# Capital markets from an evolutionary perspective: the State Preference Model reconsidered

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## 1. Introduction

The State-Preference Model (SPM) developed by Arrow (1964) and constructed on the equilibrium framework of Debreu (1959) is regarded as the basic model of the neoclassical capital market theory. Many subsequent works of this type e.g. the Capital-Asset-Pricing Model (Sharpe (1964)) or the Arbitrage Pricing Theory (Ross (1976)) take recourse to certain assumptions and results of the SPM.

The SPM describes an individual's decision about his optimal portfolio choice with respect to exogenously given states of the environment. In consideration of certain conditions the aim of the agent is to maximize his expected utility. Under the assumptions of a complete capital market and state independence of the risk utility function, the existence of a capital market equilibrium under uncertainty is shown. All individuals are optimally adapted to each other and to the environment. Therefore, every change of the equilibrium price is the result of an exogenous shock generating mechanism. This aspect is almost valid for the whole neoclassical capital market theory. Due to this model specifications, arbitrage opportunities or learning and adjustment mechanisms are not describable.

Contrarily, the adaptive, evolutionary approach focuses an evolving, self-transforming economic system.[1] The system elements endogenously change, and new variables as well as new mechanisms of interaction can appear from within the system itself, leading to a changing taxonomy. Of special interest are the mechanisms that describe how agents make decisions, how prices are determined, and how changes take place out of equilibrium (Day/Chen (1993)). Instead of a given, and for all individuals binding state space the formation of individual state spaces is regarded.

This fundamental shift of perspective leads to a more or less explicitly modelling of the microscopic diversity in capital market theory (Landes/Loistl (1992)). It is no longer assumed that a single agent is describable by a representive market participant, acting in a full rational manner. Instead of this, the individuals can never be perfectly informed but are, to some extend, able to adapt their behaviour and to learn for themselves. However, a high degree of nonlinearity and complex behaviour characterizes the interdependences on the aggregate level.

The approaches using nonlinear methods from natural sciences have been greatly enhanced during the last decade. In some further synergetic models mutual mimetic contagion generates a dynamical system in which the behaviour of the individuals is controlled endogenously (Brenner (1994), Lux (1995)).

Typical for these models, on the one hand, is a significant rise in complexity and, on the other hand, is the lack of principles and methods of traditional decision theory. Until now, a consistent theoretical basis of the individuals' behaviour and their modifications does not exist. Obviously, general principles which should be comparable to the standards of the neoclassical theory cannot be adressed clearly. Further, the integration of traditional economic theory in evolutionary models only takes place on the nonformal level and lacks the rigorous analytical foundation. „Sadly, the simple organizing principles of economic thought which bound together the community of economists in the past has fragmented to such an extend that economists are frequently the subject of ridicule amongst members of the general public" (Foster/Wild (1994)).

The purpose of this paper is to enlarge a generally accepted and often used fundamental approach of capital market theory in the evolutionary sense. Our intention is to develop the basics

[1] The idea of a self-transforming system is emphasised by Schumpeter (1934)

of a model which is oriented on the evolutionary theory and rooted in the stringency of the neoclassical decision theory. As we mentioned above, in most cases this is the lack of the evolutionary model conceptions in our days.

Therefore, we use the SPM and overtake certain basic assumptions, concerning the decision and risk behaviour of the agents. But we do not accept the neoclassical condition that the agents are always optimally adapted to exogenous given environmental states. However, in our model the agents generate the state realisation due to their actions. The explicit development of individual and aggregate state spaces determined by the subjective price expectations of the market participants, creates the condition for evolutionary extensions. Mainly these are: Endogenous adaption processes because of heterogeneous and interacting agents, the enlargement of the mechanically optimization behaviour to cognitive founded decision routines, and the integration in more complex modelling techniques, like the neural network approach.

Furthermore, we can show that an evolutionary oriented model, on the one hand, can be logically constructed on neoclassical insights but, on the other hand, can generate results which are beyond the neoclassical findings. The applicability of this model for simulation runs allows a more realistic and evident description of how capital markets work.

The paper is organized as follows:
We start with a short explanation of the basic assumptions and the equilibrium implications of the SPM. In the following section we enlarge this model by integrating expectations and derive individual demand functions of risky securities. The shape and the slope of these curves are determined by the price expectations and the risk attitudes of the agents. By using these demand functions, we specify in the next section the micro- and macrostructure of the market as the individual respectively aggregate state spaces. Each state is destinated by the degree of the decision makers' heterogenity. In the following section two simulation runs point out the main results and possible evolutionary enlargements are discussed. Finally we summarize and give an outlook for further work.

## 2. The General Assumptions and the Equilibrium Implications of the SPM

The model of Arrow has a finite number of exogenously given states s = 1,...,S describing the environment in the next period. By definition, the S states are mutually exclusive and exhaustive. Let Ki,..,7ts , Z, = lπ,denote the objective probability that state s occurs at date-one. At date-zero the individual makes a decision about the optimal consumption vector a = (c,w) = $(c, w_1, \ldots, w_s)$, where c denotes the current consumption and $w_s$ denotes the possible consumption if state s occurs at date-one. Every individual has preferences with respect to the available consumption patterns. The risk utility function represents those preferences and formally satisfies:

**Definition 1.** Risk Utility Function

The expected utility (risk utility) of a consumption pattern a

$$V(a) = \sum_s \pi_s U(c, w_s)$$

is monotonically increasing and strictly concave for any n > 0 if for all s

$$\frac{\partial U}{\partial c} > 0, \quad \frac{\partial U}{\partial w_s} > 0 \text{ and } U(k(c'', w_s'') + (1-k)(c', w_s')) > k\,U(c'', w_s'') + (1-k)U(c', w_s')$$

where $0 < k < 1$ and $(c'', w_s'') \neq (c', w_s')$.

In addition to a market for the consumption good, a market for securities offers the individual trading opportunities. The economy consist of j = 1...,J securities (assets, options, etc.). One unit of security j is priced at $p_j$ at date-zero. With no loss of generality, the unit cost of the current consumption good equals one.

