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4 Interactions of Efficiency, Consistency, and Sufficiency across Levels

Assessing Innovation Tensions through the Lens of Paradox Theory

Marcus Wagner

Introduction

In economics and management theorizing, there is a longstanding tradition arguing in favor of a business case for sustainability, which implies a win-win logic, in that businesses can support sustainability and derive economic profit from doing so.[1] Critics of this approach have argued that this win-win logic ignores a paradox between micro-level progress and macro-level environmental deterioration.[2] For instance, solar energy and electric mobility, as the main elements of a global large-scale ecological transformation, can still be connected to polluting business practices, as Hernández Westphal's chapter on lithium-silver mining in Mexico in this book vividly illustrates. While those "green" minerals are core components of renewable energy technologies that play a crucial role in mitigating greenhouse gases, they are sourced via an intensive extraction process accompanied by high environmental and social costs. Moreover, as Westphal illustrates, companies can create a positive narrative of contributing to longer term ecological transformation while creating significant additional environmental deterioration from current production growth.[3] Cautioning more generally against the win-win hypothesis is the Impact-Population-Affluence-Technology (IPAT) equation, developed by biologists Barry Commoner and Paul Ehrlich and physicist John Holdren in 1972, the year of the first United Nations Conference on the Human Environment in Stockholm. IPAT mathematically calculates human impact on the environment (I) as the multiplicative effect of the human population on earth (P), the level of affluence (A, measured as per capita income), and a technology factor (T), which captures efficiency: $I = P * A * T$.[4] The IPAT equation suggests that alongside efficiency as one key business case mechanism, sufficiency and consistency are equally relevant drivers for environmental outcomes. While efficiency is addressed in the IPAT equation by means of a technology factor, sufficiency can be gauged as the inverse of affluence, i.e., it reflects individuals' willingness to abstain or abdicate from material consumption. Mathematically, this willingness is the inverse of per capita income in the IPAT equation. Finally, consistency is conceptually a very broad term comprising the avoidance of overpopulation or resource overuse, achieving high levels of circularity, and the usage of substances that already exist in nature; it is captured more narrowly in the IPAT equation by population level.[5]

The IPAT equation, originally developed by three natural scientists in the 1970s pursuing an ecological economics, rather than a mainstream economics approach, challenges the notion that efficiency alone is a viable strategy for large-scale ecological transformation. Rather, the IPAT equation suggests that other factors, such as population and affluence, need to be considered as well. The three factors are furthermore not independent but interdependent. To illustrate this point, efficiency gains can lead to increased affluence (for example, by means of rebound effects, which shall be discussed in more detail below). Equally, technological improvements and higher income levels can increase population levels due to improvements in healthcare and medical support.

Sufficiency thus needs to be a complement to efficiency in large-scale ecological transformations, and the same applies to consistency in its variety of interpretations. The IPAT equation also suggests that different factors may need to or can be traded off. Such trade-offs, which potentially create strong to insurmountable tensions, can be understood as a special case of ambivalence. A more recent theoretical development in the field of management, namely, the so-called paradox theory, supports this interpretation. As this contribution wishes to illustrate, paradox theory enables management scholars and economists (but potentially also other scientific disciplines) to address tensions and trade-offs, and in doing so ultimately helps to address the idea that corporate sustainability actions can still be complicit in creating global environmental damage. This in turn helps to answer the following question: Under what conditions can technology and innovation lead to firms maximizing contributions to support sustainable development?

In the remainder of this chapter, I explain in more detail this recent theorizing in the economics and management domain about tensions and paradoxes (both of which will be defined in the next section) and then link this with studies focusing on the role of innovation and technology for global sustainability. As part of this approach, I attempt to integrate different literatures relating to the environmental humanities in terms of efficiency, consistency, and sufficiency, as well as ecological modernization and philosophical views on technology with paradox theory. In my analysis, I develop a multi-level perspective to account for interactions between the macro-, the meso-, and the micro-levels with regard to tensions, sustainability, and technology.[6]

