ELSEVIER

Resource and Energy Economics 25 (2003) 81–103

RESOURCE and ENERGY ECONOMICS

www.elsevier.com/locate/econbase

An endogenous growth model with embodied energy-saving technical change

Adriaan van Zon[a,*], I. Hakan Yetkiner[b]

[a] *Department of Economics and MERIT, Maastricht University, P.O. Box 616, 6200 MD Maastricht, The Netherlands*

[b] *Department of Economics, University of Groningen, Groningen, The Netherlands*

Received 1 May 2001; received in revised form 5 April 2002; accepted 10 May 2002

Abstract

In this paper, we extend the Romer [Journal of Political Economy 98 (Part 2) (1990) S271] model in two ways. First we include energy consumption of intermediates. Second, intermediates become heterogeneous due to endogenous energy-saving technical change. We show that the resulting model can still generate steady state growth, but the growth rate depends negatively on the growth of real energy prices. The reason is that real energy price rises will lower the profitability of using new intermediate goods, and hence, the profitability of doing research, and therefore have a negative impact on growth. We also show that the introduction of an energy tax that is recycled in the form of an R&D subsidy may increase growth. We conclude that in order to have energy efficiency growth and output growth under rising real energy prices, a combination of R&D and energy policy is called for.

JEL classification: O31; O41; Q43

Keywords: Endogenous growth; Energy-saving technological change; Energy efficiency

1. Introduction

Steady state economic growth requires a corresponding growth of energy consumption, unless the energy efficiency of production grows faster than output itself.[1] The last 30 years or so have indeed shown a significant growth of the energy efficiency of production. A striking example in this respect is Japan.[2] During the period 1955–1973, Japan's manufacturing

* Corresponding author. Tel.: +31-43-388-3875.
E-mail address: adriaan.vanzon@merit.unimaas.nl (A. van Zon).

[1] The energy efficiency of production is defined as the inverse of the consumption of energy per unit of output.

[2] See Watanabe (1999). See also Table 1 in Smulders and de Nooij (2001), showing that the US, France, West Germany, and UK have succeeded in substituting technology for energy, too.

0928-7655/02/$ – see front matter
PII: S0928-7655(02)00018-0

industry enjoyed an average annual growth rate of 13.3%, which was supported by a stable supply of cheap energy, growing at 12.9% per year (the annual increase in rate of energy efficiency was only 0.4% in that period). In the Seventies, however, the world economy experienced two big energy-price shocks, and policy makers in Japan had to take strict measures to increase energy efficiency. They were very successful indeed, since Japan's manufacturing industry grew at 3% per year on average during the years 1974–1994, while its energy consumption declined by 0.4% (hence, energy efficiency increased by 3.4%). The key to this miracle was energy-saving technological change through the development and production of more energy-efficient products.

Although the influence of energy on growth has been a popular topic in 'old' growth theory, mainly in the context of exhaustible resources,[3] in 'new' growth theory energy consumption has so far not been a serious issue, although there are some exceptions (Aghion and Howitt, 1998; Smulders and de Nooij, 2001). Energy-economy modellers, on the other hand, have shown a renewed interest in the relationship between energy use and technology, mainly in the form of induced technological change (henceforth, ITC).[4] Their main research question has been whether price shocks and policy changes induce the development of energy-saving technologies. For example, Newell et al. (1999) have empirically tested the induced innovation hypothesis at the product level, using a dataset on consumer durables. They did indeed find evidence that the energy efficiency of these durables had increased in response to rising energy prices and government regulations, besides autonomous overall technological change. Popp (2001) has addressed the ITC question at the aggregate level by relating U.S. patent data from 1970 to 1994 to changes in energy-prices. He finds that there is a strong positive impact of energy prices on technological change. The ITC idea has been quickly assimilated in environment-economy models.[5] Not only because induced innovations are a reality to be taken into account, and certainly so in the long term, but also because induced energy-saving technical change makes for less gloomy growth prospects from an energy consumption perspective. The reason for the latter is that if price changes induce energy-saving technological change, then policies that raise the user price of energy (e.g. environmental taxes and regulations) may help pollution abatement, while the negative impacts of higher energy prices on the growth of an economy may in part be overcome through induced energy-saving technological change. Recent studies nonetheless showed that that 'wish' is hard to realise. Two recent examples are Goulder and Schneider (1999) and Nordhaus (2002). The numerical model of Goulder and Schneider (1999) show that a carbon-tax may stimulate research in alternative energy industries. Such a tax however may discourage R&D by non-energy industries and by carbon-based energy industries. The reduction in the latter industries may even slow down their output growth, and hence, the overall growth of economy. Nordhaus (2002) compares the implications of policy changes in two different set-ups: in the basic model increases in the price of carbon energy relative to other inputs induce users to purchase more fuel-efficient equipment or employ less-energy-intensive products and services. In the modified model a rise in the

[3] See, for example, Dasgupta and Heal (1974).

[4] The formal theory of induced innovation goes back to 1960s (e.g. Nelson, 1959; Kennedy, 1962). A recent comprehensive work on ITC-related issues is Ruttan (2001).

[5] See Jaffe et al. (2002) for a review of the literature on technological change and the environment.