The vector $z = (z_1, \ldots, z_J)$ summarizes the individual's portfolio of security holdings at date-zero. The total cost of that portfolio therefore adds up to $zP = \sum_j z_j p_j$, where $P = (p_1, \ldots, p_J)$. The gross payoff across securities and states at date-one is exogenously given and summarized at the following J x S matrix A :

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1S} \\ \vdots & & \vdots \\ a_{J1} & \cdots & a_{JS} \end{bmatrix}.$$

where the single element $a_{js}$ denotes the gross payoff of security j in state s.

The individual's resources are his endowed wealth, denoted by $\bar{w}$. Its value depends on the initial endowments in securities $\bar{z}$, and in the current consumption good $\bar{c}$.

Therefore, the budget constraint is given by:

$$c + \sum_j z_j P_j \leq \bar{w} = \bar{c} + \sum_j \bar{z}_j P_j .$$

The individual's decision problem leads to:

Definition 2. Standard Problem I

The individual solves the maximization problem

$$\max_a V(a) = \max_{(c,z)} V(c, zA) = \max_{(c,z)} V\left(c, \sum_j z_j a_{js}\right)$$

subject to

$$c + \sum_j z_j P_j \leq \bar{c} + \sum_j \bar{z}_j P_j .$$

Assuming a complete capital market and $i = 1, ..., I$ noninteracting individuals solving the Standard Problem I the equilibrium looks like the following:

Definition 3. General Capital Market Equilibrium

Consider a pay off matrix A, individuals with preferences $V_i$, $i = 1, ..., I$, and initial endowments $(\bar{c}_i, \bar{z}_i)$. Then a price vector P and allocation $(c_i, z_i)$ constitute a general capital market equilibrium if,

(i) $(c_i, z_i)$ solves the individual standart problem I and,

(ii) $(c_i, z_i)$ satisfies the constraints $\sum_i c_i = \sum_i \bar{c}_i$ and $\sum_i z_{ij} = \sum_i \bar{z}_{ij}$ for all $j = 1, ..., J$.

That basic model of the neoclassical capital market theory was modified in several ways. However, in all variants the existence of the equilibrium price vector is demonstrated which efficiently evaluates the individual's uncertainty at date-zero.

A usual modification of this model is to differentiate the agents' attitudes towards risk aversion. In general, risk averse behaviour of the individuals is determined by the state independence combined with the concavity of V(.). The neoclassical theory mainly uses two measures characterizing risky behaviour.

**Definition 4.** Absolute and Relative Risk Aversion

Agent i is absolutely (relatively) more risk averse than agent j if his utility function of Definition 1 is additive separabel, i.e. $U(c,w) = U^1(c)+U^2(w)$, and moreover for $k \in \{ij\}$, $i \neq j$ the following inequality holds:[2]

$A_i(w)>A_j(w)$ with $A_k(w) = - \frac{\wedge - \wedge -}{U\,k(w)}$ $(R_i(w)>R_j(w)$ with $R_k(w) = - \frac{\wedge \wedge y}{U\,k(w)}\,W)$.

Despite all elegance and logical stringency one problem still remains in all model specifications of that type. Every variation of the equilibrium price vector only occurs because of an exogenously given change in the parameters. Then, the instantaneous reaction of all individuals appears as an optimal adaption. Therefore, arbitrage opportunities and learning or adaption processes, which are observed in real capital markets, cannot be described. Moreover, individual optimality always guaranties an optimal market result where interactive components are irrelevant.

In the following, we develop a model that, on the one hand, adopts certain basic assumptions of the SPM and, on the other hand, is extensible to evolutionary elements.

## 3. The Model

### 3.1 Specification of the Basic Model

We also assume that the economy consist of i = 1,...,I agents, where $\overline{w_t}$ denotes the endowed wealth agent i. At date-zero, every agent makes a decision about his portfolio of security holdings. There are only two securities to select: The risk-free security 0 and the risky security M. In contrast to the neoclassical formulation above, we assume that current consumption is independent of the investment in securities.[3] In addition to that, we assume that the prices of both securities are well known and equal to one at date-zero. While the individuals know the price of the risk-free security at date-one, they have to build expectations about the price of the uncertain security M. For every market participant only two states of the security M are of interest: State 1 reflects an expected gain, and state 2 an expected loss situation. These price expectations are summarized in the following expectation matrix $E_p$:[4]

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[2] There is: $U^2{}'(w)_k = \frac{JTT2}{dw}$ and $U^2{}''(w)_k = \frac{J\,2T\,T2}{dw}$.

[3] Short selling is explicitly allowed (see e.g. Sargent(1979)).

[4] We assume that all ecpected profits of M are included in that price expectations.

$$E_p = \begin{bmatrix} e_{11} & e_{12} \\ \vdots & \vdots \\ e_{I1} & e_{I2} \end{bmatrix}.$$

In this I x 2 - matrix the single element $e_{is}$, SG{1,2} denotes the price expectation of agent i if he assumes that state s is realized at date-one. Depending on the state of nature the agent's expected wealth is given by:

$$w_{is} = mi\ e_{is} + Oj\ p_o$$

where mi (Oi) denotes the demand of security M (O) and po denotes the price of security 0 at date-one. To tract the expected gain or loss situation analytically, the price expectations have to look like $1 < eii < \infty$ and $0 \leq ei2 \leq 1$. Moreover, and with no loss of generality we assume that the price of the risk free security remains unchanged.

Notice here, in contrast to the formulation of the SPM, that in our case both states are expected with a certain subjective probability and not given exogenously. Moreover, because of their generality, those states have to be considered as aggregate values respectively state classes. For the formation of the expectations on the individual level those two states are classified more or less detailed. We describe possible expectation building mechanisms below.

