * 9 + tempYCoords / counterCoords)
/ 10

                MoveAgent("InnoEasy/Space", this, newX, newY)
                // This is a task.
                setIntCoolFriends(counterCoords)

            } else  {

            }

        } else  {

            // This is a task.
            if (blnDebugAgent == true) {System.out.println("I have
no ("+counter+") friends and so they don't have any effect on
me.")}
```

```
        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method publicSectorInfluence
     *
     */
    public def publicSectorInfluence() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        def counter = 0
        def ownCapitalStock = 0
        def ownInnoRent = 0
        // This is a task.
        Context context = FindContext("InnoEasy")
        Network community =
(Network)context.getProjection("Community")
        Iterator list = new NetworkAdjacent(community,
this).query().iterator()
        PublicSector state = list.next()
        def subsistenceMinimum = state.dblSubsistenceMinimum

        // This is an agent decision.
        if (dblSocialContribution > intRiskAversion /
subsistenceMinimum * 8) {

            // This is a task.
            setBlnLessWelfare(true)
            if (blnDebugAgent == true) {System.out.println("My
social contribution was "+dblSocialContribution+" and my risk
aversion of  "+intRiskAversion+" as well as the subsistence minimum
of "+subsistenceMinimum+" make me think that the latter is too
high.")}

        } else  {

            // This is a task.
            setBlnLessWelfare(false)
            if (blnDebugAgent == true) {System.out.println("My
social contribution was "+dblSocialContribution+" and my risk
aversion of  "+intRiskAversion+" as well as the subsistence minimum
of "+subsistenceMinimum+" make me think that the latter is not too
high.")}

        }

        // This is an agent decision.
        if (dblSocialContribution < intRiskAversion /
subsistenceMinimum * 2) {
```

```
            // This is a task.
            setBlnMoreWelfare(true)
            if (blnDebugAgent == true) {System.out.println("My
social contribution was "+dblSocialContribution+" and my risk
aversion of  "+intRiskAversion+" as well as the subsistence minimum
of "+subsistenceMinimum+" make me think that the latter is too
low.")}

        } else  {

            // This is a task.
            setBlnMoreWelfare(false)
            if (blnDebugAgent == true) {System.out.println("My
social contribution was "+dblSocialContribution+" and my risk
aversion of  "+intRiskAversion+" as well as the subsistence minimum
of "+subsistenceMinimum+" make me think that the latter is not too
low.")}

        }
        // This is a task.
        setDblSocialContribution(0)
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method takeBankOrFund
     *
     */
    public boolean takeBankOrFund(boolean ForSavings) {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        def InterestGap = (getAvgInterestRate(false) -
getAvgInterestRate(true)) * 100
        if (blnDebugAgent == true) {System.out.println("The
interest gap between funds and banks I can see is
"+InterestGap+"%.")}
        def SavingsCoefficient = (intRiskAversion-5) *
intRiskAversion
        def ProvisionCoefficient = (intRiskAversion-2) *
intRiskAversion

        // This is an agent decision.
        if (ForSavings) {


            // This is an agent decision.
            if (InterestGap > SavingsCoefficient) {

                // This is a task.
                if (blnSavingsAtBank == true)
{deleteAccount(blnSavingsAtBank, ForSavings)}
                setBlnSavingsAtBank(false)
```

```
                    if (blnDebugAgent == true) {System.out.println("I 
will invest my savings at a fund because the interest gap 
("+InterestGap+") is greater than my risk aversion coefficient: 
"+SavingsCoefficient+".")}
                    returnValue = false

                } else  {

                    // This is a task.
                    if (blnSavingsAtBank == false) 
{deleteAccount(blnSavingsAtBank, ForSavings)}
                    setBlnSavingsAtBank(true)
                    if (blnDebugAgent == true) {System.out.println("I 
will invest my savings at a bank because the interest gap 
("+InterestGap+") is smaller than my risk aversion coefficient: 
"+SavingsCoefficient+".")}
                    returnValue = true

                }

            } else  {


                // This is an agent decision.
                if (InterestGap > ProvisionCoefficient) {

                    // This is a task.
                    if (blnProvisionAtBank == true) 
{deleteAccount(blnProvisionAtBank, ForSavings)}
                    setBlnProvisionAtBank(false)
                    if (blnDebugAgent == true) {System.out.println("I 
will invest my risk provision at a fund because the interest gap 
("+InterestGap+") is greater than my risk aversion coefficient: 
"+ProvisionCoefficient+".")}
                    returnValue = false

                } else  {

                    // This is a task.
                    if (blnProvisionAtBank == true) 
{deleteAccount(blnProvisionAtBank, ForSavings)}
                    setBlnProvisionAtBank(true)
                    if (blnDebugAgent == true) {System.out.println("I 
will invest my risk provision at a bank because the interest gap 
("+InterestGap+") is smaller than my risk aversion coefficient: 
"+ProvisionCoefficient+".")}
                    returnValue = true

                }

            }
            // Return the results.
            return returnValue

        }

        /**
         *
         * This method provides a human-readable name for the agent.
         * @method toString
         *
         */
```

```
    @ProbeID()
    public String toString() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // Set the default agent identifier.
        returnValue = this.agentID
        // Return the results.
        return returnValue

    }


}
```

4) File PublicSector.groovy

```
/**
 *
 * This file was automatically generated by the Repast Simphony
Agent Editor.
 * Please see http://repast.sourceforge.net/ for details.
 *
 */

/**
 *
 * Set the package name.
 *
 */
package innoeasy

/**
 *
 * Import the needed packages.
 *
 */
import java.io.*
import java.math.*
import java.util.*
import javax.measure.unit.*
import org.jscience.mathematics.number.*
import org.jscience.mathematics.vector.*
import org.jscience.physics.amount.*
import repast.simphony.adaptation.neural.*
import repast.simphony.adaptation.regression.*
import repast.simphony.context.*
import repast.simphony.context.space.continuous.*
import repast.simphony.context.space.gis.*
import repast.simphony.context.space.graph.*
import repast.simphony.context.space.grid.*
import repast.simphony.engine.environment.*
import repast.simphony.engine.schedule.*
import repast.simphony.engine.watcher.*
import repast.simphony.groovy.math.*
import repast.simphony.integration.*
import repast.simphony.matlab.link.*
import repast.simphony.query.*
import repast.simphony.query.space.continuous.*
import repast.simphony.query.space.gis.*
import repast.simphony.query.space.graph.*
import repast.simphony.query.space.grid.*
import repast.simphony.query.space.projection.*
import repast.simphony.parameter.*
import repast.simphony.random.*
import repast.simphony.space.continuous.*
import repast.simphony.space.gis.*
import repast.simphony.space.graph.*
import repast.simphony.space.grid.*
import repast.simphony.space.projection.*
import repast.simphony.ui.probe.*
import repast.simphony.util.*
import simphony.util.messages.*
import static java.lang.Math.*
import static repast.simphony.essentials.RepastEssentials.*
```

```
/**
 *
 * This is an agent.
 *
 */
public class PublicSector  {

    /**
     *
     * This is an agent property.
     * @field dblPercentSocContribution
     *
     */
    @Parameter (displayName = "% Soc Contrib", usageName =
"dblPercentSocContribution")
    public double getDblPercentSocContribution() {
        return dblPercentSocContribution
    }
    public void setDblPercentSocContribution(double newValue) {
        dblPercentSocContribution = newValue
    }
    public double dblPercentSocContribution = 0.2

    /**
     *
     * This is an agent property.
     * @field dblSocialReceipts
     *
     */
    @Parameter (displayName = "Soc. Receipts", usageName =
"dblSocialReceipts")
    public double getDblSocialReceipts() {
        return dblSocialReceipts
    }
    public void setDblSocialReceipts(double newValue) {
        dblSocialReceipts = newValue
    }
    public double dblSocialReceipts = 0

    /**
     *
     * This is an agent property.
     * @field dblSocialExpenses
     *
     */
    @Parameter (displayName = "Soc. Expenses", usageName =
"dblSocialExpenses")
    public double getDblSocialExpenses() {
        return dblSocialExpenses
    }
    public void setDblSocialExpenses(double newValue) {
        dblSocialExpenses = newValue
    }
    public double dblSocialExpenses = 0

    /**
     *
     * This is an agent property.
     * @field dblCurrentSocialReceipts
     *
     */
```

```
    @Parameter (displayName = "Curr. Soc. Receipts", usageName =
"dblCurrentSocialReceipts")
    public double getDblCurrentSocialReceipts() {
        return dblCurrentSocialReceipts
    }
    public void setDblCurrentSocialReceipts(double newValue) {
        dblCurrentSocialReceipts = newValue
    }
    public double dblCurrentSocialReceipts = 0

    /**
     *
     * This is an agent property.
     * @field dblCurrentSocialExpenses
     *
     */
    @Parameter (displayName = "Curr. Soc. Expenses", usageName =
"dblCurrentSocialExpenses")
    public double getDblCurrentSocialExpenses() {
        return dblCurrentSocialExpenses
    }
    public void setDblCurrentSocialExpenses(double newValue) {
        dblCurrentSocialExpenses = newValue
    }
    public double dblCurrentSocialExpenses = 0

    /**
     *
     * This is an agent property.
     * @field intBadYear
     *
     */
    @Parameter (displayName = "Bad Year", usageName = "intBadYear")
    public int getIntBadYear() {
        return intBadYear
    }
    public void setIntBadYear(int newValue) {
        intBadYear = newValue
    }
    public int intBadYear = 0

    /**
     *
     * This is an agent property.
     * @field intExcessiveYear
     *
     */
    @Parameter (displayName = "Exc. Year", usageName =
"intExcessiveYear")
    public int getIntExcessiveYear() {
        return intExcessiveYear
    }
    public void setIntExcessiveYear(int newValue) {
        intExcessiveYear = newValue
    }
    public int intExcessiveYear = 0

    /**
     *
     * This is an agent property.
     * @field intGoodYear
     *
```

```
     */
    @Parameter (displayName = "Good Year", usageName =
"intGoodYear")
    public int getIntGoodYear() {
        return intGoodYear
    }
    public void setIntGoodYear(int newValue) {
        intGoodYear = newValue
    }
    public int intGoodYear = 0

    /**
     *
     * This is an agent property.
     * @field dblInheritance
     *
     */
    @Parameter (displayName = "Inheritance", usageName =
"dblInheritance")
    public double getDblInheritance() {
        return dblInheritance
    }
    public void setDblInheritance(double newValue) {
        dblInheritance = newValue
    }
    public double dblInheritance = 0

    /**
     *
     * This is an agent property.
     * @field dblSubsistenceMinimum
     *
     */
    @Parameter (displayName = "Subsistence Minimum", usageName =
"dblSubsistenceMinimum")
    public double getDblSubsistenceMinimum() {
        return dblSubsistenceMinimum
    }
    public void setDblSubsistenceMinimum(double newValue) {
        dblSubsistenceMinimum = newValue
    }
    public double dblSubsistenceMinimum = 0

    /**
     *
     * This is an agent property.
     * @field blnDebugAgent
     *
     */
    @Parameter (displayName = "Debugger", usageName =
"blnDebugAgent")
    public boolean getBlnDebugAgent() {
        return blnDebugAgent
    }
    public void setBlnDebugAgent(boolean newValue) {
        blnDebugAgent = newValue
    }
    public boolean blnDebugAgent = false