A Primer on Paradox Theory

The notion of paradox, initially of Greek origin and referring to a (seemingly) unavoidable contradiction, is increasingly used in management studies in the context of sustainability-related debates to refer to issues of appropriate behavior of actors such as businesses, governments, or consumers in unsuitable incentive structures, even to the degree that trade-offs become unfeasible. An illustrative example of such a paradox is when these actors become increasingly concerned and active in supporting environmental protection or social justice, but global environmental quality or social equality continue to worsen. More specifically, in the context of management research, paradoxes have been defined as "contradictory, yet interrelated, demands embedded in an organization's goals,"[7] and therefore paradoxical tensions refer to "[…] elements that seem logical in isolation but absurd and irrational when appearing simultaneously"[8]; for instance, this would be the case if a business wants to increase photovoltaic energy generation at their sites but would need to cut down many trees to do so.

Specifically, this implies that tensions become paradoxical when competing elements are simultaneously contradictory and interrelated and persist over time.[9] A paradox lens in such a situation aims to find ways to simultaneously address competing objectives in a so-called both/and thinking[10] approach (as opposed to either-or thinking of mutually exclusive alternatives or choices). Both/and thinking does not aim at achieving an ideal balance that "solves" the paradox but at working through said paradox by embracing tensions.[11]

There is a debate on whether paradoxical tensions are inherent in systems or socially or cognitively constructed, with some scholars referring to the philosophy of social construction for the latter option.[12] Others argue that paradoxes are inherent in the structure of our physical world, for example, in terms of the inherently paradoxical nature of quantum physics.[13] In a somewhat self-referential application of both- and thinking, it would seem likely that the constitution of paradoxical tensions is a combined process based on feedback loops, which involves both social or cognitive construction, and the inherent properties of underlying realities. To illustrate this point, the laws of nature mean that burning fossil fuels unavoidably creates greenhouse gas emissions that fuel global warming and climate change, which is an inherent property of the physical world. At the same time, the decision to burn fossil fuels in the first place is strongly linked to processes of cultural evolution and discovery, as well as the development of social norms that build on socially embedded cognitions of individuals. These processes can potentially stretch over long time periods that involve historical path dependencies but ultimately remain human interpretations, choices, and constructions—even though they can equally create strong inertia.

In paradox theory, a distinction is further made between salient and latent tensions. While tensions between, for example, social, environmental, and economic requirements in the context of sustainable development are (in principle) universal, they only become manifest when "consciously observed, articulated, and experienced by organizational actors."[14] This distinction also matters for businesses' responses to paradoxes and paradoxical tensions. Specifically, proactive responses (having their origins partly in the ambidexterity concept, which refers to an organization's ability to be both efficient in the management of today's business and responsive to possible future demands) address competing demands, such as employees being asked to simultaneously maintain contact with customers and reduce business travel for ecological reasons. Companies can do so by means of temporal or spatial separation of the demands, for example, by means of video conferencing. Proactive responses therefore imply that tensions and tradeoffs are made visible and are consciously considered and that contradictions are acknowledged and discussed. Ultimately, proactive responses are mostly seen as the better approach to creating generative solutions to a paradox.

Opposed to this, defensive responses suppress, ignore, or displace one of the two poles (i.e., opposing demands) of the paradox. For example, in the context of sustainability and ecological transformation, companies may only pursue symbolic actions or green-washing rhetoric. As a result, economic demands are implicitly prioritized at the expense of social or environmental concerns, in which case adoption of the latter type of response neglects competing demands, which can then create vicious cycles that result in inertia and paralysis.[15]

Extending the notion of defensive responses, other work has stressed the importance of power dynamics that impact the capacity of individuals to "[…] engage [effectively] with paradoxical tensions."[16] This line of reasoning argues that individuals, such as employees in a company, who are insufficiently empowered are typically missing resources to respond adequately to the contradictory demands that characterize paradoxes and paradoxical tensions. As a consequence, they experience such tensions as so-called pragmatic paradoxes, which lack any acknowledgement of the necessity of competing demands as a precondition for engaging generatively with paradoxes, since some actors have a vested interest in supporting one pole rather than the other. A telling example of such a constellation is the "Dieselgate" scandal, when Volkswagen employees were faced with competing demands (producing sellable cars and meeting exhaust emission legislation) but left without adequate resources and agency to simultaneously address both in a productive manner.[17]