In accordance with neoclassical theory we assume that subjective probabilities $7ti_s$ with $Z_s\ 7t_{is}$ = 1 exist reflecting the individual's confidence in the occurance of the two expected states. But, in our approach, these probabilities have a completely different meaning. The agents act according to their expectations and generate in this way the state that arises at date-one endogenously. This includes the possibility, that the state that is realized is not identical with the states the individuals have expected. In the SPM the alternative states are determined exogenously and could be regarded as an „either/or" restriction. In our model the realization of the state at date-one depends on the expectations of the market participants. Hence, the state probability reflects the individual's belief that his price expectation prevails on the market. So, this subjective estimation could be regarded as a second expectation component wich is highly influenced by interaction. With this distinction we are following to a certain extend the uncertainty concept of Knight (1921). In section 4.2 we explicitly take this aspect into account.

The risk utility function in Definition 1 totally represents the preferences of the individuals. In analogy to most of the neoclassical capital market models we suppose the formal property of linear risk tolerance for the individual utility functions, defined as follows (Ohlson 1987):

**Definition 5.** Linear Risk Tolerance

The time-additive and state independent utility function $U(c,w) = U^1(c)+U^2(w)$ satisfies linear risk tolerance if $U^2(w)$ solves the following differentia! equation:

$$-\frac{U^{2\prime}(w)}{U^{2\prime\prime}(w)} = \rho + \beta w \quad \text{with} \quad U^{2\prime}(w) = \frac{dU^2}{dw}, \quad U^{2\prime\prime}(w) = \frac{d^2U^2}{dw^2}$$

where p and P are independent of w.

The solution of the differential equation of Definition 5 is unique up to a linear transform, and one gets three classes of utility functions, depending on the value of P and p:

$$\text{(i)} \quad \beta \neq 0,1 \quad \Rightarrow \quad U^2(w) = \frac{n}{1-n}(\rho + \beta w)^{1-n} \text{ with } n := \frac{1}{\beta},$$

$$\text{(ii)} \quad \beta = 1 \quad \Rightarrow \quad U^2(w) = \log(\rho + w),$$

$$\text{(iii)} \quad \beta = 0 \quad \Rightarrow \quad U^2(w) = -\rho\, e^{-\frac{w}{\rho}}.$$

One easily verifies that for $p > 0$ and $P > 0$ (case (i)) the concavity property of Definition 1 is satiesfied for all $w > 0$.[5]

Furthermore, for modelling the microstructure of the capital market exactly, we need a property of the individual utility function.

**Definition 6.** Uniqueness of the Risk Measures

The utility functions of agent i respectively agent j are unique with regard to the risk measures Ai(w) and Aj(w) (Ri(w) and Rj(w)) if for all w:

$$Ai(w) > Aj(w) \; (Ri(w) > Rj(w)).$$

For linear risk tolerant utilities of Type (i) and (ii) the uniqueness of the relative risk aversion is always satisfied for $p = 0$ and $P > 0$ because of $R(w) = n$ respectively $R(w) = 1$. The function of Type (iii) satisfies uniqueness for absolute risk aversion. In this case $A(w) = p^{-1}$. In the following we consider the uniqueness of relative risk aversion which allows a more general analysis. You will see below that it is also possible to describe the quality properties of the utility function of Type (iii).

[5] For a more detailed discussion of linear risk tolerant utilities see Ohlson (1987).

Finally, the decision problem of an individual becomes to:

**Definition 7.** Standard Problem II

The individual i solves the maximization problem:

$$\max_{(w_{i1},w_{i2})} V_i(w_{i1},w_{i2}) = \max_{(w_{i1},w_{i2})} \sum_s \pi_{is} U_i^2(w_{is}) = \max_{(m_i,o_i)} \sum_s \pi_{is} U_i^2(m_i e_{is} + o_i p_o)$$

subject to

$$m_i + o_i = \bar{w}_i .$$

According to that model specification the microstructure of the capital market is completely determined by the expectation matrix $E_p$ and by the individual utility function $U_i^2(\,.\,)$.

## 3.2 The Derivation and the Analysis of the Individual Security Demand Function

The solution of the Standard Problem II leads to the optimality condition:[6]

$$-\frac{\pi_i U_i'(w_{i1})}{(1-\pi_i)U_i'(w_{i2})} = T_i, \quad T_i := \frac{e_{i2}-1}{e_{i1}-1}$$

where the existence and the uniqueness is given by Definition 1. Notice, that we exclude corner solutions as not economically significant for our purpose, i.e. $\pi_i \in \Pi$ with $\Pi = [\pi^u, \pi^o]$ and $0 < \pi^u < \pi^o < 1$. Therefore, the behaviour of agent i is determined by three decision variables: The individual state probability $\pi_i$, the price expectations $e_{i1}$ and $e_{i2}$, and the initial endowment $\bar{w}_i$. The individual security demand function results from the optimal expected wealth $w_{is}$:

$$m_i = m_i(\pi_i, T_i, \bar{w}_i) \text{ and } o_i = o_i(\pi_i, T_i, \bar{w}_i).$$

In our approach, the individual's confidence in the expectations plays an important role. Therefore, we first consider the influence of the state probability on the individual demand function $m_i(\pi_i, .\,.)$ in a comparative static way.

**Proposition 1:** The individual security demand function $m_i = m_i(\pi_i, T_i, \bar{w}_i)$ is strict monotonically increasing subject to the state probability $\pi_i$. Furthermore, and in relation to the relative risk aversion $n > 0$ the slope of that curve is as follows:

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[6] In the following, we do not longer distinguish between $U^1(.)$ und $U^2(.)$.

