Environmental Innovation and Societal Transitions xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Environmental Innovation and Societal Transitions

journal homepage: www.elsevier.com/locate/eist

The role of lock-in mechanisms in transition processes: The case of energy for road transport

Antje Klitkou[a,*], Simon Bolwig[b], Teis Hansen[c], Nina Wessberg[d]

[a] NIFU Nordic Institute for Studies in Innovation, Research and Education, P.O. Box 5183 Majorstuen, N-0302 Oslo, Norway
[b] Department of Management Engineering, Technical University of Denmark (DTU), Roskilde, Denmark
[c] Department of Human Geography & Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE), Lund University, Sweden
[d] VTT Technical Research Centre of Finland, Espoo, Finland

ARTICLE INFO

Article history:
Received 18 February 2015
Received in revised form 28 June 2015
Accepted 5 July 2015
Available online xxx

Keywords:
Path dependency
Lock-in mechanism
Transition process
Road transport
Renewable energy

ABSTRACT

This paper revisits the theoretical concepts of lock-in mechanisms to analyse transition processes in energy production and road transportation in the Nordic countries, focussing on three technology platforms: advanced biofuels, e-mobility and hydrogen and fuel cell electrical vehicles. The paper is based on a comparative analysis of case studies.

The main lock-in mechanisms analysed are learning effects, economies of scale, economies of scope, network externalities, informational increasing returns, technological interrelatedness, collective action, institutional learning effects and the differentiation of power.

We show that very different path dependencies have been reinforced by the lock-in mechanisms. Hence, the characteristics of existing regimes set the preconditions for the development of new transition pathways. The incumbent socio-technical regime is not just fossil-based, but may also include mature niches specialised in the exploitation of renewable sources. This implies a need to distinguish between lock-in mechanisms favouring the old fossil-based regime, well-established (mature) renewable energy niches, or new pathways.

1. Introduction

The concept of lock-in has been extensively used to explain the persistence of fossil fuel-based technological systems despite the fact that their well-known environmental externalities contribute to climate change. Moreover, this 'carbon lock-in' inhibits the diffusion and adoption of carbon-saving technologies (Frantzeskaki and Loorbach, 2010; Unruh, 2000).

Lock-in can be defined as positive feedbacks or increasing returns to the adoption of a selected technology (Arthur, 1994b; Unruh, 2000, 2002). As a result, incumbent technologies have a distinct advantage over new entrants, not because they are necessarily better, but because they are more widely used and diffused. Positive feedback mechanisms decrease production costs and create additional benefits for users. A stable incumbent regime is the outcome of various lock-in processes and it favours incremental as opposed to radical innovation. The cost and performance of a new technology are more uncertain compared to incumbent technologies (Sandén and Azar, 2005).

* Corresponding author. Fax: +47 22595101.
E-mail addresses: antje.klitkou@nifu.no (A. Klitkou), sibo@dtu.dk (S. Bolwig), teis.hansen@keg.lu.se (T. Hansen), nina.wessberg@vtt.fi (N. Wessberg).

http://dx.doi.org/10.1016/j.eist.2015.07.005

Please cite this article in press as: Klitkou, A., et al., The role of lock-in mechanisms in transition processes: The case of energy for road transport. Environ. Innovation Soc. Transitions (2015), http://dx.doi.org/10.1016/j.eist.2015.07.005

The discussion of lock-in mechanisms in this paper is motivated by our interest in transition processes, especially transitions towards more sustainable energy and road transportation systems. In this regard, initially "minor changes and marginal developments may evolve into massive structural configurations that then restrict the variety of directions to future changes" (Voß and Kemp, 2006:13). Such transition processes are, therefore, path-dependent. In this paper, we do not focus on processes of path-creation, but rather on the lock-in mechanisms that set the preconditions for these new paths.[1] Lock-in mechanisms are conceptualised as mechanisms, which reinforce a certain pathway of economic, technological, industrial and institutional development and can lead to path-dependency.