Links of Paradoxes and Tensions with the Role of Innovation for Global Sustainability

In this section, I want to integrate paradox theory, as introduced in the previous section, in more depth with different literatures relating to the environmental humanities in terms of efficiency, consistency, and sufficiency, in order to clarify how tensions and paradoxes in large-scale ecological transformations can be addressed by innovation and technology and where this has limits. This integration attempt as a starting point focuses the technology factor in the IPAT equation, which, as explained before, represents efficiency, and thus ultimately innovation, that enables businesses' efficiency gains. Innovation, in terms of products but also production processes, is a potentially very promising strategy for resolving (even paradoxical) tensions. In the field of economics and management theorizing, innovation leads to so-called creative destruction, that is, the simultaneous creation of new business opportunities and the market exit of firms that become uncompetitive due to not pursuing these opportunities.[18] This process can enable a business case for sustainability beyond pure rhetoric, as exemplified (among others) in discourses about new and more sustainable business models. One example in this regard is manufacturer Patagonia having offered to repair or exchange used jackets, rather than incentivizing consumers to buy more new clothing. Therefore, the mechanisms underlying creative destruction raise a serious question about how paradoxical

"paradoxical" tensions really are, or, stated differently, to what degree technology and innovation via efficiency gains can ultimately resolve grand challenges in the context of sustainable development, as technology optimists would hope.

Innovation economics distinguishes the rate and direction of inventive activity, which can be generalized to innovation and technological development.[19] This means that technological progress toward carbon neutrality may not be necessarily equally conducive for biodiversity, while the invention and commercialization of new computer applications will not always support sustainable development. By this, I mean that climate change in the long run changes habitat conditions globally, which in turn increases the likelihood for species migrating. At the same time, the installation of new renewable energy-generation capacity such as photovoltaics and wind turbines, or the increased adoption of biofuels (all of which mitigate climate change), may also have negative effects on biodiversity. Equally, while digitalization is often associated with positive contributions to sustainability, this depends highly on the specific application case. For example, computer game development is a highly successful IT-based industry, yet scientists raise concerns about negative social effects, especially for adolescents, such as social disconnection or physical health problems.

These examples clarify that, mathematically, innovation can be conceived of as a vector, which helps to explain why a business case for sustainability may or may not emerge from efficiency improvements and other forms of innovation and technological development, depending on what direction the improvement is traveling. In this sense, an innovation (be it from large, established firms, also called "incumbents," or from small start-ups and market entrants) is at most a necessary condition for the aforementioned business case, albeit not a sufficient one.

Economic theory furthermore suggests that more radical innovations are more difficult to realize, not least because incumbents tend to have strong incentives to pursue more incremental innovation.[20] For example, the large-scale transition toward electric mobility was significantly accelerated by automotive firms Tesla and BYD, which newly entered the automotive industry and focused from the outset on electric cars. Therefore, even though incrementalism may be necessary to some degree to enable more radical technological change in the longer term, it holds the risk of short-termism or symbolic action, especially by incumbents, or even worse, it could lead to lobbyism or collusive behavior aimed at stabilizing market positions and related private profits at the expense of social welfare. The Dieselgate scandal is an extreme example of this point, with the incumbent Volkswagen even resorting to illegal means to support its short-term profits, symbolically pretending to meet emission limits in official tests. At the same time, other incumbents in the industry have also used similar means, which is an example of collusive behavior whereby firms, rather than competing for better solutions, coordinate or jointly keep secret the unproductive or even destructive solutions they apply.

Paradox theory enables deeper analyses of these phenomena since the notion of tensions speaks to forms of societal or regulatory framing and framework conditions at different levels that can support or hinder more radical innovation. This has been documented in the case of environmental regulation and for system-level innovation—as needed in the case of large-scale ecological transformations such as transitions to a renewable energy base of industrial and social processes.[21]

In the context of paradox theory, innovation can be understood as a very promising strategy for actively responding to and generatively resolving tensions. Such thinking can be extended to the aspect of consistency, which has been argued to be—at least in some definitional variants—quite alike to efficiency. As explained earlier, consistency is a conceptually very broad term that comprises elements such as high levels of circularity, the usage of substances that already exist in nature, and the avoidance of over-population and resource overuse.