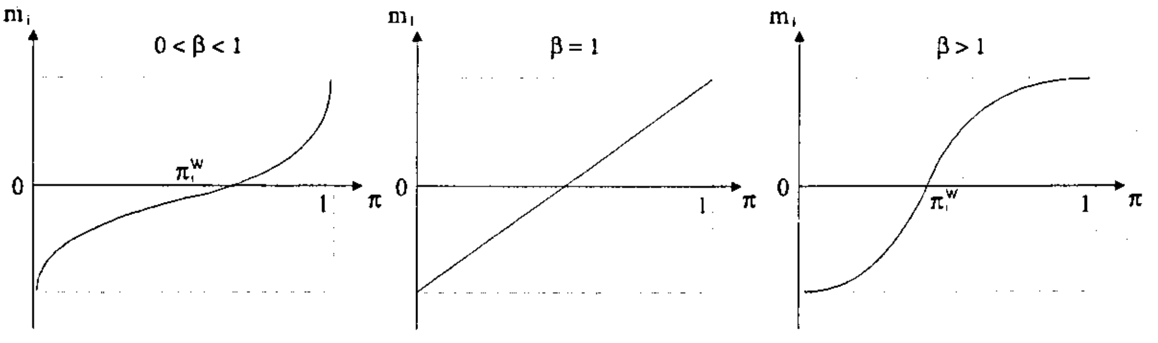
(i) $\quad n>1\ (\Leftrightarrow 0<\beta<1) \quad \Rightarrow \quad \frac{\partial^2 m_i}{\partial \pi_i^2}<0\ (>0)$ für $\pi_i<\pi_i^W\ (\pi_i>\pi_i^W),\ \ \pi_i^W \in \Pi$,

(ii) $\quad n=1\ (\Leftrightarrow \beta=1) \quad \Rightarrow \quad \frac{\partial^2 m_i}{\partial \pi_i^2}=0$, for all $\pi_i \in \Pi$,

(iii) $\quad n<1\ (\Leftrightarrow \beta>1) \quad \Rightarrow \quad \frac{\partial^2 m_i}{\partial \pi_i^2}>0\ (<0)$ for $\pi_i<\pi_i^W\ (\pi_i>\pi_i^W),\ \ \pi_i^W \in \Pi$.

Those three functions are shown in Figure 1. Notice, that the limits result from the optimization problem.

**Figure 1**




**Proof:**[7] Differentiating the first order conditions of the optimization problem, one gets:

$$\frac{\partial m}{\partial \pi}=-\frac{\partial m}{\partial w_1}\frac{\partial w_1}{\partial \pi}=-\frac{U'(w_1)-TU'(w_2)}{(e_1-1)(\pi U''(w_1)+(1-\pi)T^2\,U''(w_2))}:=-(e_1-1)^{-1}\frac{g(.)}{h(.)}.$$

One can easily verify, that this term is always positive.

In order to proof the second part of Proposition 1 we consider the curves of Type (i) and Type (iii). The shape requires the existence and the uniqueness of an inflection point (saddle point). The second differentiation of the first order condition yields:

$$\frac{\partial^2 m}{\partial \pi^2}:=m''=-[(e_1-1)h^3]^{-1}\,g\,(-2g'\,h+h'g)$$

with

$$g':=\frac{\partial g}{\partial w_1}=U''(w_1)-T^2\,U''(w_2) \quad \text{and} \quad h':=\frac{\partial h}{\partial w_1}=\pi\,U'''(w_1)+(1-\pi)\,T^3\,U'''(w_2).$$

The existence of inflection points (saddle points) requires:

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[7] If no ambiguities appear, we neglect the subscipt i here and in the following proofs.

$$m'' = 0 \quad \text{and therefore} \quad -2g'h = -h'g.$$

Due to $h \neq 0$ and $g \neq 0$, the condition mentioned above is only satisfied in the following two cases:

$$\text{case 1: } g' = h' = 0, \quad \text{case 2: } g' \neq 0, h' \neq 0 \text{ and } -2g'h + h'g = 0.$$

From case 1 immediately follows that $U''(w_1) = T^2 U''(w_2)$. Considering the linear risk tolerance and the optimality condition, one gets $U''(w_1) = (1-\pi/\pi) T^2 U''(w_2)$. Both conditons are satisfied if and only if $\pi^W = 0.5$.

In case 2 we assume that $U''(w_2) = \alpha U''(w_1)$, $\alpha > 0$. The term $-2g'h = -h'g$ can be transformed into $2(1-KT)^2 - 2(1-KT) = -(1+\beta)(1-KT)(1+KT)$ with $K := w_1 / w_2$, derivated from the linear risk tolerance. Finally, one gets:

$$\pi^W = \frac{1}{2} - \frac{\beta}{2}\frac{1+KT}{1-KT}.$$

The two solutions of $\pi^W$ show the possibility of the existence of an inflection point (saddle point). If such a point exists it can be seen that it is unique too. Furthermore, $\pi^W = 0.5$ also holds for $KT = -1$. The possibility of the existence can be limited in a more precise way by examinating the neighbourhood of the possible inflection point (saddle point). Hence, we take a look at the intersection point of the security demand function. Because of $m = 0$ yields $w_1 = w_2 = \overline{w}$ this point is given by $\pi^S = T/T-1$. Here, the condition $0 < \pi^S < 1$ is satisfied for each T. Moreover, $\pi^S$ is independent of $\beta$ and the intersection point equals the inflection point (saddle point) for $T = -1$ at $\pi^S = \pi^W = 0.5$. The sign of $m''$, precising the positive slope of m can now be calculated at $\pi^S$. Using the term $-2g'h + h'g$ this leads to

$$B_1 := \frac{1-2\pi^S}{1-\pi^S}(\beta - 1) \quad \text{respectively} \quad B_2 := (1+T)(\beta - 1).$$

and $\text{sign}(m'') = \text{sign}(B_1) = \text{sign}(B_2)$.

First, for $\beta = 1$ both conditions are zero, independent of $\pi^S$ and T. Therefore, the security demand function of type (ii) is a straight line. Second, for $\pi^S < 0{,}5$ respectively $T > -1$ combined with $\beta > 1$ ($< 1$) sign( $m''$ ) is positive (negative). The reverse case holds for $\pi^S > 0$ and $T < -1$. Finally, we have to analyse the location of $\pi^S$ in relation to $\pi^W$. The optimality condition yields:

$$-T = \frac{\pi^S}{1-\pi^S} = \frac{\pi^W}{1-\pi^W} L, \quad \text{with } L := \frac{U'(w_1)}{U'(w_2)}.$$

We define the following distance function $\varepsilon$ (.):

$$\varepsilon(\pi^W) = \pi^W - \pi^S = \pi^W \frac{1-\pi^W - L(1-\pi^W)}{1+\pi^W(L-1)} .$$

In the relevant range ($0 < \pi^W < 1$) this function becomes zero at $L = 1$ and therefore $\pi^W = 0.5$. Furthermore, $\varepsilon > 0$ ($< 0$) for $L < 1$ ($> 1$) and $\pi^W < 0.5$ ($> 0.5$). The derivation of the optimality condition leads to a more detailed characterization of L. Differentiating the optimal values for $w_1$ and $w_2$ with respect to T yields:

$$\frac{\partial w_1}{\partial T} = -\frac{(1-\pi)\,U'(w_2)}{\pi\, U''(w_1)} > 0 \quad \text{and} \quad \frac{\partial w_2}{\partial T} = \frac{(1-\pi)\,U'(w_2)^2}{\pi\, U'(w_1)\, U''(w_2)} .$$

For the range $-1 < T < 0$ one can see that at the inflection point (saddle point) $w_1 > w_2$, and hence $L < 1$, due to the concavity of U ( . ). For $T < -1$ one gets the opposite case.