    /**
     *
     * This is an agent property.
```

```
     * @field intCountPeriods
     *
     */
    @Parameter (displayName = "Count Periods", usageName =
"intCountPeriods")
    public int getIntCountPeriods() {
        return intCountPeriods
    }
    public void setIntCountPeriods(int newValue) {
        intCountPeriods = newValue
    }
    public int intCountPeriods = 0

    /**
     *
     * This value is used to automatically generate agent
identifiers.
     * @field serialVersionUID
     *
     */
    private static final long serialVersionUID = 1L

    /**
     *
     * This value is used to automatically generate agent
identifiers.
     * @field agentIDCounter
     *
     */
    protected static long agentIDCounter = 1

    /**
     *
     * This value is the agent's identifier.
     * @field agentID
     *
     */
    protected String agentID = "PublicSector " + (agentIDCounter++)

    /**
     *
     * This is the step behavior.
     * @method initialize
     *
     */
    public def initialize() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.

setDblSubsistenceMinimum(GetParameter("subsistenceMinimum"))
        if (blnDebugAgent == true) {System.out.println("State: I
have found the subsistence mimimum to be :
"+dblSubsistenceMinimum+".")}

setDblPercentSocContribution(GetParameter("avgRiskProvision"))
        // Return the results.
```

```
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method calculateContribution
     *
     */
    @ScheduledMethod(
        start = 1d,
        interval = 1d,
        shuffle = true
    )
    public def calculateContribution() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        def individualModel = GetParameter("individualModel")

        // This is an agent decision.
        if ((individualModel) || ((dblCurrentSocialReceipts == 0)
&& (dblCurrentSocialExpenses == 0))) {


        } else  {


            // This is an agent decision.
            if (dblCurrentSocialReceipts >=
dblCurrentSocialExpenses) {


                // This is an agent decision.
                if (dblCurrentSocialReceipts > 2 *
dblCurrentSocialExpenses) {

                    // This is a task.
                    intGoodYear ++
                    setIntBadYear(0)
                    intExcessiveYear ++
                    if (blnDebugAgent == true)
{System.out.println("State: The receipts of
"+dblCurrentSocialReceipts+" are much higher than the expenses of
"+dblCurrentSocialExpenses+", so we record the
"+intExcessiveYear+"th excessive year and the "+intGoodYear+"th
good year in a row.")}

                } else  {

                    // This is a task.
                    intGoodYear ++
                    setIntBadYear(0)
                    setIntExcessiveYear(0)
                    if (blnDebugAgent == true)
{System.out.println("State: The receipts of
```

```
"+dblCurrentSocialReceipts+" are higher than the expenses of
"+dblCurrentSocialExpenses+", so we record the "+intGoodYear+"th
good year in a row.")}

                }

            } else  {

                // This is a task.
                intBadYear ++
                setIntGoodYear(0)
                setIntExcessiveYear(0)
                if (blnDebugAgent == true)
{System.out.println("State: The receipts of
"+dblCurrentSocialReceipts+" are smaller than the expenses of
"+dblCurrentSocialExpenses+", so we record the "+intBadYear+"th bad
year in a row.")}

            }
            // This is a task.
            dblSocialReceipts += dblCurrentSocialReceipts
            dblSocialExpenses += dblCurrentSocialExpenses
            setDblCurrentSocialReceipts(dblCurrentSocialExpenses =
0)

            // This is an agent decision.
            if ((intBadYear >= 4) || (dblSocialReceipts +
dblInheritance < dblSocialExpenses)) {

                // This is a task.
                dblPercentSocContribution += 0.02
                setIntBadYear(2)
                if (blnDebugAgent == true)
{System.out.println("State: We had "+intBadYear+" bad years in a
row (or the budget is negative), so we raise the social
contribution to "+(100*dblPercentSocContribution)+"%. The
corresponding subsistence minimum is "+dblSubsistenceMinimum+".")}
                setIntGoodYear(0)
                setIntExcessiveYear(0)

            } else  {


            }

            // This is an agent decision.
            if ((intGoodYear >= 10) || (intExcessiveYear>= 4)) {

                // This is a task.
                dblPercentSocContribution -= 0.02
                setIntGoodYear(2)
                if (intExcessiveYear >= 4) {intExcessiveYear = 2}
                if (dblPercentSocContribution <= 0.0)
{dblPercentSocContribution = 0.0}
                if (blnDebugAgent == true)
{System.out.println("State: We had "+intGoodYear+" good years in a
row, so we lower the social contribution to
"+(100*dblPercentSocContribution)+"%. The corresponding subsistence
minimum is "+dblSubsistenceMinimum+".")}

            } else  {
```

```
            }

        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method setSubsistenceMinimum
     *
     */
    @ScheduledMethod(
        start = 4d,
        interval = 4d,
        shuffle = true
    )
    public def setSubsistenceMinimum() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        def individualModel = GetParameter("individualModel")

        // This is an agent decision.
        if (individualModel) {


        } else  {

            // This is a task.
            Context context = FindContext("InnoEasy")
            ContinuousSpace space =
(ContinuousSpace)context.getProjection("Space")
            Network community =
(Network)context.getProjection("Community")
            // This is a task.
            def counter = 0
            def counterLess = 0
            def counterMore = 0

            // This is a loop.
            for (citizen in ( FindAgentsInContext("InnoEasy",
"SELECT * FROM innoeasy.Human"))) {

                // This is a task.
                if ((citizen.blnMoreWelfare == true) &&
(citizen.blnLessWelfare == false)) {counterMore ++}
                if ((citizen.blnLessWelfare == true) &&
(citizen.blnMoreWelfare == false)) {counterLess ++}
                counter++
                if (blnDebugAgent == true)
{System.out.println("State: This citizen wants more
("+citizen.blnMoreWelfare+") or less ("+citizen.blnLessWelfare+")
welfare.")}
```

```
            }

            // This is an agent decision.
            if (counterMore >= counter / 2) {

                // This is a task.
                setDblSubsistenceMinimum(dblSubsistenceMinimum *
1.1)
                if (blnDebugAgent == true)
{System.out.println("State: Since we have "+counterMore+" people
who don't like the risk, we increased the subsistence minimum to
"+dblSubsistenceMinimum+".")}

            } else  {


                // This is an agent decision.
                if (counterLess >= counter / 2) {

                    // This is a task.
                    setDblSubsistenceMinimum(dblSubsistenceMinimum
* 0.9)
                    if (blnDebugAgent == true)
{System.out.println("State: Since we have "+counterLess+" people
who like the risk, we lowered the subsistence minimum to
"+dblSubsistenceMinimum+".")}

                } else  {


                }

            }

        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method endSimulation
     *
     */
    @ScheduledMethod(
        start = 1d,
        interval = 1d,
        priority = -1.7976931348623157E308d,
        shuffle = true
    )
    public def endSimulation() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()
```

```
        // This is a task.
        Context context = FindContext("InnoEasy")
        ContinuousSpace space =
(ContinuousSpace)context.getProjection("Space")
        Network community =
(Network)context.getProjection("Community")
        // We will end the simulation by default after "numPeriods"
periods.
        intCountPeriods ++
        def numPeriods = GetParameter("numPeriods")
        if (intCountPeriods > numPeriods)
{RunEnvironment.getInstance().endRun()}

        // This is an agent decision.
        if (intCountPeriods > numPeriods) {

            // This is a task.
            RunEnvironment.getInstance().endRun()

        } else  {


        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This method provides a human-readable name for the agent.
     * @method toString
     *
     */
    @ProbeID()
    public String toString() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // Set the default agent identifier.
        returnValue = this.agentID
        // Return the results.
        return returnValue

    }


}
```

5) File Bank.groovy

```
/**
 *
 * This file was automatically generated by the Repast Simphony
Agent Editor.
 * Please see http://repast.sourceforge.net/ for details.
 *
 */

/**
 *
 * Set the package name.
 *
 */
package innoeasy

/**
 *
 * Import the needed packages.
 *
 */
import java.io.*
import java.math.*
import java.util.*
import javax.measure.unit.*
import org.jscience.mathematics.number.*
import org.jscience.mathematics.vector.*
import org.jscience.physics.amount.*
import repast.simphony.adaptation.neural.*
import repast.simphony.adaptation.regression.*
import repast.simphony.context.*
import repast.simphony.context.space.continuous.*
import repast.simphony.context.space.gis.*
import repast.simphony.context.space.graph.*
import repast.simphony.context.space.grid.*
import repast.simphony.engine.environment.*
import repast.simphony.engine.schedule.*
import repast.simphony.engine.watcher.*
import repast.simphony.groovy.math.*
import repast.simphony.integration.*
import repast.simphony.matlab.link.*
import repast.simphony.query.*
import repast.simphony.query.space.continuous.*
import repast.simphony.query.space.gis.*
import repast.simphony.query.space.graph.*
import repast.simphony.query.space.grid.*
import repast.simphony.query.space.projection.*
import repast.simphony.parameter.*
import repast.simphony.random.*
import repast.simphony.space.continuous.*
import repast.simphony.space.gis.*
import repast.simphony.space.graph.*
import repast.simphony.space.grid.*
import repast.simphony.space.projection.*
import repast.simphony.ui.probe.*
import repast.simphony.util.*
import simphony.util.messages.*
import static java.lang.Math.*
import static repast.simphony.essentials.RepastEssentials.*
```

```
/**
 *
 * This is an agent.
 *
 */
public class Bank  {

    /**
     *
     * This is an agent property.
     * @field dblInterest
     *
     */
    @Parameter (displayName = "Interest rate", usageName =
"dblInterest")
    public double getDblInterest() {
        return dblInterest
    }
    public void setDblInterest(double newValue) {
        dblInterest = newValue
    }
    public double dblInterest = 0.03

    /**
     *
     * This is an agent property.
     * @field dblInterestPayments
     *
     */
    @Parameter (displayName = "InterestPayments", usageName =
"dblInterestPayments")
    public double getDblInterestPayments() {
        return dblInterestPayments
    }
    public void setDblInterestPayments(double newValue) {
        dblInterestPayments = newValue
    }
    public double dblInterestPayments = 0

    /**
     *
     * This is an agent property.
     * @field dblInterestReceipts
     *
     */
    @Parameter (displayName = "Interest Receipts", usageName =
"dblInterestReceipts")
    public double getDblInterestReceipts() {
        return dblInterestReceipts
    }
    public void setDblInterestReceipts(double newValue) {
        dblInterestReceipts = newValue
    }
    public double dblInterestReceipts = 0

    /**
     *
     * This is an agent property.
     * @field dblClientsCredits
     *
     */
```

```
    @Parameter (displayName = "Client's Credits", usageName =
"dblClientsCredits")
    public double getDblClientsCredits() {
        return dblClientsCredits
    }
    public void setDblClientsCredits(double newValue) {
        dblClientsCredits = newValue
    }
    public double dblClientsCredits = 0

    /**
     *
     * This is an agent property.
     * @field dblClientsSavings
     *
     */
    @Parameter (displayName = "Client's Savings", usageName =
"dblClientsSavings")
    public double getDblClientsSavings() {
        return dblClientsSavings
    }
    public void setDblClientsSavings(double newValue) {
        dblClientsSavings = newValue
    }
    public double dblClientsSavings = 0.0