Ultimately, consistency is proposing to make the production and consumption systems of humankind more cyclical and more compatible with natural ecosystems. This is one important basis for requiring that a circular economy is largely bio-based and renewable in terms of materials and energy provision, since it not being sufficiently bio-based would be problematic, for example in relation to issues such as dissipation (i.e., the wide diffusion of human-made substances, such as microplastics or pesticides).

Similarly, while, for example, non-natural composite materials could be used in a circular economy to produce electric cars with carbon fiber bodies, the extensive recycling required, for which almost all energy needs would have to be renewable-based, on a large scale could negatively impact biodiversity and other environmental goods (see my comment above on the relationship between climate change and biodiversity). Therefore, human-made composite materials have only limited compatibility with a circular economy, even though the consistency of human-made substances might increase over time due to technological improvements and innovation. Equally, sufficiency could allow the use of a certain (or higher) amount of human-made materials within a circular economy.

Generalizing this specific case, the views opposed to the win-win logic of a business case for sustainability have linked the disconnect between micro-level progress and continued macro-level damage to the difference in absolute and relative decoupling, as it is termed in the language of ecological modernization.[22] To use again the example of circular economies for illustration purposes, while renewable energies are partly considered a "backstop technology" for supplying a resource at low costs for infinity,[23] this may have some limitations, depending on the scale of implementation.[24] A similar scaling argument applies to the negative investment effects of transitioning to a circular economy from implementing technological innovations that require additional energy and material inputs. Ultimately, therefore, a circular economy will not avoid global limits and issues of absolute decoupling without involving sufficiency.

Put differently, the business case for sustainability (at least in the long term and for the case of profit-oriented firms) implies too high growth requirements to remain within planetary boundaries and limits to growth if it does not integrate sufficiency into business model considerations. For example, corporate attempts to support sustainable development are often confounded by the rebound effects of innovation and novel technologies, as in the case when more energy-efficient appliances increase energy needs due to incorporating more functionality.[25]

Overall, the analysis to this point therefore suggests that next to efficiency, consistency and sufficiency are equally relevant factors for reducing environmental damage, but that the interaction of these three factors can create paradoxical tensions. While this already represents a challenge to solutions, the situation is further complicated by interactions of such tensions across levels, as I detail in the following section. As an initial illustration, a possible example of interaction across levels is seen in the form of globally increasing carbon dioxide emissions and concentrations vis-à-vis sustainability initiatives run by individuals or in firms, cities, regions, industries, or countries.

Paradoxes and Tensions from the Individual to the Global Level

Links between paradox theory and the role of innovation for global sustainability from the perspective of management and economics relate especially to the paradoxical role that companies or organizations are said to play in the context of sustainability.[26] For example, while firms in many ways depend on resources sourced from nature, at the same time—through their operations—they act as a major driver for the decline of biodiversity. These paradoxical tensions for biodiversity reveal interaction across levels, since competing demands exist across different levels for the roles firms are expected to perform.[27] This partly also relates to trade-offs between the short and the long term[28] For example, employees want to save jobs in a company, while the countries in which the company operates want sufficient environmental protection. However, if the latter implies heightened costs, job safety may be under threat, at least in the short term. Yet, in the long term, innovation may reduce costs so that the demands are less contradictory. Similarly, while the global chemical industry has benefited from selling human-made pesticides, society and the environment in many countries have suffered as a consequence.[29] These illustrations demonstrate that paradoxical tensions emerge even more so when a multi-level perspective is taken, for example in terms of countries or regions at the macro-, industries or companies at the meso-, and groups or individuals at the micro-level.[30]

Since it has been proposed that sustainable development is inherently paradoxical, it is important to understand more thoroughly specific instances in this regard, such as biodiversity, particularly, because it has been argued that paradoxes are often latent, only becoming salient through specific processes such as sensemaking,[31] e.g., in our specific illustration due to observable effects and impacts resulting from biodiversity loss.[32] More generally, sensemaking here is understood as an approach in which an actor (which can be, among others, an individual or a firm or an industry) "uses tensions and inconsistencies between considerations to prompt elaboration and clarification of each objective, duty, and concern."[33] Salience is more likely once a multi-level perspective is adopted.