□

Notice here, that the qualitative characteristics of the security demand function generated by the utility functon of Type (iii) in Definition 5 ($\beta = 0$) can be approximated by the utility function of Type (i) for $0 < \beta < 1$.

In the following we investigate how changes in the agent's risk behaviour and/or price expectations effect the security demand function. In our model the measure of the relative risk aversion $R_i(w_i) = n_i$ reflects the risk behaviour of the agents while changing price expectations affect the parameter $T_i$.

**Proposition 2:** Changes in the agent's risk behaviour ceteris paribus affect the slope of the security demand function $m_i(\pi_i, .)$ in the neighbourhood of the intersection point $(\pi_i^S, 0)$ in the following way: The slope increases (decreases) if the relative risk aversion decreases (increases). Formally, this is:

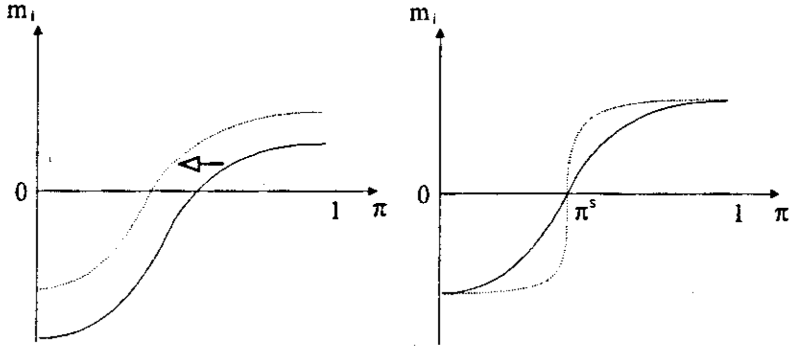
$$\frac{d\, m_i'}{d R_i}(\pi_i^S, 0) < 0 \quad \text{with} \quad m_i' := \frac{\partial m_i}{\partial \pi_i} .$$

An increasing price expectation of an agent (given by the increase of either $e_{i1}$ or $e_{i2}$ ) shifts ceteris paribus the security demand function $m_i(\pi_i, .)$ to the left. Formally, this is:

$$\frac{d\, m_i}{d\, e_{is}} > 0, \quad s \in \{1,2\}.$$

Figure 2 shows this for $\beta > 1$. On the left, changing price expectations by an increasing value of T leads to a shift of the curve, mentioned above. On the right, the decrease of the relative risk aversion by a decreasing value of R changes the slope of the curve.

**Figure 2**




**Proof:** At the point of intersection holds: $w_1 = w_2 = \overline{w}$. Multiplying numerator and denominator of $m'$ with $\overline{w}/U'(\overline{w})$ yields:

$$m' = \frac{\overline{w}}{(e_1 - 1)R(\overline{w})\,\pi} \quad \text{and therefore} \quad \frac{\partial m'}{\partial R} = -\frac{\overline{w}}{(e_1 - 1)R(\overline{w})^2\,\pi} < 0.$$

With regard to the results of the preceeding proof one gets:

$$\frac{\partial m}{\partial e_s} = \frac{\partial m}{\partial T}\frac{\partial T}{\partial e_s} > 0, \quad \text{because of} \quad \frac{\partial T}{\partial e_s} > 0, \quad s = \{1,2\}.$$

□

After that relative general specifications of the security demand function we can explicitly compute this function for agent i as

$$m_i = \left(\frac{1}{e_{i1} - 1}\right)\left(\frac{\overline{w}_i\,(1 - \tau_i^{\beta_i})}{\tau_i^{\beta_i} - T_i}\right) \quad \text{with} \quad \tau_i := -\frac{1-\pi}{\pi}T_i\,, \quad 0 < \beta_i\,.$$

We derived that function from the utility function of Type (i). As we already mentioned, this function is transferable in Type (ii) and includes the quality properties of Type (iii). Therefore, we can qualitatively model the security market for the whole class of linear risk tolerant utilities.

### 3.3 Model Structure of the Security Market

The model structure of our security market consists of a micro- and a macrostructure. The individual's decision about the holdings of risky securities takes place at the microlevel or, in our notation, at the individual state space which is defined as follows:

**Definition 8:** Individual state space (microeconomic decision space)
The individual state space (II,Qj) c $IR^2$, with Qi = [mi (tt$^u$ ,.), mi (n°, .)] of every agent i = 1,...,I is completly described by m; ( K , . ), T ,, w i, and R, .

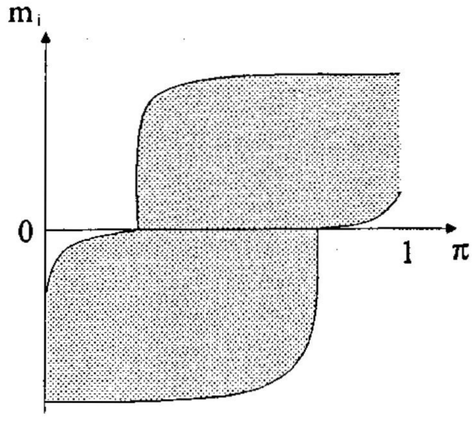
The portfolio decision of Agent i takes place on the individual state space, primarily determined by the expectation components Ti and Ti . Therefore, the agent has an individual gain respectively loss expectation concerning the security holding of M. In addition to that, he estimates the possibility about the realization of this gain- or loss expectation by Kj.