    /**
     *
     * This is an agent property.
     * @field dblCreditRequests
     *
     */
    @Parameter (displayName = "CreditRequests", usageName =
"dblCreditRequests")
    public double getDblCreditRequests() {
        return dblCreditRequests
    }
    public void setDblCreditRequests(double newValue) {
        dblCreditRequests = newValue
    }
    public double dblCreditRequests = 0

    /**
     *
     * This is an agent property.
     * @field intYearsWOCustomer
     *
     */
    @Parameter (displayName = "Years w/o customer", usageName =
"intYearsWOCustomer")
    public int getIntYearsWOCustomer() {
        return intYearsWOCustomer
    }
    public void setIntYearsWOCustomer(int newValue) {
        intYearsWOCustomer = newValue
    }
    public int intYearsWOCustomer = 0

    /**
     *
     * This value is used to automatically generate agent
identifiers.
```

```
     * @field serialVersionUID
     *
     */
    private static final long serialVersionUID = 1L

    /**
     *
     * This value is used to automatically generate agent
identifiers.
     * @field agentIDCounter
     *
     */
    protected static long agentIDCounter = 1

    /**
     *
     * This value is the agent's identifier.
     * @field agentID
     *
     */
    protected String agentID = "Bank " + (agentIDCounter++)

    /**
     *
     * This is the step behavior.
     * @method creditRequest
     *
     */
    public boolean creditRequest(double AmtRequested) {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()


        // This is an agent decision.
        if (dblClientsSavings - dblClientsCredits > AmtRequested) {

            // This is a task.
            dblClientsCredits += AmtRequested
            returnValue = true
            dblCreditRequests += AmtRequested

        } else  {

            // This is a task.
            returnValue = false
            dblCreditRequests += AmtRequested

        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method adjustRate
     *
```

```
     */
    @ScheduledMethod(
        start = 1d,
        interval = 1d,
        shuffle = true
    )
    public def adjustRate() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()


        // This is an agent decision.
        if (dblCreditRequests > dblClientsSavings) {

            // This is a task.
            dblInterest += 0.01
            //System.out.println("I have "+dblClientsSavings+" in
savings and they requested "+dblCreditRequests+" EUR. So, I need
more savings and I will raise my interest rate to
"+dblInterest+"%.")
            setDblCreditRequests(0)
            if (dblClientsSavings < 0.00001) {dblClientsSavings =
0.0}

        } else  {

            // This is a task.
            dblInterest -= 0.01
            if (dblInterest < 0.001) {dblInterest = 0.00}
            //System.out.println("I have "+dblClientsSavings+" in
savings and they requested "+dblCreditRequests+" EUR. So, I need
more credit requests and I will decrease my interest rate to
"+dblInterest+"%.")
            setDblCreditRequests(0)
            if (dblClientsSavings < 0.00001) {dblClientsSavings =
0.0}

        }
        // This is a task.
        Context context = FindContext("InnoEasy")
        ContinuousSpace space =
(ContinuousSpace)context.getProjection("Space")
        //System.out.println("My coordinates are:
"+space.getLocation(this))
        // Return the results.
        return returnValue

    }

    /**
     *
     * The bank checks if it is really used by the customers
     * @method isNecessary
     *
     */
    public def isNecessary() {

        // Define the return value variable.
```

```
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        Context context = FindContext("InnoEasy")
        Network banking = (Network)context.getProjection("Banking")
        Iterator list = new NetworkAdjacent(banking,
this).query().iterator()

        // This is an agent decision.
        if (list.hasNext()) {

            // This is a task.
            setIntYearsWOCustomer(0)

        } else  {

            // This is a task.
            intYearsWOCustomer += 1

        }

        // This is an agent decision.
        if (intYearsWOCustomer > 5) {

            // This is a task.
            Context c = RemoveAgentFromModel(this)

        } else  {


        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This method provides a human-readable name for the agent.
     * @method toString
     *
     */
    @ProbeID()
    public String toString() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // Set the default agent identifier.
        returnValue = this.agentID
        // Return the results.
        return returnValue

    }

}
```

6) File Fund.groovy

```
/**
 *
 * This file was automatically generated by the Repast Simphony
Agent Editor.
 * Please see http://repast.sourceforge.net/ for details.
 *
 */

/**
 *
 * Set the package name.
 *
 */
package innoeasy

/**
 *
 * Import the needed packages.
 *
 */
import java.io.*
import java.math.*
import java.util.*
import javax.measure.unit.*
import org.jscience.mathematics.number.*
import org.jscience.mathematics.vector.*
import org.jscience.physics.amount.*
import repast.simphony.adaptation.neural.*
import repast.simphony.adaptation.regression.*
import repast.simphony.context.*
import repast.simphony.context.space.continuous.*
import repast.simphony.context.space.gis.*
import repast.simphony.context.space.graph.*
import repast.simphony.context.space.grid.*
import repast.simphony.engine.environment.*
import repast.simphony.engine.schedule.*
import repast.simphony.engine.watcher.*
import repast.simphony.groovy.math.*
import repast.simphony.integration.*
import repast.simphony.matlab.link.*
import repast.simphony.query.*
import repast.simphony.query.space.continuous.*
import repast.simphony.query.space.gis.*
import repast.simphony.query.space.graph.*
import repast.simphony.query.space.grid.*
import repast.simphony.query.space.projection.*
import repast.simphony.parameter.*
import repast.simphony.random.*
import repast.simphony.space.continuous.*
import repast.simphony.space.gis.*
import repast.simphony.space.graph.*
import repast.simphony.space.grid.*
import repast.simphony.space.projection.*
import repast.simphony.ui.probe.*
import repast.simphony.util.*
import simphony.util.messages.*
import static java.lang.Math.*
import static repast.simphony.essentials.RepastEssentials.*
```

```
/**
 *
 * This is an agent.
 *
 */
public class Fund  {

    /**
     *
     * This is an agent property.
     * @field dblInterest
     *
     */
    @Parameter (displayName = "Interest rate", usageName =
"dblInterest")
    public double getDblInterest() {
        return dblInterest
    }
    public void setDblInterest(double newValue) {
        dblInterest = newValue
    }
    public double dblInterest = 0.03

    /**
     *
     * This is an agent property.
     * @field dblInterestPayments
     *
     */
    @Parameter (displayName = "InterestPayments", usageName =
"dblInterestPayments")
    public double getDblInterestPayments() {
        return dblInterestPayments
    }
    public void setDblInterestPayments(double newValue) {
        dblInterestPayments = newValue
    }
    public double dblInterestPayments = 0

    /**
     *
     * This is an agent property.
     * @field dblClientsSavings
     *
     */
    @Parameter (displayName = "Client's Savings", usageName =
"dblClientsSavings")
    public double getDblClientsSavings() {
        return dblClientsSavings
    }
    public void setDblClientsSavings(double newValue) {
        dblClientsSavings = newValue
    }
    public double dblClientsSavings = 0

    /**
     *
     * This is an agent property.
     * @field dblCapitalStock
     *
     */
```

```
    @Parameter (displayName = "Capital Stock", usageName =
"dblCapitalStock")
    public double getDblCapitalStock() {
        return dblCapitalStock
    }
    public void setDblCapitalStock(double newValue) {
        dblCapitalStock = newValue
    }
    public double dblCapitalStock = 0

    /**
     *
     * This is an agent property.
     * @field dblInvestedMoney
     *
     */
    @Parameter (displayName = "Invested Money", usageName =
"dblInvestedMoney")
    public double getDblInvestedMoney() {
        return dblInvestedMoney
    }
    public void setDblInvestedMoney(double newValue) {
        dblInvestedMoney = newValue
    }
    public double dblInvestedMoney = 0

    /**
     *
     * This is an agent property.
     * @field dblInnoRent
     *
     */
    @Parameter (displayName = "InnoRent", usageName =
"dblInnoRent")
    public double getDblInnoRent() {
        return dblInnoRent
    }
    public void setDblInnoRent(double newValue) {
        dblInnoRent = newValue
    }
    public double dblInnoRent = 0

    /**
     *
     * This is an agent property.
     * @field blnDebugFund
     *
     */
    @Parameter (displayName = "DebugFund", usageName =
"blnDebugFund")
    public boolean getBlnDebugFund() {
        return blnDebugFund
    }
    public void setBlnDebugFund(boolean newValue) {
        blnDebugFund = newValue
    }
    public boolean blnDebugFund = 0

    /**
     *
     * This is an agent property.
     * @field dblCumClientsSavings
```

```
     *
     */
    @Parameter (displayName = "Cumulated Client's Savings",
usageName = "dblCumClientsSavings")
    public double getDblCumClientsSavings() {
        return dblCumClientsSavings
    }
    public void setDblCumClientsSavings(double newValue) {
        dblCumClientsSavings = newValue
    }
    public double dblCumClientsSavings = 0

    /**
     *
     * This is an agent property.
     * @field intNegativeYears
     *
     */
    @Parameter (displayName = "Negative Years", usageName =
"intNegativeYears")
    public int getIntNegativeYears() {
        return intNegativeYears
    }
    public void setIntNegativeYears(int newValue) {
        intNegativeYears = newValue
    }
    public int intNegativeYears = 0

    /**
     *
     * This is an agent property.
     * @field intNoInterestYears
     *
     */
    @Parameter (displayName = "Low I% Years", usageName =
"intNoInterestYears")
    public int getIntNoInterestYears() {
        return intNoInterestYears
    }
    public void setIntNoInterestYears(int newValue) {
        intNoInterestYears = newValue
    }
    public int intNoInterestYears = 0

    /**
     *
     * This value is used to automatically generate agent
identifiers.
     * @field serialVersionUID
     *
     */
    private static final long serialVersionUID = 1L

    /**
     *
     * This value is used to automatically generate agent
identifiers.
     * @field agentIDCounter
     *
     */
    protected static long agentIDCounter = 1
```

```
    /**
     *
     * This value is the agent's identifier.
     * @field agentID
     *
     */
    protected String agentID = "Fund " + (agentIDCounter++)

    /**
     *
     * This is the step behavior.
     * @method investMoney
     *
     */
    @ScheduledMethod(
        start = 2d,
        interval = 1d,
        shuffle = true
    )
    public def investMoney() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        Context context = FindContext("InnoEasy")
        ContinuousSpace space =
(ContinuousSpace)context.getProjection("Space")
        // This is a task.
        Network banking = (Network)context.getProjection("Banking")
        // This is a task.
        dblCapitalStock += dblClientsSavings
        setDblClientsSavings(0)

        // This is a loop.
        for (invention in ( FindAgentsInContext("InnoEasy", "SELECT
* FROM innoeasy.Invention ORDER BY (dblRent/dblCost) DESC"))) {


            // This is an agent decision.
            if ((invention.blnFinanced == false) &&
(invention.blnSuccess == false) && (invention.blnFailed == false))
{


                // This is an agent decision.
                if (dblCapitalStock > invention.dblCost) {

                    // This is a task.
                    if (blnDebugFund == true)
{System.out.println("Fund: I just want to make sure, we'll get the
right ones. This invention's finance status is
"+invention.blnFinanced+" and its rent/cost ratio is
"+(invention.dblRent/invention.dblCost)+" with a cost of
"+invention.dblCost+" and a rent of "+invention.dblRent+".")}
                    financeInnovation(invention)

                } else  {
```

```
                }
            } else  {

            }
        }

        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method RentFromInnovations
     *
     */
    @ScheduledMethod(
        start = 2d,
        interval = 1d,
        shuffle = true
    )
    public void RentFromInnovations() {