To illustrate this suggestion, the paradox that firms, as an important structural element in many societies, through their core activities harm the context in which they are embedded (in our illustrative case, the natural environment, as exemplified through biodiversity, and thus ultimately also society) is modulated by contextual aspects that lead to more nuanced experiences of how paradoxical tensions become salient. Tensions may vary, for example, across companies or industries at the meso level, and groups or individuals at the micro level, while still interacting between levels. This means that tensions (e.g., those relating to biodiversity or natural capital) may become salient across different levels.[34] Depending on how exactly salience occurs at a specific level, there may be more proactive—or rather reactive—responses to tension. For instance, for firms, tension may become salient in terms of stakeholder pressure, whereas for individuals it may become salient as a feeling of grief when walking in spring through silent landscapes where birds can no longer be heard. Determined further by factors such as the empowerment available to actors at different levels, responses may be more or less generative, even to the extreme that actors experience the tension as a pragmatic paradox.

The heterogeneity across levels discussed in this section is also important for considering tensions across levels, since responding to tensions at only one level may create tensions at another level.[35] Therefore, while the paradox of sustainable development is mirrored by the IPAT equation, the consideration of (paradoxical) tensions across levels reveals heterogeneity—the analysis of which provides some guidelines on how innovation can best address said paradox.

Discussion

Engaging with notions of (potentially paradoxical) tensions concerning innovation and surfacing across levels enables new and more interactive approaches that support necessary comprehensive system transformations, especially in the contexts of climate change, continued global economic and human population growth, and sustainability in a finite world, which due to historic path dependencies and inertia are often very difficult to realize. A paradox lens in this context specifically helps address power issues related to the fact that the realization of sustainable development implies (relative) gains and losses that challenge historically developed and reproduced power distributions and infrastructures. Considering paradoxes and paradoxical tensions in the context of global economic growth (typically resulting from more short-term private benefit or profit opportunities) and long-term sustainability (which ultimately can only be derived from social responsibility concerns) might be further enriched by considering philosophical views on technology.

As a starting point in this respect, Hardensett[36] proposes that modern processes of technology development and innovation require a deep exploration of human nature—much in the way that sufficiency suggests this requirement.[37] While acknowledging an unavoidable human element in technology, Hardensett at the same time strongly advocates for contextualizing technology as being influenced by culture and other social factors relating to the P (population) and A (affluence) factors in the IPAT equation. These considerations almost seamlessly carry over to the work of German philosopher Hans Jonas, who is probably best known for calling for a need to act in a manner that the effects of one's action are compatible with permanent and genuine human life on earth.[38] This so-called ecological imperative builds on a deep philosophical analysis of technological development that stresses positive feedback loops and historic path dependencies that create a technological drift toward forms of innovation that paradoxically simultaneously improve the quality of human life while at the same time deteriorating the state of our planet (in turn negatively affecting conditions for humankind on earth).

Jonas relates this (in line with the interdependency of the factors in the IPAT equation raised above) to the effects of technology increasingly extending in time and space, resulting in those (yet unborn) that have to bear the majority of these effects not being able to influence or demand compensation from those who create and trigger them.[39] The famous World Commission on Environment and Development (WCED) definition of sustainable development as "[…] development that meets the needs of the present without compromising the ability of future generations to meet their own needs"[40] refers to this tension exactly and thus can be considered a (derived and somewhat more operationalized) variant of the ecological imperative itself.

Jonas discusses this point further, arguing that even if nuclear fusion (as another potential backstop technology) were indeed available, the inherent mechanisms and dynamics of technology and innovation would require balancing efficiency gains with consistency and sufficiency to avoid the paradoxical decline of humankind.[41] He derives similar limitations, as discussed above, with regard to renewable energy technologies and, as a consequence, advocates caution and sufficiency, contending further that what is avoidable and which is unavoidable can only be clarified after giving avoidance a serious try.[42] Such thinking would do well as a conceptual elaboration of sufficiency, beyond the operationalization of the latter in the IPAT equation.