Aggregating the individual state spaces leads to the the macrostructure of the market giving the total demand of m for all it e II.

**Definition 9:** Aggregate state space (macrostructure of the market)
The aggregate state space (II,Q ) ci $IR^2$ with **Q** = [**Q** i , Qj ] of the security market is completly described by the demand structure m ( it, . ) = (mi ( it,.),..., mi ( it,. )), the expectation structure T = Ti ,..., Ti , the structure of the initial endowments w = $\overline{w}$ i,...,$\overline{w}$ i, and the risk structure R = Ri ,...,Ri. Thereby, **Q** i and **Q** j indicate each of the limits. That means for i * j, i,j = 1,...,I holdsm, **<m j,V 7rG II.**

Figure 3 shows the aggregate state space in which the market activities take place. In the range of m < 0 (m > 0) and for small it this space is bounded by the demand function of the most relative risk averse (risky) agent with the highest gain- and the lowest loss expectation. The opposite case holds for great $\tau$ In that case, the boundaries are given by the function of the most relative risky (risk averse) agent with the lowest gain- and the highest loss expectation.

**Figure 3**




Therefore, in contrast to the original SPM, the market participants in our model themselves create the state that occurs. Their expectations determine the security price in the next period. To model this, we need a price adjustment function representing the market structure adequately, i.e. $p_M = p_M(\Pi,\Omega)$.

## 4. Model Simulation and Possible Evolutionary Extensions

### 4.1 Simulation of the Model

For making the concept of the individual and the aggregate state spaces more precise, we do some simulation runs. Our model specification allow a strict distinction between the individual's relative attitude toward risk and their expectations which do not exist in the equilibrium implications of the SPM. For this reason, we pay particular attention to the implication of different risk and expectation structures as to the market result. Nevertheless, according to the relatively simple one period model one should always be aware that we have to vary both structures exogenously. In section 4.2 we give certain hints for an endogenous modelling.

We consider 100 individuals acting in the market of risky securities M. These agents are characterized by $n_1$ ,..., $n_{100}$ relative risk measures and $T_1$ ,..., $T_{100}$ relative price expectations. With no loss of generality we put: $n_i \in [0.2,1.8]$, $e_{i1} \in [1.05,1.2]$, and $e_{i2} \in [0.8,0.95]$. Therefore, the agents' range goes from relative low risk aversion ($n_i = 0.2$) to relative high risk aversion ($n_i = 1.8$). In the most favorable (unfavorable) case they expect a price increase of 20 (5) percent and a price decrease of 5 (20) percent. For simplicity, we assume identical individual probabilities $\pi_i$. We also discuss a relaxation of that assumption in section 4.2.

The market structure is represented by the following price adjustment function:

$$p_M(m) = p_M^0\,[1 + dp_M(m)]$$

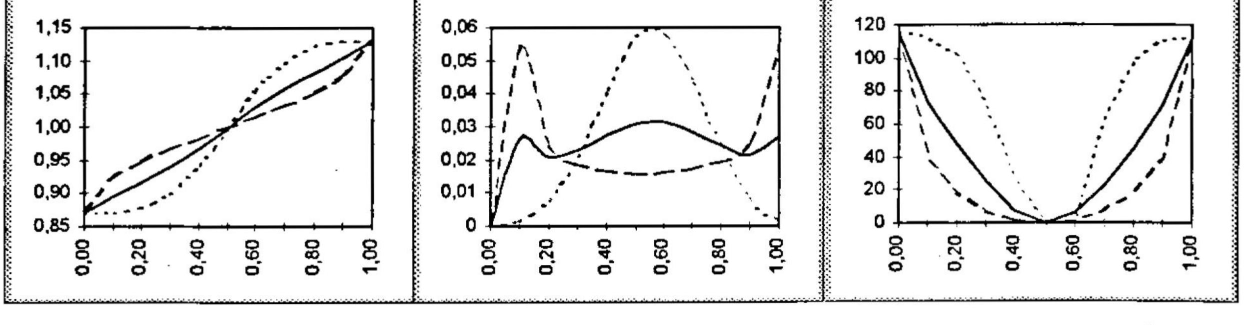
where $p_M^0$ denotes the price of M at date-zero (as is generally known, this is 1), m denotes the aggregate security demand, and $dp_M$ (m) denotes the price adjustment, calculated as follows:

$$dp_M(m) = \begin{cases} \left(\frac{1}{100}\sum_{i=1}^{100} e_{i2} - 1\right)\frac{dD(m)}{m(0)} & \text{for} \quad dD(m) < 0 \\ \left(\frac{1}{100}\sum_{i=1}^{100} e_{i1} - 1\right)\frac{dD(m)}{m(1)} & \text{for} \quad dD(m) > 0 \end{cases}, \quad \text{with } dD(m) = D(m) - S(m).$$

The aggregate security demand m (0) and m (1) represents the demand for $\pi \rightarrow 0$ and $\pi \rightarrow 1$. In particular, this price adjustment function has to admit so called „self-fulfilling prophecies". If all agents belief that the most unfavorable/favorable price expectations take place ($\pi \rightarrow 0$ / $\pi \rightarrow 1$) it will be established in the next period.

The following simulation runs have two aims: The first one explicitly illustrates the influence of different risk distributions on the price movement, on the price volatility, and on the potential market profit. Therefore, we distinguish three market populations. The first one is equally distributed in the interval mentioned above and the average value of the market risk measure n = (1/100) $\sum_i n_i$ equals 1.023. The second population represents a relative risky market structure by drawing 100 random numbers from the interval [0.2,0.5]. In the average this leads to n = 0.352. The third population represents a relative risk averse market structure. This leads to $n_i \in [1.5,1.8]$, and in the average to n = 1.652. All populations have equal price expectations given by equally distributed random numbers of the above intervals. Figure 4 shows the simulation results subject to the realization probabilities. The solid lines give the developments of population 1, the dotted respectively dashed lines those of population 2 and population 3.