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        Context context = FindContext("InnoEasy")
        ContinuousSpace space =
(ContinuousSpace)context.getProjection("Space")
        // This is a task.
        Network innovativeness =
(Network)context.getProjection("Innovator")
        Network financing =
(Network)context.getProjection("Financier")
        // This is a task.
        dblCapitalStock += dblInnoRent
        dblCapitalStock -= dblInterestPayments
        //this means that the capital stock is increased by not
paid out profits from last year or decreased if the interest paid
was too high.
        if (blnDebugFund == true) {System.out.println("Fund: We
just increased the capital stock by last year's inno rent of
"+dblInnoRent+" and lowered it by the interest payments of
"+dblInterestPayments+" to an amount of "+dblCapitalStock+".")}
        setDblInnoRent(dblInterestPayments = 0)

        // This is a loop.
        for (partFinanced in (new NetPathWithin(financing, this,
1).query())) {


            // This is an agent decision.
            if (partFinanced.blnSuccess == true) {

                // This is a task.
```

```
                dblInnoRent += partFinanced.dblRent *
partFinanced.dblWeight / 2

            } else  {


            }

        }

        // This is a task.
        if (blnDebugFund == true) {System.out.println("Fund: Ok, so
I get "+(dblInnoRent + dblInterestPayments)+" EUR from my
innovations and the interest payments were
"+dblInterestPayments+".")}
        // End the method.
        return

    }

    /**
     *
     * This is the step behavior.
     * @method calculateInterestRate
     *
     */
    @ScheduledMethod(
        start = 3d,
        interval = 1d,
        shuffle = true
    )
    public def calculateInterestRate() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        if (dblCumClientsSavings > 0.0) {dblInterest = dblInnoRent
/ dblCumClientsSavings / 2} // we'll divide by 2 to save some money
for times when there is no sufficient rent from the innovations.
This assumption can be easily removed.
        if (dblInterest < 0.0) {dblInterest = 0.0}
        if (dblInterest > 5.0) {dblInterest = 5.0}
        dblCapitalStock += (dblInnoRent / 2)   //the other half is
put into the capital stock to be able to refund investors who wish
to withdraw their money
        if ((dblCapitalStock > 0.0) && (dblCumClientsSavings <=
0.0) && (dblInnoRent > 0.0)) {dblInterest += 0.1}
        // This is a task.
        if (blnDebugFund == true) {System.out.println("Fund: The
new interest rate is "+dblInterest+" since we administered
"+dblCumClientsSavings+" EUR from investors and received a rent of
"+dblInnoRent+".")}
        // Return the results.
        return returnValue

    }

    /**
```

```
     *
     * The bank checks if it is really used by the customers
     * @method isSuccessful
     *
     */
    @ScheduledMethod(
        start = 3d,
        interval = 1d,
        shuffle = true
    )
    public def isSuccessful() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()


        // This is an agent decision.
        if (dblCapitalStock >= 0) {

            // This is a task.
            setIntNegativeYears(0)

        } else  {

            // This is a task.
            intNegativeYears += 1

        }
        // This is a task.
        Context context = FindContext("InnoEasy")
        Network investing =
(Network)context.getProjection("Investing")
        Network financing =
(Network)context.getProjection("Financier")
        if (blnDebugFund == true) {System.out.println("Fund: We had
"+intNegativeYears+" negative years.")}

        // This is an agent decision.
        if (intNegativeYears > 25) {


            // This is a loop.
            for (investor in (new NetworkPredecessor(investing,
this).query())) {


                // Make a decision.
                if (investor instanceof Human) {

                    // This is a task.
                    investor.dblSavings = 0
                    investor.intRiskAversion += 3
                    if (investor.intRiskAversion > 10)
{investor.intRiskAversion = 10}
                    RemoveEdge("InnoEasy/Investing", investor,
this)
                    if (blnDebugFund == true)
{System.out.println("Fund: We have to close another account.")}
```

```
                } else  {


                }

            }


            // This is a loop.
            for (partInvention in (new
NetworkPredecessor(financing, this).query())) {


                // This is an agent decision.
                if (partInvention instanceof Invention) {

                    // This is a task.
                    RemoveEdge("InnoEasy/Financier", partInvention,
this)
                    if (blnDebugFund == true)
{System.out.println("Fund: We have to delete another invention from
portfolio.")}

                } else  {


                }

            }

            // This is a task.
            Context c = RemoveAgentFromModel(this)
            if (blnDebugFund == true) {System.out.println("Fund:
The fund is out of money. It has just been liquidated.")}

        } else  {


        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This is the step behavior.
     * @method financeInnovation
     *
     */
    public def financeInnovation(Invention invention) {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        Context context = FindContext("InnoEasy")
        Network inventing =
(Network)context.getProjection("Inventor")
```

```
        Iterator list = new NetworkAdjacent(inventing,
invention).query().iterator()
        if (blnDebugFund == true) {System.out.println("Fund:  we'll
finance the invention. Let's see if it works.")}

        // This is an agent decision.
        if (list.hasNext()) {

            // This is a task.
            Human inventor = list.next()
            //only a living inventor can implent his invention into
an innovation
            // This is a task.
            dblInvestedMoney += invention.dblCost
            dblCapitalStock -= invention.dblCost
            if (blnDebugFund == true) {System.out.println("Fund: We
have just financed a new invention which costs
"+invention.dblCost+" from the capital stock which has now left
"+dblCapitalStock+". So, in total, we have now invested
"+dblInvestedMoney+".")}

            // This is an agent decision.
            if (RandomHelper.nextDoubleFromTo(0.0, 3.0) -  1 +
inventor.intInnovated / inventor.intInvented > 0.5) {

                // This is a task.
                inventor.intInnovated++
                if (blnDebugFund == true)
{System.out.println("Fund: Great, the invention turned out to be an
innovation.")}
                // inventor.intNewInno++  'This would only have an
effect if the fund is executed after the corresponding agent, since
the value is reset to 0 at the beginning of the agent rules. Since
the value is only for statistics and it can be derived by
subtracting two intInnovated-values, it is not problematic to leave
it out here
                inventor.intRiskAversion -= 1
                if (inventor.intRiskAversion < 0)
{inventor.intRiskAversion = 0}
                inventor.intFamilyInnovations++
                // This is a task.
                CreateEdge("InnoEasy/Financier", this, invention,
1.0)
                CreateEdge("InnoEasy/Innovator", inventor,
invention, 1.0)
                invention.blnSuccess = true
                invention.blnFinanced = true

            } else  {

                // This is a task.
                inventor.intFailedInnos++
                invention.blnFailed = true
                if (blnDebugFund == true)
{System.out.println("Fund: Unfortunately, the invention failed.")}
                inventor.intRiskAversion += 1
                if (inventor.intRiskAversion > 10)
{inventor.intRiskAversion = 10}
                //inventor.intNewFailed ++  'This would only have
an effect if the fund is executed after the corresponding agent,
since the value is reset to 0 at the beginning of the agent rules.
Since the value is only for statistics and it can be derived by
```

```
subtracting two intFailedInnos-values, it is not problematic to
leave it out here

            }

        } else  {

            // This is a task.
            invention.blnDeadInventor = true
            if (blnDebugFund == true) {System.out.println("Fund:
Oops, the inventor is no longer with us.")}

        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * The bank checks if it is really used by the customers
     * @method needToMove
     *
     */
    @ScheduledMethod(
        start = 3d,
        interval = 1d,
        shuffle = true
    )
    public def needToMove() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()


        // This is an agent decision.
        if (dblInterest > 0.0) {

            // This is a task.
            setIntNoInterestYears(0)

        } else  {

            // This is a task.
            intNoInterestYears += 1

        }
        // This is a task.
        Context context = FindContext("InnoEasy")
        ContinuousSpace space =
(ContinuousSpace)context.getProjection("Space")
        if (blnDebugFund == true) {System.out.println("Fund: We had
"+intNoInterestYears+" no interest years.")}

        // This is an agent decision.
        if (intNoInterestYears > 5) {

            // This is a task.
            def counter = 0
```

```
            def tempXCoords = 0
            def tempYCoords = 0
            setIntNoInterestYears(0)

            // This is a loop.
            for (richie in (new ContinuousWithin(space, this,
10).query())) {


                // Make a decision.
                if (richie instanceof Human) {


                    // Make a decision.
                    if (richie.dblSavings + richie.dblRiskProvision
> 20) {

                        // This is a task.
                        NdPoint point = space.getLocation(richie)
                        tempYCoords += point.getY()
                        tempXCoords += point.getX()
                        if (blnDebugFund == true)
{System.out.println("I found a rich human and will move closer.")}
                        counter ++

                    } else  {


                    }

                } else  {


                }

            }


            // This is an agent decision.
            if (counter > 0) {

                // This is a task.
                NdPoint point = space.getLocation(this)
                def myY = point.getY()
                def myX = point.getX()
                if (blnDebugFund == true)
{System.out.println("Fund: I'm moving.")}
                // This is a task.
                double newX=(myX + tempXCoords / counter) / 2
                double newY=(myY + tempYCoords / counter) / 2
                // This is a task.
                MoveAgent("InnoEasy/Space", this, newX, newY)

            } else  {


            }

        } else  {


        }
```

```
        // Return the results.
        return returnValue

    }

    /**
     *
     * This method provides a human-readable name for the agent.
     * @method toString
     *
     */
    @ProbeID()
    public String toString() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // Set the default agent identifier.
        returnValue = this.agentID
        // Return the results.
        return returnValue

    }


}
```

7) File Invention.groovy

```
/**
 *
 * This file was automatically generated by the Repast Simphony
Agent Editor.
 * Please see http://repast.sourceforge.net/ for details.
 *
 */

/**
 *
 * Set the package name.
 *
 */
package innoeasy

/**
 *
 * Import the needed packages.
 *
 */
import java.io.*
import java.math.*
import java.util.*
import javax.measure.unit.*
import org.jscience.mathematics.number.*
import org.jscience.mathematics.vector.*
import org.jscience.physics.amount.*
import repast.simphony.adaptation.neural.*
import repast.simphony.adaptation.regression.*
import repast.simphony.context.*
import repast.simphony.context.space.continuous.*
import repast.simphony.context.space.gis.*
import repast.simphony.context.space.graph.*
import repast.simphony.context.space.grid.*
import repast.simphony.engine.environment.*
import repast.simphony.engine.schedule.*
import repast.simphony.engine.watcher.*
import repast.simphony.groovy.math.*
import repast.simphony.integration.*
import repast.simphony.matlab.link.*
import repast.simphony.query.*
import repast.simphony.query.space.continuous.*
import repast.simphony.query.space.gis.*
import repast.simphony.query.space.graph.*
import repast.simphony.query.space.grid.*
import repast.simphony.query.space.projection.*
import repast.simphony.parameter.*
import repast.simphony.random.*
import repast.simphony.space.continuous.*
import repast.simphony.space.gis.*
import repast.simphony.space.graph.*
import repast.simphony.space.grid.*
import repast.simphony.space.projection.*
import repast.simphony.ui.probe.*
import repast.simphony.util.*
import simphony.util.messages.*
import static java.lang.Math.*
import static repast.simphony.essentials.RepastEssentials.*
```