Applying the considerations discussed so far, again to the case of the circular economy and its tensions and paradoxes (at different levels), enables us to recognize the need to contribute to efficiency, sufficiency, and consistency jointly. This necessitates, for example, considering detrimental effects to biodiversity in the definition and implementation of renewable energy strategies as one crucial engine for a circular economy (because—as explained above—only a largely bio-based and renewable circular economy appears to achieve necessary levels of consistency in the absence of nuclear fusion being available on a large scale). While initial trade-offs between biodiversity and reducing greenhouse gas emissions may reverse over time and are currently without suitable alternatives in the long term, as laid out above, transition paths still matter because the technological progress best supporting carbon neutrality may differ from the technological progress best supporting biodiversity, and uncertainty makes trading-off between the two types of progress difficult for now.

Even in a sufficiently bio-based and renewable circular economy, a great deal of increased energy and material efficiency is needed to address the backstop technology issue for renewable energy, which may not be resolvable otherwise. Yet, while efficiency thus appears to be one necessary element for the feasibility of a large-scale ecological transformation, consistency and sufficiency seem to additionally be necessary or could even point to an alternative trajectory into a sustainable future. Specifically, advances toward a circular economy exemplify well the definitional elements of a paradoxical tension, namely contradiction, interrelatedness, and persistence. This can be seen from the fact that even in transitioning to a circular economy set up for the absolute decoupling of economic growth from environmental degradation, sufficiency still has a crucial role, at least in terms of buying time in the short term, which corresponds to the caution and sufficient level of frugality advocated by Jonas.[43]

These considerations beg the question as to how to achieve a better balance by building on the various elements of paradox theory. For example, in relation to the salience of tensions, it can be argued that current productivity measures do not account well for increased energy inputs to production systems. Farming productivity, for instance, has seemingly increased, especially as part of the so-called Green Revolution, but in fact the energy intensity of farming has risen a lot, and this can be extended to wider historical evidence on such increased energy inputs, thereby suggesting that more reflective productivity modeling is needed to understand and address the growth implications of apparent efficiency gains, which in reality run counter to consistency and sufficiency efforts.[44]

The potential of sufficiency was involuntarily demonstrated by CO_2 reductions driven by the COVID lockdowns in Germany in 2020. Given this was forced in a much unwanted way, it can be seen as an existence proof of feasible system configurations and at the same time as an indication of the need to proactively coordinate efficiency, consistency, and sufficiency efforts well across levels, to avoid the deprivations and shortages associated with the lockdowns. This is underscored further by some scientists arguing that the COVID pandemic was in effect triggered by human population growth, which, as detailed above, reflects the positive effects of innovation and technological progress.[45]

At the same time, the limitations caused by the COVID lockdowns led to innovation, for example in terms of novel patterns of work, life, and leisure that created new views, perceptions, experiences, and reflections—all of which would seem to hold significant generative potential in the sense of paradox theory, with one example being the large-scale adoption of video conferencing worldwide. Yet, even efficiency and consistency improvements at a scale that enables a "tunnel effect"-style transformation path, e.g., by means of digitalization, would according to paradox theory raise the question whether generative solutions are possible without sufficiency. For example, with regards to digitalization, it has been pointed out that new information technologies

> can […] both be used to speed up the pace of life (work and leisure), thus promoting a society of harried mass consumers, or it can be used to conserve precious natural resources (energy and non-energy) by doing things more intelligently and improving the quality of life without adding stress to the environment[46].

This last distinction is in fact well aligned to Jonas's idea that leisure and abundance possibly paradoxically require each other[47] and also to proposed generative solutions to this tension in terms of prioritizing prosperity, not growth.[48]

Moreover, the abovementioned tunnel effect from efficiency gains remains doubtful from a historic perspective, based on empirical evidence that suggests a tenfold gap in innovation speed, for example with regard to CO_2 efficiency improvements, but also in relation to the efficiency of providing most of the crucial materials in today's increasingly globalized—and thus homogenized—world economy.[49] Moreover, the history of digitalization to date is rather riddled with examples of rebound effects that can be explained by means of their value for addressing the perceived and advertised needs of current generations, albeit at the expense of potentially ignoring the needs of future generations in the sense of the WCED definition of sustainable development. This can be interpreted well through the lens of paradox theory by referencing power effects and pragmatic paradoxes.[50]

