1 Introduction: environmental policy and modelling in evolutionary economics

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This chapter functions as a short introduction to the five essays and also provides a summary of the discussions during the workshop in Amsterdam held on 18 May 2006. It does not aim to provide a literal account of these discussions. The objective is rather to formulate an advice on how to use evolutionary economic modelling for environmental research and policy. Section 1.1 will first explain shortly why environmental agencies should be interested in exploring the possibilities of evolutionary economic modelling. Section 1.2 summarizes the discussions on existing evolutionary economic models and the lessons they provide for new modelling activities. Finally, section 1.3 draws some conclusions.

1.1 Why evolutionary economic modelling

Where social science is increasingly used for sustainability assessment, a proper tool to include social issues is often lacking. Presently this gap is often filled with a neoclassical economic approach. Neoclassical economics generally offers consistency as well as the availability of sound data, which makes it a strong basis for economic analysis. However, the neoclassical approach is not very fit to grasp system changes, radical innovations or socio-economic transitions, because it is not capable to deal with diversity of behaviour and imperfect rationality (see Van den Bergh et al., 2005 for a discussion on evolutionary versus neoclassical economics). An evolutionary economic approach could overcome some of these limitations of neoclassical models currently dominant (even if evolutionary models have limits of their own). In particular, evolutionary economics has a more realistic stance towards modelling economic agents. In contrast to neoclassical models, evolutionary models will have to take a number of defining characteristics into account (Nelson and Winter, 1982; essay Verspagen):

1. the bounded rationality of agents (firms, consumers, governments),
2. the heterogeneity of agents (firms, consumers, governments) and contexts (geographical, institutional),
3. the path dependent nature of technological development creating irreversibility in the socio-economic system, and
4. multiple equilibria, which act as attractors but are rarely reached in time (rather than an instantaneously reached, single equilibrium as in neoclassical economic models).

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Given these characteristics, evolutionary models can provide new understandings and new tools for the analysis and layout of environmental innovation policy. In particular, following recent governmental initiatives in the Netherlands organised under the heading of *transition management*, evolutionary models may be helpful in assessing and developing policy strategies to trigger technological transitions from one technological system to a future technological system (Grübler, 1998; Unruh, 2000, 2002; Hoogma et al., 2002; Frenken et al., 2004; Könnölä et al., 2006; Van den Bergh et al., 2005; Dosi and Grazzi, 2006; Carrillo-Hermosilla, 2006; Zhang et al., 2006). There is a growing consensus that societies should reduce their dependence on fossil fuels and shift to more sustainable alternatives (e.g., from a gasoline to a fuel cell car system). However, it is far from clear which of the alternative technologies should be selected and introduced at a large scale. Given the current uncertainties, the development of a large variety of technological options is to be preferred.

The specific features and (therefore) added value of an evolutionary approach compared to traditional neoclassical approach in the context of technological transitions can be summarised in three aspects:

1. **Technological trajectories and technological paradigms**

Neoclassical (endogenous) models of technology adoption focus solely on changes in factor prices that induce the level and the choice of technology. In the context of technological transitions, these models tend to favour policies that ‘correct’ prices through taxes and subsidies to reflect the true welfare consequences of various technologies. These price changes will then trigger firms to adopt – or start developing – cleaner technologies. Evolutionary economic models, on the other hand, focus on the idea that technological development follows certain technological trajectories of incremental change (due to learning, network externalities and increasing returns to scale) within the boundaries of a technological paradigm (Dosi, 1982; Frenken, 2006) or what has been termed a techno-institutional complex in the context of the carbon-based technologies (Unruh, 2002). Only occasionally, transitions occur between two technological paradigms, yet these transitions are triggered not only by higher prices of the old paradigm, but also by the exhaustion of technological opportunities in the old paradigm and new, or newly recognised, technological opportunities in alternative paradigms. The classic example is the limited effect of the oil crisis in the 1970s on the subsequent direction of technological development. Higher oil prices did not induce radically different alternatives but rather pushed for incremental innovations within the oil-based technologies, aimed at saving fuel or reducing pollution. By contrast, the current peak in oil prices seems to trigger R&D efforts of a more radical nature because profit returns along the current technological trajectory have decreased and institutional pressures towards sustainability have increased. The shift in dynamics between 1970s and today cannot be explained by a neoclassical model including price changes only, but is more in line with an evolutionary model that stresses the incremental innovation strategies of firms and governments. This is not to say, however, that economic incentives play no role at all in evolutionary modelling (e.g., essay Schwoon). Rather, an evolutionary approach stresses that price changes alone are insufficient to explain the rate and direction of technological development and that a broader perspective should be taken into account.