```
/**
 *
 * This is an agent.
 *
 */
public class Invention  {

    /**
     *
     * This is an agent property.
     * @field dblRent
     *
     */
    @Parameter (displayName = "Rent", usageName = "dblRent")
    public double getDblRent() {
        return dblRent
    }
    public void setDblRent(double newValue) {
        dblRent = newValue
    }
    public double dblRent = 0

    /**
     *
     * This is an agent property.
     * @field dblCost
     *
     */
    @Parameter (displayName = "Cost", usageName = "dblCost")
    public double getDblCost() {
        return dblCost
    }
    public void setDblCost(double newValue) {
        dblCost = newValue
    }
    public double dblCost = 0

    /**
     *
     * The weight of an innovation decreases over time
     * @field dblWeight
     *
     */
    @Parameter (displayName = "Weight", usageName = "dblWeight")
    public double getDblWeight() {
        return dblWeight
    }
    public void setDblWeight(double newValue) {
        dblWeight = newValue
    }
    public double dblWeight = 1

    /**
     *
     * This is an agent property.
     * @field blnFailed
     *
     */
    @Parameter (displayName = "failed?", usageName = "blnFailed")
    public boolean getBlnFailed() {
        return blnFailed
```

```
    }
    public void setBlnFailed(boolean newValue) {
        blnFailed = newValue
    }
    public boolean blnFailed = false

    /**
     *
     * This is an agent property.
     * @field blnSuccess
     *
     */
    @Parameter (displayName = "Success?", usageName = "blnSuccess")
    public boolean getBlnSuccess() {
        return blnSuccess
    }
    public void setBlnSuccess(boolean newValue) {
        blnSuccess = newValue
    }
    public boolean blnSuccess = false

    /**
     *
     * This is an agent property.
     * @field blnFinanced
     *
     */
    @Parameter (displayName = "Financed?", usageName =
"blnFinanced")
    public boolean getBlnFinanced() {
        return blnFinanced
    }
    public void setBlnFinanced(boolean newValue) {
        blnFinanced = newValue
    }
    public boolean blnFinanced = false

    /**
     *
     * This is an agent property.
     * @field blnRent10
     *
     */
    @Parameter (displayName = "Rent > 10", usageName = "blnRent10")
    public int getBlnRent10() {
        return blnRent10
    }
    public void setBlnRent10(int newValue) {
        blnRent10 = newValue
    }
    public int blnRent10 = 0

    /**
     *
     * This is an agent property.
     * @field blnRent20
     *
     */
    @Parameter (displayName = "Rent > 20", usageName = "blnRent20")
    public int getBlnRent20() {
        return blnRent20
    }
```

```
    public void setBlnRent20(int newValue) {
        blnRent20 = newValue
    }
    public int blnRent20 = 0

    /**
     *
     * This is an agent property.
     * @field blnRent30
     *
     */
    @Parameter (displayName = "Rent > 30", usageName = "blnRent30")
    public int getBlnRent30() {
        return blnRent30
    }
    public void setBlnRent30(int newValue) {
        blnRent30 = newValue
    }
    public int blnRent30 = 0

    /**
     *
     * This is an agent property.
     * @field blnRent40
     *
     */
    @Parameter (displayName = "Rent > 40", usageName = "blnRent40")
    public int getBlnRent40() {
        return blnRent40
    }
    public void setBlnRent40(int newValue) {
        blnRent40 = newValue
    }
    public int blnRent40 = 0

    /**
     *
     * This is an agent property.
     * @field blnRent50
     *
     */
    @Parameter (displayName = "Rent > 50", usageName = "blnRent50")
    public int getBlnRent50() {
        return blnRent50
    }
    public void setBlnRent50(int newValue) {
        blnRent50 = newValue
    }
    public int blnRent50 = 0

    /**
     *
     * This is an agent property.
     * @field blnDeadInventor
     *
     */
    @Parameter (displayName = "Dead inventor", usageName =
"blnDeadInventor")
    public boolean getBlnDeadInventor() {
        return blnDeadInventor
    }
    public void setBlnDeadInventor(boolean newValue) {
```

```
        blnDeadInventor = newValue
    }
    public boolean blnDeadInventor = 0

    /**
     *
     * This value is used to automatically generate agent
identifiers.
     * @field serialVersionUID
     *
     */
    private static final long serialVersionUID = 1L

    /**
     *
     * This value is used to automatically generate agent
identifiers.
     * @field agentIDCounter
     *
     */
    protected static long agentIDCounter = 1

    /**
     *
     * This value is the agent's identifier.
     * @field agentID
     *
     */
    protected String agentID = "Invention " + (agentIDCounter++)

    /**
     *
     * This is the step behavior.
     * @method initialize
     *
     */
    public def initialize() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // This is a task.
        RandomHelper.createPoisson(25)
        setDblRent(RandomHelper.getPoisson().nextInt())
        setDblCost(RandomHelper.nextDoubleFromTo(dblRent/2,
dblRent*2))
        setDblWeight(1)
        // This is a task.
        if (dblRent>15) {blnRent10 = 1; blnRent20 = 0; blnRent30 =
0; blnRent40 = 0; blnRent50 = 0;}
        if (dblRent>20) {blnRent10 = 0; blnRent20 = 1; blnRent30 =
0; blnRent40 = 0; blnRent50 = 0;}
        if (dblRent>25) {blnRent10 = 0; blnRent20 = 0; blnRent30 =
1; blnRent40 = 0; blnRent50 = 0;}
        if (dblRent>30) {blnRent10 = 0; blnRent20 = 0; blnRent30 =
0; blnRent40 = 1; blnRent50 = 0;}
        if (dblRent>35) {blnRent10 = 0; blnRent20 = 0; blnRent30 =
0; blnRent40 = 0; blnRent50 = 1;}
        // Return the results.
```

```
    return returnValue

}

/**
 *
 * This is the step behavior.
 * @method depreciate
 *
 */
@ScheduledMethod(
    start = 0d,
    interval = 1d,
    shuffle = true
)
public def depreciate() {

    // Define the return value variable.
    def returnValue

    // Note the simulation time.
    def time = GetTickCountInTimeUnits()


    // This is an agent decision.
    if (dblWeight > 0) {

        // This is a task.
        setDblWeight(dblWeight - 0.05)
        if (dblWeight <= 0.0) {dblWeight = 0.0}

    } else  {

        // This is a task.
        setDblWeight(0)
        checkForRemoval()

    }
    // Return the results.
    return returnValue

}

/**
 *
 * This behavior is called by the Humans
 * @method isInnovation
 *
 */
public boolean isInnovation() {

    // Define the return value variable.
    def returnValue

    // Note the simulation time.
    def time = GetTickCountInTimeUnits()


    // This is an agent decision.
    if (blnSuccess == true) {

        // This is a task.
```

```
            returnValue = true

        } else  {

            // This is a task.
            returnValue = false

        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * An invention with a weight of 0 and a dead inventor can be removed from the simulation in order to reduce the necessary computational power
     * @method checkForRemoval
     *
     */
    public def checkForRemoval() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()


        // This is an agent decision.
        if (blnDeadInventor) {


        } else  {

            // This is a task.
            Context c = RemoveAgentFromModel(this)

        }
        // Return the results.
        return returnValue

    }

    /**
     *
     * This method provides a human-readable name for the agent.
     * @method toString
     *
     */
    @ProbeID()
    public String toString() {

        // Define the return value variable.
        def returnValue

        // Note the simulation time.
        def time = GetTickCountInTimeUnits()

        // Set the default agent identifier.
        returnValue = this.agentID
```

```
            // Return the results.
            return returnValue

        }


    }
```

Appendix B: Rules for the agents

Generate Revenue	Human	(1) *if human is neither retired nor unemployed nor too young to work then* receive work income depending on health level (2) receive rent from innovations[1] (3) add or subtract interest payments (4) pay back credit from earlier period[2]
Social Risk Provision	Human	(1) *if Revenue > Subsistence Minimum then* pay percentage of contribution required (2) *if Revenue < Subsistence Minimum then* receive difference from social insurance
Individual Risk Provision	Human	(1) *if Revenue > Subsistence Minimum then* a. *if satisfied with returns then* pay money into one's own provision stock according to risk aversion and time preference. b. *if dissatisfied with return then* move entire provision stock to different bank and pay money into one's own provision stock according to risk aversion and time preference. (2) *if Revenue < Subsistence Minimum then* a. take money from the risk provision stock and from other savings if necessary to add up to the Subsistence Minimum b. *if Money left Available < Subsistence Minimum then* try to get a credit from the financial market c. *if no credit available then* die of starvation (3) deduce subsistence minimum in all cases unless death
Save or Consume	Human	(1) compute savings ratio by varying average consumption ratio with a. amount of savings relative to revenue (+) b. time preference (+) and c. offered interest rate (-) (2) compute amount consumed from amount available (3) *if remaining amount > 0 then* place remaining amount in savings account and find bank to invest money (4) *else* look for bank to lend the money

[1] This is accomplished by the innovation itself. The rule "Generate Revenue" will call the rule "Pay rent" in each invention connected to the individual.

[2] The credit has to be paid back directly so that the savings accounts can be balanced. Otherwise we could have the problem, that a bank could go out of business because it lacks the funds to pay out the savings invested. If a credit cannot be repaid then the amount is deducted from all the savings. Since the savings have been put in the period before, this is always in balance or positive thanks to the interest difference that the bank receives.

Innovate	Human	(1) Compute invention propensity according to her education, work experience, innovation experience, network stimuli, her happiness, merit goods, her tinkerer propensity and her risk aversion (2) *if an invention is made then* compute financing propensity according to her wealth and the cost of the innovation a. *if willing to finance then* compute risk propensity according to risk aversion, risks privately borne and innovation experience i. *if willing to risk then* carry out innovation 1. *if successful then* add innovation to portfolio
UpdateVariables	Human	(1) Set new values for age, health, risk aversion, experience (2) *if age is above DeathAge then* be reborn (3) Update environmental influences a. friends network b. financing of inventions (4) *if we are in the governmental model then* set voting behavior
Calculate Contribution	Public Sector	(1) Compare the payments to the receipts from contributions (2) *if all payments are covered then* record good year a. *if receipts are more than twice the payments then* record excessive year (3) *else if payments are larger than receipts then* record bad year (4) *if there were four bad periods in a row then* raise percentage of contribution *(5) if there were four excessive periods or ten good or excessive periods in a row then* lower percentage of contribution
Set Subsistence Minimum	Public Sector	(1) *if we are in an election period then* find the median voter a. *if median voter wants more social insurance then* increase subsistence minimum by 10% b. *if median voter wants less social insurance then* lower subsistence minimum by 10%
Award credit	Bank	(1) Consider the credit request from Human agent (2) Award credit to the individual if money available
Calculate interest rate	Bank	(1) *if money requested > money saved then* increase rate (2) *else* lower rate by 1% but not below 0%

Invest Money	Fund	(1) Considering all unfinanced inventions, find the most attractive one (2) finance the innovation (3) repeat as long as there are funds available
Calculate interest rate	Fund	(1) keep half of the rent from innovations to increase capital stock (2) set interest rate as return from left over rent from innovations to money invested at fund
Relocate	Fund	(1) analyze new interest rate offer to see if it has been a good year (2) *if it has been the fifth consecutive year without return then* look out as far as vision permits (3) considering all Humans, move closer to wealthy Humans
Is Successful	Fund	(1) analyze capital stock to see if it is negative showing a potentially dangerous drain of resources (2) *if it has been the fifteenth consecutive year with a negative capital stock then* close fund
Depreciate	Invention	(1) reduce weight by five percentage points

Appendix C: Verification of the runs

1) Public Sector Agent

This is an exemplary message which the Public Sector agent may return during the course of one year.