**Figure 4**

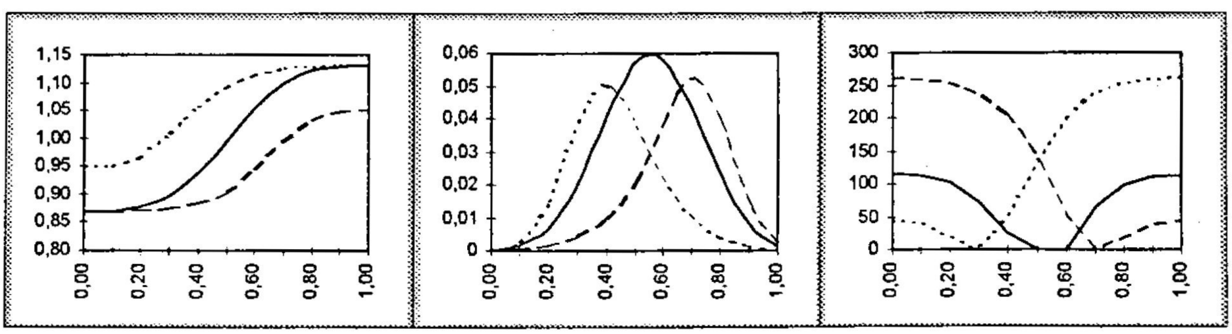



price movement price volatility potential market profit

First of all it is obvious, that the curves of the price movements qualitatively look like the individual demand functions (Proposition 1). This is not surprising. On the one hand, the price movement reflects the excess demand and, on the other hand, the subjective probabilities reflecting the individual's confidence in the realization of the two expected situations are the same for the whole population. This effects the price volatility in the following way: A relative risky market is much more volatile in the relativly uncertain areas, i.e. $\pi \in [0.3, 0.8]$ than other market structures. Notice, that the volatility in this areas is more or less constant for a relative risk averse market. This is due to the different slopes of the individual demand functions reflecting different risk attitudes. According to this, risky market participants increase their demand to a stronger degree if the general profit expectations become better. At the end, that leads to a higher price increase of the risky security. The same applies for the aggregate profits but, in that case this holds over all anticipated probabilities. The argumentation follows in analogy to the price volatilities. Therefore, the risky agents increase their demand of O respectively of M to a stronger degree independent of state estimation. In this way, they realize higher aggregate profits if the market is predominant risky, or in other words, if the most market participants react in the same way. We assumed that explicitly by setting the same $\pi$ for all agents.

In the second simulation study the risk structure is held constant for analysing the influence of different price expectations on the developments mentioned above. Therefore, we model three structures of price expectations. The first one, represented by the solid line is identical to the previous run. The second one (dotted line) reflects a more optimistic structure by fixing the most unfavorable price expectation for all agents at $\hat{e}_2 = 0.95$ while the most favorable expectation remains unchanged. The third population (dashed line) is a more pessimistic one. Here, the most favorable expectation is fixed at $e_1 = 1.05$ while the other one remains unchanged. The developments for a relative risky market structure are shown in Figure 5.

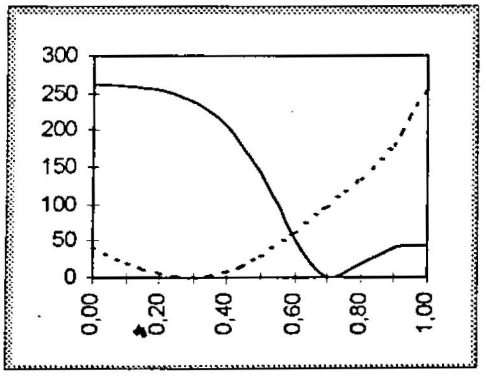
**Figure 5**




price movement | price volatility | potential market profit

In analogy to the individual security demand function a more optimistic expectation structure shifts the previous price movement to the left. A more pessimistic structure leads to a right shift. The price volatilities and the potential market profits show the same shifts. For the latter, the unsymetric curve movements of the optimistic and pessimistic expectation structure attract interest. Because of the expected 5 percent loss respectively gain limit, an estimated state realization near the boundaries (0,0.3] and [0.7, 1) leads to relative low market profits. Despite this, the profits in the other areas are clearly higher than before. Therefore, the market sentiment which is induced by the expectations enables a higher profit potential. Figure 6 points out this statement. A relative risk averse market structure (dotted line) combined with a more optimistic expectation structure can realize higher gains than a more risky population (solid line) combined with a pessimistic expectation structure. In our example this holds up to a value of $\pi = 0.6$.

**Figure 6**



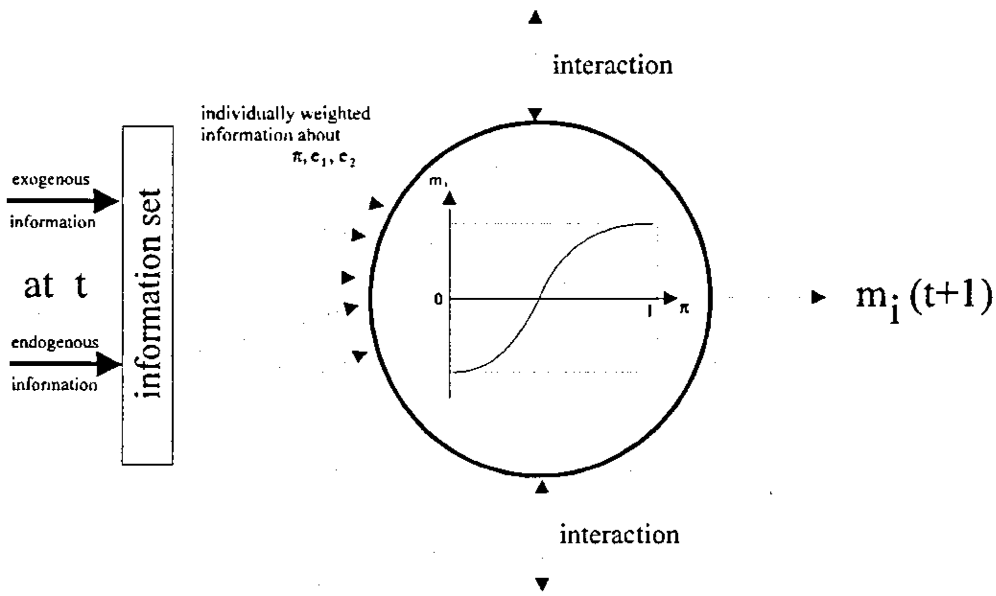
potential market profit

Therefore, changing price expectations can partly compensate the outcome resulting from the risk behaviour.