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4 On the concept of variety in evolutionary economics, see Saviotti (1996) and Stirling (1998, 2004).
2. Taking demand seriously

A second fundamental difference is the treatment of demand. Rather than reducing human consumption to given preferences, which are articulated solely through prices, an evolutionary approach to consumption stresses that preferences are subject to change (Witt, 2001; essay Jager). Changing preferences may result in public action towards sustainability, for example in the form of imposing stricter regulatory standards, new labels, or even the banning of certain products or materials. In this context, it is crucial to have insight into the effects of standards on industrial dynamics (essay Saint-Jean) as well as into the political processes that lead societies to introduce particular standards (Könnölä et al., 2006). Changing preferences can also lead to user-led innovations as demanding ‘niche users’ are often crucial as the frontrunners to a technology’s emergence and success (Von Hippel, 1988; essay Windrum). Thus, in an evolutionary world, the role of consumers lies not so much in reacting to price differentials but more in their ability to change their preferences, possibly triggering new niche out-of-paradigm niche markets.

3. A co-evolutionary perspective on policy

In evolutionary economics, institutions including government policy are seen as an integral part of technological paradigms rather than being independent from it. For example, part of the technological paradigm surrounding the current car system is a complex set of institutions including tax laws, environmental laws, fuel supply infrastructure, safety requirements, technological standards, traffic rules, trade treaties, consumer organisations, producer organisations, training and research institutions, brand names, consumer typologies, et cetera. These institutions strengthen the current paradigm and contribute to its economic efficiency and social acceptance. Environmental innovation policy thus requires not only specific policies to favour certain developments within the existing paradigm or the development of alternative paradigms, but policies should also change the institutions inherited from the previous/current technological system in desirable directions. As such, evolutionary economics takes a meta-institutional perspective on technological development in which technological change, consumer demand and institutions co-evolve and mutually interact (essay Windrum).

1.2 Models

Evolutionary models can be used for policy making in a way similar to neoclassical models in that one can experiment with different policy measures and evaluate their effect \(ex \ ante\) (for example, in terms of welfare, in terms of CO\(_2\) reduction, etc.).\(^5\) Obviously, experimenting with different policy measures using models that simulate society is less costly and less risky than actual experiments with true policy. However, the insight gained through computer simulation crucially depends on the ‘degree of correspondence’ of the model to real-world society. Correspondence in this context does not necessarily mean that models that try to take into account more aspects of reality also achieve a higher degree of correspondence. What matters most is that models capture the most relevant mechanisms at work in specific social processes.

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\(^5\) Another use of models is to specify the model as a game and to let stakeholders play with the model and discuss the results.
1.2.1 Existing evolutionary economic models

A wide range of existing models falls under the family name of ‘evolutionary economics’ (see especially the essay by Verspagen). In particular, there is a variety of approaches towards evolutionary economic modelling for studying technological development. Within the variety of evolutionary models one can distinguish broad comprehensive models from more specific models. Within the second type of models one can subsequently distinguish four different focussing strategies.

1. **Comprehensive evolutionary models**: models that take into account all relevant aspects of technological development. These models include different co-evolving populations (consumers, producers, governments) and different mechanisms (competition, innovation, learning, externalities, market segmentation) in a comprehensive and (more or less) integrated approach and a broad framework. Windrum’s essay provides an overview of elements that could be included in such a model based on a review of theory, models and case studies. Comprehensive evolutionary models may serve to describe and understand the integrated *context* of large scale technological developments, without the disadvantages of including detailed bottom-up technical studies. Methodologically, these models have a high level of aggregation and they may suffer from the many parameters that are present in the model, due to the large number of (sometimes poorly understood) mechanisms of social processes included. This renders their validation significantly more difficult than simpler models.

2. **Specific evolutionary models**: these models focus on understanding a specific aspect of technological innovation, thus greatly reducing the complexity of the modelling task at hand. These specific models usually have less parameters and lead to more conclusive insight, but they run the risk of lacking a clear perspective on the broader framework in which technological development takes place. There are mainly four focusing strategies in specific evolutionary models:

   a. To focus on one specific technology
   b. To concentrate on one specific mechanism
   c. To focus on one specific population of agents
   d. To follow a modular approach in which different parts of a technological system are modelled in separate models with clear interfaces among them

All four strategies are exemplified in the essays. Verspagen follows strategy a. by focusing on micro co-generation technologies. Saint-Jean follows strategy b. by focusing on the impact of environmental standards on product and process innovation. Jager follows strategy c. discussing the behaviour of consumers as one of the relevant populations in the economy. Finally, Schwoon adopts strategy d. in his study on the technological system of fuel cells.

During the workshop consensus emerged that specific evolutionary modelling – which can also be termed middle range theorizing – is more attractive than the first type of wide range theorizing, since it offers more perspective on practical modelling application, without having to make an unacceptably large number of assumptions beforehand. Presently, the development of comprehensive, integrated evolutionary models for the study of technological systems is still regarded to be a bridge too far. The specific strategies to reduce the complexity of the modeling task at hand, then, apply in different contexts:
1. **Strategy a** is especially relevant when a policy maker is interested in assessing the potential of a specific new technology (including its sub-variants) as well as to investigate what type of policy is most helpful in stimulating the technology given its specific technological characteristics and market conditions.