```
State: This citizen wants more (true) or less (false) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (false) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (true) or less (false) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (true) or less (false) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (true) or less (false) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (true) or less (false) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (true) or less (false) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (true) or less (false) welfare.
State: This citizen wants more (true) or less (false) welfare.
State: This citizen wants more (true) or less (false) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (false) welfare.
State: This citizen wants more (false) or less (false) welfare.
State: This citizen wants more (false) or less (false) welfare.
State: This citizen wants more (false) or less (false) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (false) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (false) welfare.
State: This citizen wants more (true) or less (false) welfare.
State: This citizen wants more (true) or less (false) welfare.
State: This citizen wants more (false) or less (false) welfare.
State: This citizen wants more (true) or less (false) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (true) or less (false) welfare.
State: This citizen wants more (false) or less (true) welfare.
State: This citizen wants more (true) or less (false) welfare.
State: Since we have 28 people who like the risk, we lowered the
subsistence minimum to 7.2.
```

State: The receipts of 608.2934771105091 are much higher than the expenses of 184.54069347894568, so we record the 3th excessive year and the 3th good year in a row.

2) Fund agent

This is an exemplary message which a Fund agent may return during the course of one year.

```
Fund: The new interest rate is 0.12131576934303498 since we
administered 1633.3408350212649 EUR from investors and received a
rent of 396.29999999999984.
Fund: We just increased the capital stock by last year's inno rent
of 396.29999999999984 and lowered it by the interest payments of
198.1499999999997 to an amount of 2743.9004223935776.
Fund: Ok, so I get 357.5999999999998 EUR from my innovations and
the interest payments were 0.0.
Fund: I just want to make sure, we'll get the right ones. This
invention's finance status is false and its rent/cost ratio is
1.0437548606235647 with a cost of 23.951984266750515 and a rent of
25.0.
Fund:  we'll finance the invention. Let's see if it works.
Fund: We have just financed a new invention which costs
23.951984266750515 from the capital stock which has now left
4353.28927314809. So, in total, we have now invested
3002.880054414971.
Fund: Unfortunately, the invention failed.
Fund: I just want to make sure, we'll get the right ones. This
invention's finance status is false and its rent/cost ratio is
0.9898436283139894 with a cost of 30.307817459106445 and a rent of
30.0.
Fund:  we'll finance the invention. Let's see if it works.
Fund: We have just financed a new invention which costs
30.307817459106445 from the capital stock which has now left
4322.981455688983. So, in total, we have now invested
3033.1878718740772.
Fund: Unfortunately, the invention failed.
Fund: I just want to make sure, we'll get the right ones. This
invention's finance status is false and its rent/cost ratio is
0.9871498118632411 with a cost of 26.338454090291634 and a rent of
26.0.
Fund:  we'll finance the invention. Let's see if it works.
Fund: We have just financed a new invention which costs
26.338454090291634 from the capital stock which has now left
4296.643001598692. So, in total, we have now invested
3059.526325964369.
Fund: Great, the invention turned out to be an innovation.
Fund: I just want to make sure, we'll get the right ones. This
invention's finance status is false and its rent/cost ratio is
0.9821820059959481 with a cost of 17.30840098496992 and a rent of
17.0.
Fund:  we'll finance the invention. Let's see if it works.
Fund: We have just financed a new invention which costs
17.30840098496992 from the capital stock which has now left
4279.334600613722. So, in total, we have now invested
3076.834726949339.
Fund: Great, the invention turned out to be an innovation.
Fund: I just want to make sure, we'll get the right ones. This
invention's finance status is false and its rent/cost ratio is
0.8151471730465409 with a cost of 30.669308349024504 and a rent of
25.0.
Fund:  we'll finance the invention. Let's see if it works.
Fund: We have just financed a new invention which costs
30.669308349024504 from the capital stock which has now left
4248.665292264697. So, in total, we have now invested
3107.5040352983633.
```

```
Fund: Unfortunately, the invention failed.
Fund: I just want to make sure, we'll get the right ones. This
invention's finance status is false and its rent/cost ratio is
0.5823391310553426 with a cost of 49.79916075267829 and a rent of
29.0.
Fund:  we'll finance the invention. Let's see if it works.
Fund: We have just financed a new invention which costs
49.79916075267829 from the capital stock which has now left
4198.866131512019. So, in total, we have now invested
3157.3031960510416.
Fund: Unfortunately, the invention failed.
Fund: I just want to make sure, we'll get the right ones. This
invention's finance status is false and its rent/cost ratio is
0.5677447924108948 with a cost of 45.79522409988567 and a rent of
26.0.
Fund:  we'll finance the invention. Let's see if it works.
Fund: We have just financed a new invention which costs
45.79522409988567 from the capital stock which has now left
4153.070907412133. So, in total, we have now invested
3203.0984201509273.
Fund: Great, the invention turned out to be an innovation.
Fund: I just want to make sure, we'll get the right ones. This
invention's finance status is false and its rent/cost ratio is
0.5314233738962361 with a cost of 60.21564269065857 and a rent of
32.0.
Fund:  we'll finance the invention. Let's see if it works.
Fund: We have just financed a new invention which costs
60.21564269065857 from the capital stock which has now left
4092.8552647214747. So, in total, we have now invested
3263.314062841586.
Fund: Unfortunately, the invention failed.
Fund: I just want to make sure, we'll get the right ones. This
invention's finance status is false and its rent/cost ratio is
0.506095544728359 with a cost of 33.59049526730087 and a rent of
17.0.
Fund:  we'll finance the invention. Let's see if it works.
Fund: We have just financed a new invention which costs
33.59049526730087 from the capital stock which has now left
4059.264769454174. So, in total, we have now invested
3296.9045581088867.
Fund: Great, the invention turned out to be an innovation.
Fund: We had 0 no interest years.
Fund: We had 0 negative years.
```

3) Human agent

This is an exemplary message which a Human agent may return during the course of a year.

