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The impact of energy conservation on technology and economic growth

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Abstract

We present a model of growth driven by energy use and endogenous factor-augmenting technological change. Both the rate and direction of technological progress are endogenous. The model captures four main stylised facts: total energy use has increased; energy use per hour worked increased slightly; energy efficiency has improved; and the value share of energy in GDP has steadily fallen. We study how energy conservation policies affect growth over time and in the long run. Policies that reduce the level of energy use are distinguished from those that reduce the growth rate of energy inputs. Although these policies may stimulate innovation, they unambiguously depress output levels. The former policy has no impact on long-run growth; the latter reduces long-run growth both in the short run and in the long run.

JEL classification: O41; Q43

Keywords: Economic growth; Energy; Innovation

1. Introduction

Central to the economic analysis of climate change policies are the interactions among energy use, technological change and economic growth. The stabilisation of greenhouse gas concentrations requires reductions in fossil fuel energy use, which is a major essential input throughout all modern economies. Cuts in energy use are likely to seriously affect GDP and economic growth. However, if energy conservation can be realised through new energy efficient technologies, the trade-off between energy reduction and growth becomes less severe.

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Economists have increasingly stressed the crucial role of technical change in the context of climate change, environmental and energy policy (see Loeschel, 2002, for a survey). It is found that the cost of such policies crucially depends on how fast energy efficiency improves. Technical change should be viewed as an endogenous variable: either directly or through changing energy prices, policies may induce innovation by providing incentives to allocate more resources to the development of energy-saving technologies. Climate policy assessments based on the conventional assumption of autonomous energy efficiency improvements ignore these effects. This is why recent studies stress evidence of induced technical change (see Jaffe et al., 2000), focus on learning effects associated with abatement activities and clean technology, and turn to (mostly ad hoc) modelling of induced technical change (see the survey by Azar and Dowlatabadi, 1999).

To enhance our understanding of how environmental and energy policies induce technical change, and how they affect economic growth, we need a general-equilibrium analysis of the allocation of research and development activities in the total economy. Policy may not only affect innovation related to energy and clean technologies, but may also crowd out other innovation projects when changing the direction of technical change. We need to know how policy affects the *direction* of innovation as well as the aggregate *rate* of innovation. The interaction between these two is neglected in most of the literature so far.

The aim of this paper is to develop a growth model in which energy is an essential input and endogenous technical change drives long-run growth. We require that this model is consistent with the main stylised facts concerning energy use and growth. We model innovation as rational investment behaviour driven by profit maximisation. We build the model in order to find analytical results concerning the effects of a reduction in energy use ("energy conservation") on the rate and direction of technical change, and on GDP and growth over time.

For our purposes, the model has to be consistent with at least four stylised facts. Jones (2002), based on EIA (1999) summarises these for the US over the period 1950–1998. First, energy efficiency (GDP per unit of energy input) has improved at an annual rate of 1.4% on average. Second, per capita energy use has increased at an average annual rate of about 1%. Third, the share of energy cost in GDP has declined at an average annual rate of about 1%. Fourth, energy prices per unit of labour cost have declined (see also Nordhaus, 1992; Simon, 1996). Needless to say, the trends for the period 1971–1980 are markedly different, with even faster improvements in the energy efficiency, falling per capita energy inputs, and a sharply rising energy cost share (from 2% in 1970 to 7% in 1980). In Table 1 and Figs. 1 and 2, we present figures based on own calculations for the US, Japan, and three large European economies.[1] The trends after 1969 are similar to those of the US.

In our model, per capita energy evolves exogenously and ongoing technical change explains the steady decline in energy intensity, energy share, and price of energy relative to wages. Labour and energy inputs enter the production function symmetrically as gross com-

[1] We used data from the International Sectoral Database (OECD, 1999), and the OECD energy balances. Following the approach outlined in de Nooij et al. (2001), we used the sectoral data to include the transformation losses and the deliveries of the electricity sector to other sectors in the macro-economic energy use. From the Penn World Tables (Summers and Heston, 1991, mark 5.6) we used the data on population (1), real GDP per capita in constant dollars (3), real GDP per worker 1985 international prices (19) and non-residential capital stock per worker in 1985 international prices (20; numbers refer to the ordering in Summers and Heston).