### 4.2 Possible Evolutionary Extensions

In the evolutionary sense, endogenous state realizations primarily take place by selection, imitation, and mutation processes. Our model allows endogenous state realizations but requires exogenously given individual state spaces. Therefore, for taking into account the evolutionary elements a dynamization of our basic model is necessary. In contrast to dynamic optimization models we consider in the terminology of Grinspun (1995) so called „one shot decisions". That means that at the beginning of every period the agents build price expectations which determine their activity. For example, that can be modelled in using the neural net approach (NN) where a set of objects is tied together in a connective structure to a highly complex system. In analogy to biological networks like the human brain, that objects are also called artificial neurons. In modelling a security market with a NN it seems probable to interpretate that neurons as decision units or, in our terminology, as individual state spaces (Zimmermann (1990), (1994) and Kugler/Hanusch (1995)). In Figure 7 such an unit is shown representing the decision behaviour of agent i.

**Figure 7**




The risk attitude of agent i is given by $n_i$. At period t he makes a decision about the investment in risky securities $m_i(t+1)$. Therefore, the agent forms price expectations $e_{i1}$ and $e_{i2}$, and estimates the realization probability $\pi_i$ by individually weighting the information set. A NN consists of a interdependent connection of i = 1,...,I neurons. In our teminology that is the aggregate state space generating the state realisation at period t+1. A dynamization takes place if such a NN runs through t = 0,1,2,... periods. The endogenous change of the decision units are describable by the processes mentioned above in the following way.

Selection processes take place at the individual and at the aggregate state space. At the individual state space that effects the formation of the expectations. In general, the formation of expectations can be regarded as a sequential information process in a quantitative and/or qualitative manner (Frey/Stahlberg (1990)). Like in bounded rationality approaches, a quantitative selection takes place because of the limited human brain capacity. Contrarily, the qualitative selection is emphasized in behavioural studies. For example, the theory of cognitive dissonance describes that the perception of information is highly influenced by previous expectations (Festinger (1957)). A NN can take into account those aspects by an adequate individual weighting of the information.

Modelling selection processes at the aggregate state space requires an open market approach. Financial restrictions and/or changing attitudes of the agents can lead to market exits. In addition to that, higher profits and therefore a higher market attractivity can cause market entries. But, one can say that those entries actually belong to the imitation process.

However, of higher interest are imitation processes at the individual state space. It is empirically shown, that the formation of expectations is determined by own experience as well as by heterosuggestions, depending on the market sentiment (Schachter et.al. (1986)). In our model we can take that into account. On the one hand, we have price expectations and, on the other hand, we have estimations about the realization of that expectations. One interpretation of those components can be seen in the distinction mentioned above. Both expectation generating mechanisms are influenced by interaction but can base upon different information sets. Consistent to common economic studies (e.g. Beja/Goldman (1980), Day/Huang (1990)) such a differentation can be seen in fundamental respectively non-fundamental information. The first one mainly consist of economic data while the second one includes so called irrational components, becoming powerful by contagion processes. That can lead to identical estimations, as we assumed in the simulation run. The most new capital market approaches make an „either/or" classification of the agents according the used information sets. However, empirical studies show that such a strict distinction cannot be observed in real capital markets (Allen/Taylor (1990)). In our model, both influences simultaneously effect the decision behaviour of the agents.

The formation of expectations as well as the process of decision finding itself is determined by learning and adaption processes. Psychological studies show that the market movement generates a tone which has a great influence on the risk behaviour (Johnson/Tversky (1983)). In that model we can integrate short and long run changings. While the first ones are mainly concerned with the expectation formation respectively the sequential information processing, the latter ones primarily relate to the risk behaviour. The NN approache explicitly enables short and long run learning and adaption processes. In addition to that, one can think of using adaptive behaviour techniques which cover endogenous adaption processes by genetic algorithms and classifier systems (Goldberg (1989), Holland (1992)).

The neoclassical perspective of the decision finding only depends on the information set. Contrarily, the social science literature considers expectations as a basis for the decision behaviour. According to that line of research, there is lag between the agent's intention and the decision itself (Ajzen/Fishbein (1973)). Therefore, one possible enlargement of the mechanical decision behaviour of our basic model can be done by using the alghorithm of the Boltzmann - Machine which explicitly takes into account random events and other exogenous influences (Ackley/Sejnowski (1985), Zimmermann (1990), Kugler/Hanusch (1995)). The consideration of random events is a thinkable application of the mutation process in the evolutionary sense.

## 5. Summary and Outlook

Our intention for this paper was to develop the basics of a model which is, on the one hand, based on the neoclassical decision theory and which, on the other hand, can be extended in the evolutionary sense. For this purpose we reconsider the SPM and integrate expectation values which essentially determine the agents'activities. By solving this model we develop individual state spaces generating the market result endogenously. A model simulation shows that the degree of the expectations and the behaviour heterogenity of the agents generate different state realizations and allow detailed insights of the market movements. Of particular importance for further work is the integration of evolutionary elements like selection, imitation, and mutation processes. Refering to the neural network approach we show how these elements can be integrated in that basic model. If the mechanisms of the formation of expectations, the decision finding itself, and the state realization are explicitly modelled and connected with learning and adaption processes that approach may allow clearer insights in the complex structures of capital markets. Moreover, important psychological findings and more complex economic behavioural assumptions like the utility function of Friedman/Savage (1948) could be integrated (Kugler/Hanusch (1995)). In going this way, a theoretical basis for neural net approaches can be done which is also suitable for socio-economic experiments.

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