```
We'll start a new year, I'm updating my variables
My friends do have an effect on me. But to start with, I have a
risk aversion of 4, a time preference of 3 and my happiness is
61.0.
This friend has a risk aversion of 5, a time preference of 7 and
interests of 0.0 and 0.0.
This friend has a risk aversion of 5, a time preference of 4 and
interests of 0.0 and 0.0.
This friend has a risk aversion of 1, a time preference of 3 and
interests of 0.0 and 0.0.
This friend has a risk aversion of 6, a time preference of 3 and
interests of 0.0 and 0.0.
This friend has a risk aversion of 6, a time preference of 7 and
interests of 0.0 and 0.0.
My friends did have an effect on me. Now I have a risk aversion of
4, a time preference of 3 and my happiness is 58.0.
I'll see what revenue I can generate
I'm employed!
I'm working!
I'm working, I'll get an income of 29.37
And I get the rent from my innovations
Ok, so in total I get 0 EUR from my innovations.
I received 0.23412115199144307 EUR interest from my fund.
Furthermore, I get interest: From my bank, it's 0.0 and from my
fund it's 0.23412115199144307
I received or paid 0.41249547965838435 EUR interest from or to my
bank corresponding to an invested amount of 8.88073216532618.
Furthermore, I get interest: From my bank, it's 0.41249547965838435
and from my fund it's 0.0
I had no credit and just keep my savings account.
Ok, and I just repaid my credit
I have to look for my risk
Let's go for individual risk provision
Ok, I just emptied my bank account
Ok, I just deleted my savings or risk provision account
I just deleted my bank account
Here's a fund with 3.0071183065883815% interest...count for
average.
Here's a bank with 5.8401467038784185% interest...count for average
Here's a bank with 4.644836393883453% interest...count for average
Here's a bank with 4.110504244221374% interest...count for average
The interest gap between funds and banks I can see is -
1.8580441407393666%.
I will invest my risk provision at a bank because the interest gap
(-1.8580441407393666) is smaller than my risk aversion coefficient:
8.
Ok, so I found a new bank and will save my money here
I just saved 4.8436556589629625 in my bank account.
I had enough money for the subsistence minimum and I put 0.22 % as
savings into my account, that's 4.8436556589629625 EUR. Now I have
17.172960972686866 EUR left over for saving and consuming.
Now, I'll save or consume!
Here's a fund with 3.0071183065883815% interest...count for
average.
Here's a bank with 5.8401467038784185% interest...count for average
Here's a bank with 4.644836393883453% interest...count for average
Here's a bank with 4.110504244221374% interest...count for average
```

To calculate my consumption ratio, I take the interest offers from funds 0.030071183065883817 and from banks 0.058651624473277486 and the time preference 3 (as -0.04 into account.
My savings are 7.78556505337686 and I still have 17.172960972686866. Hey, I'd like to consume 81.41304981911345% of the amount of money I still have.
I just consumed 13.981031272110469 and so left over money is 3.191929700576397
I'm saving the left over money
Well, I'm out of all my investments
I just deleted my savings or my provision account
I just deleted my investment account
Here's a fund with 3.0071183065883815% interest...count for average.
Here's a bank with 5.8401467038784185% interest...count for average
Here's a bank with 4.644836393883453% interest...count for average
Here's a bank with 4.110504244221374% interest...count for average
The interest gap between funds and banks I can see is -1.8580441407393666%.
I will invest my savings at a fund because the interest gap (-1.8580441407393666) is greater than my risk aversion coefficient: -4.
Ok, so I found a new fund and will invest my money here
I just invested 3.191929700576397 in my fund.
I have been saving money which I didn't consume
My risk aversion is 4 and accordingly, the risk Influence is 1.96.
I invented something. My invention propensity was 68.404.
I couldn't finance the invention. My finance propensity was -33.37415202701445.

Appendix D: Analysis of the different runs

1) Run 1: Default values

t-test: Paired Two Sample for Mean	**Individual Model**	**Governmental Model**
	Amount of inventions	
	invent-individual	*invent-governmental*
Mean	657.65	714.73
Variance	7592.957071	7488.562727
Observations	100	100
Pearson Correlation	0.513747675	
Hypothesized Mean Difference	0	
df	99	
t Stat	-6.665382365	
P(T<=t) one-tail	7.55158E-10	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	1.51032E-09	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean	**Amount of innovations**	
	inno-individual	*inno-governmental*
Mean	272.48	325.17
Variance	23935.90869	18856.38495
Observations	100	100
Pearson Correlation	0.303317286	
Hypothesized Mean Difference	0	
df	99	
t Stat	-3.046916276	
P(T<=t) one-tail	0.001482019	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.002964039	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean	**Ratio of innovations from inventions**	
	ratio	*ratio*
Mean	0.400151169	0.451448675
Variance	0.047096872	0.032142234
Observations	100	100
Pearson Correlation	0.252298599	
Hypothesized Mean Difference	0	
df	99	
t Stat	-2.10111391	
P(T<=t) one-tail	0.019085329	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.038170657	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean	**Mean income**	
	mean inc	*mean inc (a)*
Mean	31.15618511	37.51908206
Variance	130.307857	43.67698643
Observations	100	100
Pearson Correlation	0.393355459	
Hypothesized Mean Difference	0	
df	99	
t Stat	-5.942896197	
P(T<=t) one-tail	2.0991E-08	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	4.1982E-08	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean **Mean standard deviation**

	mean sd	*mean sd (a)*
Mean	48.22591291	31.96204167
Variance	62.02009072	74.89395084
Observations	100	100
Pearson Correlation	0.263020092	
Hypothesized Mean Difference	0	
df	99	
t Stat	16.17815623	
P(T<=t) one-tail	7.46973E-30	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	1.49395E-29	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean **Mean risk aversion**

	mean r_a	*mean r_a*
Mean	6.110927869	6.030619672
Variance	0.556969204	0.52048781
Observations	100	100
Pearson Correlation	0.541343491	
Hypothesized Mean Difference	0	
df	99	
t Stat	1.142008178	
P(T<=t) one-tail	0.128102604	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.256205209	
t Critical two-tail	2.62640545	

2) Run 2: Without merit goods

t-test: Paired Two Sample for Mean	**Individual Model**	**Governmental Model**
	Amount of Inventions	
	invent	*invent*
Mean	658.47	693.35
Variance	7607.928384	6604.714646
Observations	100	100
Pearson Correlation	0.508490003	
Hypothesized Mean Difference	0	
df	99	
t Stat	-4.16786126	
P(T<=t) one-tail	3.29476E-05	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	6.58953E-05	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean	**Amount of Innovations**	
	inno	*inno*
Mean	272.81	284.6
Variance	23951.20596	22652.06061
Observations	100	100
Pearson Correlation	0.112710028	
Hypothesized Mean Difference	0	
df	99	
t Stat	- 0.579778518	
P(T<=t) one-tail	0.281690558	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.563381116	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean	**Ratio of innovations from inventions**	
	ratio	*ratio*
Mean	0.400053511	0.409576287
Variance	0.047028054	0.043895455
Observations	100	100
Pearson Correlation	0.054380356	
Hypothesized Mean Difference	0	
df	99	
t Stat	-0.324757981	
P(T<=t) one-tail	0.373024747	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.746049495	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean	**Mean income**	
	mean inc	*mean inc (a)*
Mean	31.13013733	36.10223009
Variance	130.3801956	47.58457219
Observations	100	100
Pearson Correlation	0.214384198	
Hypothesized Mean Difference	0	
df	99	
t Stat	-4.14064555	
P(T<=t) one-tail	3.64588E-05	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	7.29175E-05	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean **Mean standard deviation**

	mean sd	*mean sd (a)*
Mean	48.14648419	30.41069296
Variance	63.77418895	82.24164091
Observations	100	100
Pearson Correlation	0.181881513	
Hypothesized Mean Difference	0	
df	99	
t Stat	16.21269354	
P(T<=t) one-tail	6.40462E-30	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	1.28092E-29	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean **Mean risk aversion**

	mean r_a	*mean r_a*
Mean	6.110904918	6.126085246
Variance	0.543885991	0.41789418
Observations	100	100
Pearson Correlation	0.404878782	
Hypothesized Mean Difference	0	
df	99	
t Stat	-0.200065025	
P(T<=t) one-tail	0.420920058	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.841840117	
t Critical two-tail	2.62640545	

3) Run 3: Low subsistence minimum

	Individual Model	**Governmental Model**
t-test: Paired Two Sample for Mean	**Amount of Inventions**	

	invent	*invent*
Mean	653.46	728.02
Variance	6600.190303	6087.898586
Observations	100	100
Pearson Correlation	0.644987975	
Hypothesized Mean Difference	0	
df	99	
	-	
t Stat	11.10106891	
P(T<=t) one-tail	2.20544E-19	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	4.41087E-19	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean	**Amount of Innovations**	

	inno	*inno*
Mean	277.98	325.76
Variance	17215.79758	21841.96202
Observations	100	100
Pearson Correlation	0.133548415	
Hypothesized Mean Difference	0	
df	99	
	-	
t Stat	2.595881466	
P(T<=t) one-tail	0.005434822	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.010869643	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean	**Ratio of innovations from inventions**	
	ratio	*ratio*
Mean	0.421830026	0.445181951
Variance	0.034823272	0.037413784
Observations	100	100
Pearson Correlation	0.072337534	
Hypothesized Mean Difference	0	
df	99	
t Stat	-0.90206281	
P(T<=t) one-tail	0.184606475	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.36921295	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean	**Mean income**	
	mean inc	*mean inc (a)*
Mean	33.96177355	34.85029574
Variance	59.07253169	54.11252349
Observations	100	100
Pearson Correlation	0.265231328	
Hypothesized Mean Difference	0	
df	99	
t Stat	- 0.974143943	
P(T<=t) one-tail	0.166179662	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.332359323	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean **Mean standard deviation**

	mean sd	*mean sd (a)*
Mean	36.85520415	33.49294513
Variance	81.30638178	71.28777952
Observations	100	100
Pearson Correlation	0.107074442	
Hypothesized Mean Difference	0	
df	99	
t Stat	2.880039251	
P(T<=t) one-tail	0.002437069	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.004874138	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean **Mean risk aversion**

	mean r_a	*mean r_a*
Mean	6.120029508	6.0004
Variance	0.537268815	0.526192897
Observations	100	100
Pearson Correlation	0.443117212	
Hypothesized Mean Difference	0	
df	99	
t Stat	1.55448351	
P(T<=t) one-tail	0.061630122	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.123260245	
t Critical two-tail	2.62640545	

4) Run 4: High subsistence minimum

	Individual Model	**Governmental Model**
t-test: Paired Two Sample for Mean	**Amount of Inventions**	

	invent	*invent*
Mean	651.28	723.35
Variance	7252.122828	6865.118687
Observations	100	100
Pearson Correlation	0.547849437	
Hypothesized Mean Difference	0	
df	99	
t Stat	-9.018601613	
P(T<=t) one-tail	7.54691E-15	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	1.50938E-14	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean **Amount of Innovations**

	inno	*inno*
Mean	281.86	316.9
Variance	18875.67717	21230.13131
Observations	100	100
Pearson Correlation	0.229688907	
Hypothesized Mean Difference	0	
df	99	
t Stat	-1.993038746	
P(T<=t) one-tail	0.024504732	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.049009465	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean **Ratio of innovations from inventions**

	ratio	*ratio*
Mean	0.421706671	0.434697227
Variance	0.036705059	0.035477689
Observations	100	100
Pearson Correlation	0.19549833	
Hypothesized Mean Difference	0	
df	99	
t Stat	-0.539063527	
P(T<=t) one-tail	0.295526618	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.591053236	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean **Mean income**

	mean inc	*mean inc (a)*
Mean	24.62070296	38.90796819
Variance	159.0017223	47.97436629
Observations	100	100
Pearson Correlation	0.28956753	
Hypothesized Mean Difference	0	
df	99	
t Stat	-11.42450063	
P(T<=t) one-tail	4.4133E-20	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	8.8266E-20	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean **Mean standard deviation**

	mean sd	*mean sd (a)*
Mean	65.13009529	31.8040236
Variance	508.6517448	70.14700749
Observations	100	100
Pearson Correlation	0.126711912	
Hypothesized Mean Difference	0	
df	99	
t Stat	14.4632519	
P(T<=t) one-tail	1.87004E-26	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	3.74008E-26	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean **Mean risk aversion**

	mean r_a	*mean r_a*
Mean	6.186537705	6.101845902
Variance	0.540587306	0.427613304
Observations	100	100
Pearson Correlation	0.447828275	
Hypothesized Mean Difference	0	
df	99	
t Stat	1.155106213	
P(T<=t) one-tail	0.125413666	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.250827332	
t Critical two-tail	2.62640545	