A core argument of our paper is that the persistence of existing socio-technical systems can be explained by using more specific concepts than niche, socio-technical regime and landscape as provided by the multi-level perspective (MLP) (i.e., Geels, 2004; Kemp et al., 1998). In the MLP framework, the concept of a regime is defined as:

> "the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems—all of them embedded in institutions and infrastructures" (Rip and Kemp, 1998:338).

It is argued that the different elements of such a complex system – the material, organisational and conceptual dimensions of the system (Sandén and Hillman, 2011) – are aligned with each other. Thus, the existing socio-technical system has a stabilising influence on innovation dynamics and technological change and prevents the introduction of radically new technological trajectories.

However, a key critique of the MLP framework is that it describes lock-in in a rather totalising way, with few specifications of the specific mechanisms through which lock-ins become manifested. We argue that distinguishing between various technological and institutional lock-in mechanisms improves our understanding of the persistence of the dominant socio-technical regimes and the difficulties for emerging niches to upscale. Thus, this specifies the ways in which existing regimes set the preconditions for the development of new transition pathways. As different regimes are characterised by different lock-in mechanisms, the opportunities for upscaling a given niche depends on the specific characteristics of the relevant regime.

A comparative perspective on lock-in mechanisms in ongoing transition processes helps develop a clearer understanding of transition processes as being the result of an "interplay of path dependence, path creation and path destruction" (Martin and Sunley, 2006:408). In this paper, we analyse the transition from fossil energy to renewable energy-based road transport systems in the Nordic countries and we specify the role of various lock-in mechanisms in this transition process. We focus on possible transition pathways towards more sustainable energy and transportation systems in four Nordic countries – Denmark, Finland, Norway and Sweden – and pose the following research question:

How do different lock-in mechanisms of socio-technical regimes influence new transition pathways?

The paper is based on a comparative analysis of case studies of four Nordic countries. We selected one technology platform for each country: advanced biofuels for Finland and Sweden, battery electrical vehicles (BEV) for Denmark and fuel cell electrical vehicles (FCEV) and hydrogen for Norway.

The paper is organised as follows: in the next section, we review the academic literature on path-dependency and lock-in mechanisms and develop the analytical framework for the comparative analysis. In the third section, we describe the methodological approach and data used. In the fourth section, we discuss the technological and institutional lock-in mechanisms at work in the selected technology platforms for each country. Section 5 discusses the lock-in mechanisms across the different cases and the value of the concepts of lock-in mechanisms when analysing transition processes. Finally, we draw conclusions for further research.

2. Theory: lock-in mechanisms revisited

There have been a number of studies of technological change and innovation in economics and in organisation and institutional research, which attempt to conceptualise different lock-in mechanisms in economic, institutional and organisational development.

Early studies by Brian Arthur and Paul David have focused on increasing returns of adoption, positive feedbacks and path dependency (Arthur, 1988, 1989, 1994b) and on the role of historical small events and elements of chance in achieving a dominant market position to realise economies of scale and decreasing cost conditions (David, 1985). While neoclassical economic theory is built on the general paradigm of diminishing returns and equilibrium of prices and market shares, Arthur argues that resource-based sectors and knowledge-based sectors follow different logics. Resource-based sectors and factor-intensive technologies, like agriculture, bulk goods production, mining and power generation are mostly subject to "diminishing returns," while the knowledge-based parts of the economy are subject to "increasing returns" of adoption (Arthur, 1990, 1994a:25, 1994b:3). This difference is explained by large *initial investments* in research and development and tooling in the knowledge-based economy, where rather cheap *follow-up investments* in incremental innovation are sufficient

[1] This issue is considered in a paper that analyses selected path creation processes in Nordic energy and road transport systems (Hansen et al., 2015, in preparation). The paper also discuss the theoretical framework for path creation (i.e., Garud and Karnøe, 2001), which highlights the important role of agency in creating new trajectories.

Please cite this article in press as: Klitkou, A., et al., The role of lock-in mechanisms in transition processes: The case of energy for road transport. Environ. Innovation Soc. Transitions (2015), http://dx.doi.org/10.1016/j.eist.2015.07.005