Resource and Energy Economics 25 (2003) 105–126

RESOURCE and ENERGY ECONOMICS

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Explaining slow diffusion of energy-saving technologies; a vintage model with returns to diversity and learning-by-using

Peter Mulder [a,*], Henri L.F. de Groot [b], Marjan W. Hofkes [a]

[a] *Institute for Environmental Studies, Vrije Universiteit, De Boelelaan 1087, 1081 HV Amsterdam, The Netherlands*

[b] *Department of Spatial Economics and Tinbergen Institute, Vrije Universiteit, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands*

Received 28 April 2001; received in revised form 7 April 2002; accepted 12 May 2002

Abstract

This paper studies the adoption and diffusion of energy-saving technologies in a vintage model. An important characteristic of the model is that vintages are complementary: there are returns to diversity of using a mix of vintages. We analyse how diffusion patterns and adoption behaviour are affected by complementarity and learning-by-using. It is shown that the stronger the complementarity between different vintages and the stronger the learning-by-using, the longer it takes before firms scrap old vintages. We argue that this is a relevant part of the explanation for the observed slow diffusion of energy-saving technologies. Finally, we show that an energy price tax reduces energy consumption, because it speeds up the diffusion of new energy-saving technologies and induces substitution from capital to labour.

JEL classification: E22; O33; Q43

Keywords: Energy efficiency; Vintage models; Returns to diversity; Technology diffusion; Learning

1. Introduction

Concerns about global climate change associated with the combustion of fossil fuels urge a call for the development and widespread adoption of energy-saving technologies. It is beyond doubt that the *development* of new energy-saving technologies—often

* Corresponding author. Tel.: +31-20-444-9555; fax: +31-20-444-9553.
E-mail address: peter.mulder@ivm.vu.nl (P. Mulder).

PII: S0928-7655(02)00019-2

labelled with the subsequent phases of invention and innovation—plays an important role in meeting policy targets with respect to the stabilisation or reduction of greenhouse gas emissions. However, the *diffusion* of existing technologies is at least equally important, costly and difficult, as the development of new technologies (Jovanovic, 1997). It has indeed been shown that the widespread adoption of existing energy-saving technologies could enable a significant reduction in energy use, especially in the short and medium run (de Beer, 1998; IWG, 1997). At the same time, however, it is known that diffusion of new technologies is a lengthy process, that adoption of new technologies is costly and that many firms continue to invest in old technologies. The latter phenomenon is known as the energy efficiency paradox: the existing gap between the most energy-efficient technologies available at some point in time and those that are actually in use (Jaffe and Stavins, 1994; Jaffe et al., 1999). The aim of this paper is to contribute to our understanding of adoption behaviour of firms and of diffusion processes of new energy-saving technologies in order to improve our understanding of the observed slow diffusion of energy-saving technologies.

The question why firms do not exclusively invest in the newest technologies has already achieved much attention in the literature. We can distinguish four major explanations for the relatively slow diffusion of new technologies. The first explanation is that the combination of uncertainty and some degree of irreversibility in investment creates an option-value of waiting (Balcer and Lippman, 1984; Dixit and Pindyck, 1994; Farzin et al., 1998). The second explanation stresses strategic issues: in a world characterised by spillovers and limited appropriability, the presence of (expected) rival innovation and imitation creates an incentive for firms to postpone innovation or adoption (Kamien and Schwartz, 1972; Reinganum, 1981). The third explanation highlights the fact that over time the performance of existing technologies improves and their price reduces due to learning-by-doing and spillover effects (Jovanovic and Lach, 1989; OECD/IEA, 2000). A final explanation emphasises the role of vested interests. As switching to new technologies (temporarily) reduces expertise and hence destroys rents associated with working with relatively old technologies for particular subgroups in the economy, these groups may engage in efforts aimed at keeping the old technologies in place (Canton et al., in press; Krusell and Ríos-Rull, 1996; Mokyr, 1992).

In this paper, we offer two additional explanations for the slow diffusion of energy-saving technologies. The first explanation is rooted in a complementarity effect and the second in a learning-by-using effect associated with the use of the technology. We argue that complementarity (or, alternatively, imperfect substitutability) is not so much a by-product of past investment decisions, but an essential ingredient of the process of technological change. It is evident that at the macro level there is continuous investment in both old and new technologies. Similar patterns exist at the sector or even at the firm level, depending on the technology and the type of production process. Many new technologies pass through a life cycle, in which they initially complement older technologies, and only subsequently (and often slowly) substitute for older technologies. A number of historical examples, like the replacement of the waterwheel by the steam engine or the diffusion of new types of processes in the iron and steel industry, illustrates the relevance of complementarities in this ‘life cycle view’ of technological change (Rosenberg, 1976, 1982; Young, 1993b). One can argue that modern production processes consist of even more