As detailed earlier, there is a rate and a direction of innovation activity and, consequently, resulting technological change. As stated in the introduction, this suggests we should ask, under what conditions technological development and creative destruction would lead to firms maximizing efficiency contributions to sustainable development (i.e., what rate and direction the innovative activity of companies should have)? At the core of this question is the need for system innovation, that is, significant, large-scale, synchronized, and system-wide changes that resolve (at least as much as possible) paradoxical tensions between comprehensive changes in technology, the structure of the economy, and sociopolitical and cultural systems.[51] Innovation can therefore only provide sustainable solutions if it is embedded systematically. In other words, while technology initially does not reflect values (in the sense that it can be used in very different directions, not in that it has no historical foundations), once it is involved to achieve a goal (e.g., carbon neutrality), it unavoidably reflects values. In fact, the initial decision to develop technology is often driven by values (which economists would argue are captured by price signals that may be correct or—once externalities exist in underlying markets—biased), which points to vicious cycles and feedback loops that are one core element of paradox theory.

Conclusion

As this chapter aimed to expose, the large-scale transformation of a comprehensive system (integrating technological, economic, socio-political, and cultural sub-systems and encompassing several levels) is riddled with tensions and paradoxes. It starts with a set of values that exist in a society at some point in time (based on historic, idiosyncratic, and path-dependent generation processes). Even if, in this status quo, an agreement can be reached about (more or less) appropriate or necessary choices for the future, implementing them is not always very effective, since it oftentimes meets with paradoxical tension. One reason for this is that sustainable development is in many ways inherently paradoxical and that a reorientation toward a new norm such as sustainable development implies gains and losses (relative to the current situation). This is further complicated by interactions with power distributions and infrastructures that are again historically generated and reproduced in idiosyncratic and path-dependent processes. Westpfahl also alludes to this issue at the end of his contribution when pointing out that large-scale ecological transformations also need to meet social justice requirements.[52] As a result, there is a paradox between a comprehensive transformation of the global economic system and maintaining stability in the day-to-day environment of actors at different levels (such as individuals or companies) or of sub-systems within it.

This also relates back to the question as to whether paradoxical tensions are inherent in systems or socially or cognitively constructed.[53] The generation of paradoxes, as already mentioned, is likely a combined process involving feedback, e.g., in relation to social processes of need construction that imply a tension between the maximum level of freedom for the humans currently living as opposed to ensuring maximum sustainability with regard to later generations, unborn yet. It has been pointed out that this issue is about freedom in the short versus the long term, which can also be referred to as the tension between different forms of what ultimately could be seen as a dictatorship (of the now or the future).[54]

As outlined earlier in the context of the IPAT equation, efficiency is addressed by a technology factor that reflects innovation, sufficiency reflects a willingness to accept reductions in material consumption (when basic needs are well met) and a perception shift at the level of the individual and beyond that such consumption is of lesser relevance relative to immaterial consumption or non-consumption. A paradox lens in this context specifically enables the incorporation of emotional and affective implications and outcomes in order to ultimately support the necessary comprehensive system transformations, especially in the context of climate change and distributional justice, which, due to historic path dependencies and inertia, are often very difficult to realize in present-generation daily life and business. To paraphrase critical theory, all actors can live wrong lives to some degree, since we are faced with historic conditions that are typically not perfectly aligned with current and future demands, but there is a limit to how wrong a life can be lived to remain true (to the facts or other likely longer term trends, such as global change challenging or even threatening humankind). In much the same manner, technology can often be understood in many ways as a history-based negotiation of the future that is affected by a larger or lesser degree by current power distributions.

In the light of what was discussed in this chapter (especially in relation to possible limitations of technology and innovation to increase sufficiency and consistency), paradox theory also provides another avenue to potentially generative responses, namely, that lowering expectations can equally reduce paradoxical (i.e., potentially strong to insurmountable) tensions.[55] Such satisficing clearly is an element of sufficiency and can further help convergence toward a new collective consensus based on changed expectations because it relates voluntary behaviors in support of sustainability at the individual level with higher levels, such as organizations or societies, and in doing so helps to "stay with the trouble"[56] in a manner conducive to the core propositions of both, paradox theory and environmental humanities.

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