2. **Strategy b** is especially relevant when a policy maker wants to assess the effectiveness and efficiency of some general policy measure (subsidy, regulation, standards, etc.) in different types of markets c.q. technologies.

3. **Strategy c** is especially relevant when a policy is interested in evaluating different ways to influence particular types of agents, for example, consumers, truck drivers, firms, farmers, etc.

4. **Strategy d** is especially relevant to advance a theoretical understanding of the complete technological system. Furthermore, the different modules can be applied more specifically, using strategy *a*, *b* or *c*.

For each of these strategies the *system scale* and *time horizon* are very relevant parameters to take into account in defining the policy questions to address with the model. Verspagen points out in his essay that uncertainty is high in the study of large-scale systems, because many interconnected components are unpredictable. Because of the dependency between the components in the system at large, unpredictability multiplies at the system level. On the other hand, at micro-level studies there’s a large amount of external factors as well as a large degree of heterogeneity. Therefore, evolutionary theory is regarded to be a theory of the intermediate range. Within this approach, it is useful to take into account the ‘windows of opportunity’ for policy makers, making use of larger scale political and technological dynamics (e.g. EU regulations) as well as of the interplay between short-term and long term policies. This momentum may greatly affect the diffusion of technologies and thus ‘the right time’ for political action aimed at stimulating environmental technologies (Sartorius and Zundel, 2005). This clearly drifts away from regular neoclassical approaches of instant reaction to e.g. a tax measure.

Most evolutionary economic models do not include policy options for influencing the outcome of the modelled processes. Only a limited number of examples of policy oriented evolutionary economic models (outside environment and ecology) is available. Although the concept of evolution has found its way in management theory, its applications in economics have been less frequent. Exceptions are the Swedish MOSES-model that is used for economic policy questions (Ballot and Taymaz, 1999), a recent model of technological transitions based on fitness landscapes (Schwoon et al., 2006), work on environmental policy in the essays by Saint-Jean and Schwoon, and the papers presented at a recent workshop on ‘agent-based models for economic policy design’ organized by Professor Herbert Dawid.⁶

⁶ See: http://www.wiwi.uni-bielefeld.de/~dawid/acepol/program.htm
1.2.2 Recommendations for getting started and for a long term research agenda

Based on the essays and workshop discussions (first working sessions) the following conclusions and recommendations can be made on evolutionary economic modelling to support policy studies:

- It is impossible to build a generic model for the economic development of our society at large;
- Focus on a technology (strategy a), a mechanism (strategy b) or a population of agents (strategy c), possibly using these strategies as modules for a more integrated approach to a technological system (strategy d);
- It is important to identify the relevant stakeholders, underlying mechanisms and dynamics, and the relevant technologies (foresights);
- Evolutionary model builders should therefore work in close association with experts in a particular field, as well as experts in different kinds of (technology) foresight studies.
- Statistical and empirical information on populations, psychological, sociological and economic theory is needed to provide an adequate input to the model. It is therefore advisable to start with a well-known and well-described (in terms of mechanisms and data availability) problem.
- An interesting approach might be to link the evolutionary model with other types of models: e.g. describe system options with an Input-Output approach using the DIMITRI-model (Idenburg and Wilting, 2004), and then simulate pathways to that system with an evolutionary economic model.
- For the longer term, it is considered important to have a number of different model (concepts) available dealing with similar phenomena or questions. Within such model diversity one can envisage some level of model competition, which could enhance learning and insight in modelling approaches.
- The research organisation could be structured as in the following scheme:

![Figure 1.1 Scheme of future research organisation](image-url)
1.3 Conclusion

Evolutionary economics provides a promising theory to assess and understand processes of change in economic structure, technological development and institutions, as well as to formulate guidelines for the role of government and the design of public policy in this context. Evolutionary economic models can in principle be used to experiment with different policy measures and to evaluate \textit{ex ante} effects. However, although evolutionary economic modelling is promising in terms of describing mechanisms, there is no complete scientific consensus yet on a single modelling paradigm, but a number of examples of evolutionary economic models on micro-level problems is available as a useful starting point.

Two essential recommendations stand out for further development of evolutionary modelling with respect to environmental policy analysis:

1. focus on a specific issue (a technology or a mechanism or a population), rather than taking into account all complexities;

2. make sure that the empirical base in terms of mechanism and data is sound.

It is important to realise that the development of evolutionary economic modelling is an evolutionary process itself. It may therefore be helpful to develop competing approaches and assess their relative performance rather than aiming at one modelling paradigm.
References