5) Run 1 vs. Run 3 in the Governmental Model

	Run 1	**Run 3**
t-test: Paired Two Sample for Mean	**Amount of Inventions**	
	invent	*invent*
Mean	714.73	728.02
Variance	7488.562727	6087.898586
Observations	100	100
Pearson Correlation	0.655508025	
Hypothesized Mean Difference	0	
df	99	
t Stat	-1.933518827	
P(T<=t) one-tail	0.028014305	
t Critical one-tail	1.660391157	
P(T<=t) two-tail	0.05602861	
t Critical two-tail	1.9842169	

t-test: Paired Two Sample for Mean	**Amount of Innovations**	
	inno	*inno*
Mean	325.17	325.76
Variance	18856.38495	21841.96202
Observations	100	100
Pearson Correlation	0.491584458	
Hypothesized Mean Difference	0	
df	99	
t Stat	-0.040962763	
P(T<=t) one-tail	0.48370404	
t Critical one-tail	1.660391157	
P(T<=t) two-tail	0.967408079	
t Critical two-tail	1.9842169	

t-test: Paired Two Sample for Mean	**Ratio of innovations from inventions**	
	ratio	*ratio*
Mean	0.451448675	0.445181951
Variance	0.032142234	0.037413784
Observations	100	100
Pearson Correlation	0.446001729	
Hypothesized Mean Difference	0	
df	99	
t Stat	0.318872332	
P(T<=t) one-tail	0.375247561	
t Critical one-tail	1.660391157	
P(T<=t) two-tail	0.750495121	
t Critical two-tail	1.9842169	

t-test: Paired Two Sample for Mean	**Mean income**	
	mean inc (a)	*mean inc (a)*
Mean	37.51908206	34.85029574
Variance	43.67698643	54.11252349
Observations	100	100
Pearson Correlation	0.578385688	
Hypothesized Mean Difference	0	
df	99	
t Stat	4.140145341	
P(T<=t) one-tail	3.65265E-05	
t Critical one-tail	1.660391157	
P(T<=t) two-tail	7.30531E-05	
t Critical two-tail	1.9842169	

t-test: Paired Two Sample for Mean **Mean standard deviation**

	mean sd (a)	*mean sd (a)*
Mean	31.96204167	33.49294513
Variance	74.89395084	71.28777952
Observations	100	100
Pearson Correlation	0.437492516	
Hypothesized Mean Difference	0	
df	99	
	-	
t Stat	1.688051578	
P(T<=t) one-tail	0.047274639	
t Critical one-tail	1.660391157	
P(T<=t) two-tail	0.094549278	
t Critical two-tail	1.9842169	

t-test: Paired Two Sample for Mean **Mean risk aversion**

	mean r_a	*mean r_a*
Mean	6.030619672	6.0004
Variance	0.52048781	0.526192897
Observations	100	100
Pearson Correlation	0.541398094	
Hypothesized Mean Difference	0	
df	99	
t Stat	0.436175133	
P(T<=t) one-tail	0.33182968	
t Critical one-tail	1.660391157	
P(T<=t) two-tail	0.66365936	
t Critical two-tail	1.9842169	

Analysis of the different runs - Run 1 vs. Run 3 in the Governmental Model

t-test: Paired Two Sample for Mean **Mean subsistence minimum**

	mean s_m	*mean s_m*
Mean	8.633723825	4.286393017
Variance	0.49389612	0.048023597
Observations	100	100
Pearson Correlation	0.282382032	
Hypothesized Mean Difference	0	
df	99	
t Stat	64.45328753	
P(T<=t) one-tail	5.8801E-83	
t Critical one-tail	1.660391157	
P(T<=t) two-tail	1.17602E-82	
t Critical two-tail	1.9842169	

t-test: Paired Two Sample for Mean **Mean contribution social services**

	mean contrib	*mean contrib*
Mean	0.121967213	0.084481967
Variance	0.001238086	0.000595522
Observations	100	100
Pearson Correlation	0.530764304	
Hypothesized Mean Difference	0	
df	99	
t Stat	12.34437766	
P(T<=t) one-tail	4.73372E-22	
t Critical one-tail	1.660391157	
P(T<=t) two-tail	9.46744E-22	
t Critical two-tail	1.9842169	

6) Run 1 vs. Run 4 in the Governmental Model

t-test: Paired Two Sample for Mean	**Run 1**	**Run 4**
	Amount of Inventions	
	invent	*invent*
Mean	714.73	723.35
Variance	7488.562727	6865.118687
Observations	100	100
Pearson Correlation	0.752620205	
Hypothesized Mean Difference	0	
df	99	
t Stat	-1.444511268	
P(T<=t) one-tail	0.07587639	
t Critical one-tail	1.660391157	
P(T<=t) two-tail	0.151752781	
t Critical two-tail	1.9842169	

t-test: Paired Two Sample for Mean	**Amount of Innovations**	
	inno	*inno*
Mean	325.17	316.9
Variance	18856.38495	21230.13131
Observations	100	100
Pearson Correlation	0.634699282	
Hypothesized Mean Difference	0	
df	99	
t Stat	0.68237018	
P(T<=t) one-tail	0.248299214	
t Critical one-tail	1.660391157	
P(T<=t) two-tail	0.496598427	
t Critical two-tail	1.9842169	

Analysis of the different runs - Run 1 vs. Run 4 in the Governmental Model

t-test: Paired Two Sample for Mean	**Ratio of innovations from inventions**	
	ratio	*ratio*
Mean	0.451448675	0.434697227
Variance	0.032142234	0.035477689
Observations	100	100
Pearson Correlation	0.635767189	
Hypothesized Mean Difference	0	
df	99	
t Stat	1.06626359	
P(T<=t) one-tail	0.144448972	
t Critical one-tail	1.660391157	
P(T<=t) two-tail	0.288897943	
t Critical two-tail	1.9842169	

t-test: Paired Two Sample for Mean	**Mean income**	
	mean inc (a)	*mean inc (a)*
Mean	37.51908206	38.90796819
Variance	43.67698643	47.97436629
Observations	100	100
Pearson Correlation	0.694896166	
Hypothesized Mean Difference	0	
df	99	
t Stat	-2.623192084	
P(T<=t) one-tail	0.005044246	
t Critical one-tail	1.660391157	
P(T<=t) two-tail	0.010088492	
t Critical two-tail	1.9842169	

t-test: Paired Two Sample for Mean **Mean standard deviation**

	mean sd (a)	*mean sd (a)*
Mean	31.96204167	31.8040236
Variance	74.89395084	70.14700749
Observations	100	100
Pearson Correlation	0.606498697	
Hypothesized Mean Difference	0	
df	99	
t Stat	0.209078371	
P(T<=t) one-tail	0.417408332	
t Critical one-tail	1.660391157	
P(T<=t) two-tail	0.834816665	
t Critical two-tail	1.9842169	

t-test: Paired Two Sample for Mean **Mean risk aversion**

	mean r_a	*mean r_a*
Mean	6.030619672	6.101845902
Variance	0.52048781	0.427613304
Observations	100	100
Pearson Correlation	0.663653608	
Hypothesized Mean Difference	0	
df	99	
t Stat	- 1.255359999	
P(T<=t) one-tail	0.10615157	
t Critical one-tail	1.660391157	
P(T<=t) two-tail	0.212303141	
t Critical two-tail	1.9842169	

t-test: Paired Two Sample for Mean **Mean subsistence minimum**

	mean s_m	*mean s_m*
Mean	8.633723825	9.249894799
Variance	0.49389612	0.909216668
Observations	100	100
Pearson Correlation	0.588946152	
Hypothesized Mean Difference	0	
df	99	
t Stat	-7.864894552	
P(T<=t) one-tail	2.33405E-12	
t Critical one-tail	1.660391157	
P(T<=t) two-tail	4.6681E-12	
t Critical two-tail	1.9842169	

t-test: Paired Two Sample for Mean **Mean contribution social services**

	mean contrib	*mean contrib*
Mean	0.121967213	0.142068852
Variance	0.001238086	0.001507955
Observations	100	100
Pearson Correlation	0.639091259	
Hypothesized Mean Difference	0	
df	99	
t Stat	-6.358077802	
P(T<=t) one-tail	3.16175E-09	
t Critical one-tail	1.660391157	
P(T<=t) two-tail	6.32351E-09	
t Critical two-tail	1.9842169	

7) Run 5: Easier access to inventions

t-test: Paired Two Sample for Mean	**Individual Model**	**Governmental Model**
	Amount of Inventions	
	invent	*invent*
Mean	1351.21	1396.79
Variance	6234.692828	7904.793838
Observations	100	100
Pearson Correlation	0.54816922	
Hypothesized Mean Difference	0	
df	99	
t Stat	-5.678494331	
P(T<=t) one-tail	6.81179E-08	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	1.36236E-07	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean	**Amount of Innovations**	
	inno	*inno*
Mean	655.31	691.76
Variance	26986.17566	24767.09333
Observations	100	100
Pearson Correlation	0.269306148	
Hypothesized Mean Difference	0	
df	99	
t Stat	-1.874076522	
P(T<=t) one-tail	0.031934336	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.063868672	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean **Ratio of innovations from inventions**

	ratio	*ratio*
Mean	0.482570084	0.494016283
Variance	0.013372504	0.010603993
Observations	100	100
Pearson Correlation	0.209920476	
Hypothesized Mean Difference	0	
df	99	
t Stat	-0.830897505	
P(T<=t) one-tail	0.204015484	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.408030967	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean **Mean income**

	mean inc	*mean inc (a)*
Mean	58.05274053	56.66447212
Variance	163.8999285	84.69281221
Observations	100	100
Pearson Correlation	0.344910209	
Hypothesized Mean Difference	0	
df	99	
t Stat	1.073248857	
P(T<=t) one-tail	0.142884284	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.285768569	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean **Mean standard deviation**

	mean sd	*mean sd (a)*
Mean	59.3383171	48.34254543
Variance	68.7312029	116.5257469
Observations	100	100
Pearson Correlation	0.236630635	
Hypothesized Mean Difference	0	
df	99	
t Stat	9.198230617	
P(T<=t) one-tail	3.06699E-15	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	6.13399E-15	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean **Mean risk aversion**

	mean r_a	*mean r_a*
Mean	5.491557377	5.588245902
Variance	0.614345824	0.644567883
Observations	100	100
Pearson Correlation	0.429541157	
Hypothesized Mean Difference	0	
df	99	
t Stat	-1.140821447	
P(T<=t) one-tail	0.128348226	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.256696452	
t Critical two-tail	2.62640545	

8) Run 6: more difficult access to inventions

t-test: Paired Two Sample for Mean	**Individual Model**	**Governmental Model**
	Amount of Inventions	
	invent	*invent*
Mean	241.81	312.3
Variance	3503.81202	3443.020202
Observations	100	100
Pearson Correlation	0.653440205	
Hypothesized Mean Difference	0	
df	99	
t Stat	-14.36578424	
P(T<=t) one-tail	2.94901E-26	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	5.89802E-26	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean	**Amount of Innovations**	
	inno	*inno*
Mean	46.78	87.36
Variance	5311.304646	7978.778182
Observations	100	100
Pearson Correlation	0.267193831	
Hypothesized Mean Difference	0	
df	99	
t Stat	-4.096834253	
P(T<=t) one-tail	4.2877E-05	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	8.57539E-05	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean	**Ratio of innovations from inventions**	
	ratio	*ratio*
Mean	0.166554393	0.266651217
Variance	0.062128375	0.069293703
Observations	100	100
Pearson Correlation	0.234718683	
Hypothesized Mean Difference	0	
df	99	
t Stat	- 3.155560683	
P(T<=t) one-tail	0.001061165	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.00212233	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean	**Mean income**	
	mean inc	*mean inc (a)*
Mean	15.6787844	27.45444365
Variance	28.98094995	14.59929373
Observations	100	100
Pearson Correlation	0.440888821	
Hypothesized Mean Difference	0	
df	99	
t Stat	- 23.34557876	
P(T<=t) one-tail	2.40446E-42	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	4.80892E-42	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean **Mean standard deviation**

	mean sd	*mean sd (a)*
Mean	40.86485021	20.66804179
Variance	27.96403037	37.44551644
Observations	100	100
Pearson Correlation	0.353245412	
Hypothesized Mean Difference	0	
df	99	
t Stat	30.9630234	
P(T<=t) one-tail	5.02009E-53	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	1.00402E-52	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean **Mean risk aversion**

	mean r_a	*mean r_a*
Mean	6.525836066	6.414829508
Variance	0.511485104	0.388354191
Observations	100	100
Pearson Correlation	0.739245011	
Hypothesized Mean Difference	0	
df	99	
t Stat	2.261700006	
P(T<=t) one-tail	0.012951384	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.025902769	
t Critical two-tail	2.62640545	

9) Run 7: lower risk provision

t-test: Paired Two Sample for Mean	**Individual Model**	**Governmental Model**
	Amount of Inventions	
	invent	*invent*
Mean	662.93	720.76
Variance	5916.510202	6261.275152
Observations	100	100
Pearson Correlation	0.499395817	
Hypothesized Mean Difference	0	
df	99	
t Stat	-7.405169181	
P(T<=t) one-tail	2.20312E-11	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	4.40625E-11	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean	**Amount of Innovations**	
	inno	*inno*
Mean	281.51	337.67
Variance	18629.16152	14858.42535
Observations	100	100
Pearson Correlation	0.325644442	
Hypothesized Mean Difference	0	
df	99	
t Stat	-3.731426102	
P(T<=t) one-tail	0.000158887	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.000317773	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean	**Ratio of innovations from inventions**	
	ratio	*ratio*
Mean	0.416131893	0.467343436
Variance	0.036033352	0.024833434
Observations	100	100
Pearson Correlation	0.246000256	
Hypothesized Mean Difference	0	
df	99	
t Stat	- 2.383887331	
P(T<=t) one-tail	0.009518641	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.019037282	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean	**Mean income**	
	mean inc	*mean inc (a)*
Mean	24.50103169	39.05222451
Variance	1626.775274	37.26195427
Observations	100	100
Pearson Correlation	0.033971289	
Hypothesized Mean Difference	0	
df	99	
t Stat	-3.58518031	
P(T<=t) one-tail	0.000262501	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.000525002	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean

Mean standard deviation

	mean sd	*mean sd (a)*
Mean	55.462924	33.49061991
Variance	811.0425181	65.54172572
Observations	100	100
Pearson Correlation	0.099854501	
Hypothesized Mean Difference	0	
df	99	
t Stat	7.624219805	
P(T<=t) one-tail	7.58883E-12	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	1.51777E-11	
t Critical two-tail	2.62640545	

t-test: Paired Two Sample for Mean

Mean risk aversion

	mean r_a	*mean r_a*
Mean	6.174560656	6.048540984
Variance	0.444739623	0.543838057
Observations	100	100
Pearson Correlation	0.575437725	
Hypothesized Mean Difference	0	
df	99	
t Stat	1.938584799	
P(T<=t) one-tail	0.027699888	
t Critical one-tail	2.364605852	
P(T<=t) two-tail	0.055399777	
t Critical two-tail	2.62640545	

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