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Energy taxes and endogenous technological change

Pietro F. Peretto *

Department of Economics, Duke University, Durham, NC 27708, USA

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ABSTRACT

This paper studies the effects of a tax on energy use in a growth model where market structure is endogenous and jointly determined with the rate of technological change. Because this economy does not exhibit the scale effect (a positive relation between TFP growth and aggregate R&D), the tax has no effect on the steady-state growth rate. It has, however, important transitional effects that give rise to surprising results. Specifically, under the plausible assumption that energy demand is inelastic, there may exist a hump-shaped relation between the energy tax and welfare. This shape stems from the fact that the reallocation of resources from energy production to manufacturing triggers a *temporary acceleration* of TFP growth that generates a $\surd$-shaped time profile of consumption. If endogenous technological change raises consumption sufficiently fast and by a sufficient amount in the long run, and households are sufficiently patient, the tax raises welfare despite the fact that—in line with standard intuition—it lowers consumption in the short run.

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1. Introduction

This paper studies the effects of a tax on energy use in a growth model where technological change and market structure are endogenous. Of particular interest is the interaction between changes in the inter-industry allocation of resources across manufacturing and energy production and the intra-industry effects within manufacturing. The latter are important because the manufacturing sector is the engine of growth of the economy.

There are several reasons why such an analysis is worthwhile. The current spike in the price of oil stands out as it has once again focussed attention on how *energy prices* affect the economy in the short and the long run.

At business cycle frequency, the evidence on the macroeconomic effects of energy prices is mixed. Hamilton argues that exogenous shocks to the price of oil explain most of the fluctuations of the US economy [9,10]; Barsky and Killian, in contrast, argue that they matter very little [5,11,12]. It is fair to say, however, that the conventional wisdom emerging from time-series studies is in line with Hamilton's view—that is, the price of oil drives economic fluctuations and growth. A corollary to this view is the widespread belief (particularly in the US) that high standards of living require low energy prices.

An alternative approach is to look at cross sections of countries. The best, and most recent, example is Bretschger [6], a very interesting study that covers some of the ground that I cover here. The main difference is that [6] treats energy as a primary input (i.e., not produced by means of other inputs) and thus does not allow for the intersectoral reallocation of resources that drives my results. More importantly it does not study welfare, which instead is the main focus of my analysis. However, it includes an empirical section that provides results directly relevant to my own. First, it shows that

* Fax: +1 919 6848974.
E-mail address: peretto@econ.duke.edu

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energy demand is inelastic: in a sample of 37 developed countries with 5-year average panel data over the period 1975–2004, the estimated mean price elasticity of energy use per capita is −0.3. Also, it documents that energy use crowds out investment in physical, knowledge and human capital and therefore crowds out long-run growth: the estimated overall steady-state effect of energy use on growth is −0.1. This is a rather large effect. Moreover, it is an effect that begs further research. As Bretschger puts is: "That high energy prices can be good for growth is somewhat counterintuitive. However, intuition may have been relying too much on the business cycle in the 1970s, and not necessarily on long-run growth experience" [6, p. 3].

In summary, there is ample motivation for studying the role of energy prices and energy policy in a growth context. In light of many governments' stated goal of reducing energy intensity (the ratio of energy use to GDP) without inflicting undue harm, moreover, understanding the role of specific instruments like energy taxes becomes very important.

Over the last 10 years economists have placed more and more emphasis on the role of technological change in the analysis of energy, environmental, and climate policy.[1] The reason is that technology is now seen as a crucial factor in the assessment of the long-run costs and benefits of the proposed interventions. Perhaps surprisingly, however, the literature has not exploited to its full potential the modern theory of endogenous technological change to shed new light on these issues.[2] With this paper, I try to fill this gap.

I take a new look at the long-run implications of energy taxation (with lump-sum recycling of revenues) through the lens of modern Schumpeterian growth theory. In particular, I use a model of the latest vintage that sterilizes the scale effect through a process of product proliferation that fragments the aggregate market into submarkets whose size does not increase with the size of the workforce.[3]The model is extremely tractable and yields a closed-form solution for the economy's transition path. This in turn allows me to study analytically the welfare effects of the energy tax.

My main finding is that, under the assumption that energy demand is inelastic, in an economy with growth-favoring fundamentals and patient households there exists a hump-shaped relation between the energy tax and welfare. Interestingly, I obtain this shape abstracting from environmental externalities—a modeling choice that brings to the forefront how endogenous technological change alters dramatically the assessment of the short- and long-run *economic costs* of the energy tax.

The tax on energy use changes relative after-tax input prices and induces manufacturing firms to substitute other inputs for energy in their production operations. As energy demand falls, the economy experiences a reallocation of resources from the energy sector to the manufacturing sector. If energy demand is inelastic, associated to this reallocation is an increase in expenditure on manufacturing goods that induces an increase of aggregate R&D, the sum of cost-reducing R&D internal to the firm and entrepreneurial R&D aimed at product variety expansion. Despite this increase, steady-state growth does not change because the dispersion effect due to entry offsets the increase in aggregate R&D. This follows from the fact that the increase in the size of the manufacturing sector attracts entry and, over time, the larger number of firms generates dispersion of R&D resources across firms and thus sterilizes the scale effect. Consequently, the growth rate of total factor productivity (TFP) in manufacturing is independent of the size of the manufacturing sector.

The core of this mechanism is the reallocation of resources from energy to manufacturing that generates a *temporary acceleration* of TFP growth. Under empirically plausible conditions there exists a range of tax rates such that this acceleration generates a $\surd$-shaped time profile of consumption whereby consumption drops on impact and then rises sufficiently fast and by a sufficient amount that welfare rises. In other words, the long-run gain due to endogenous technological change more than offsets the short-run pain—the fact that holding technology constant, the higher after-tax price of energy makes goods more expensive so that consumption falls. It is worth stressing that the model's main ingredients, especially the assumption of inelastic energy demand, and its emphasis on factor reallocation across sectors rest on solid empirical ground. As I noted above, the welfare-enhancing capability of the tax stems solely from its effect on the intersectoral allocation of resources. This reallocation mitigates some of the distortions—monopolistic pricing, firms' failure to internalize technological spillovers and other pecuniary externalities related to the interaction between incumbents and entrants—that characterize models of endogenous innovation. Hence, my *positive* analysis suggests that as a second-best instrument the energy tax has desirable effects independently of its role in addressing environmental problems.[4] This feature of the analysis emphasizes how allowing for endogenous technological change alters drastically the assessment of the costs of policy interventions.

[1] This literature has grown so rapidly and extensively that any attempt at summarizing it here would do injustice to the many contributors. See [1,18,7,20] for recent reviews.

[2] One reason is that incorporating environmental externalities and resource scarcity increases dramatically the complexity of growth models. As a consequence, the early attempts have focussed mostly on first-generation models of endogenous innovation. A relatively small literature that developed recently has started to push the frontier harder and generate novel insights concerning the energy–growth relation [19,2]. These papers build models that are close in spirit to what I do here. The main difference between my paper and [6] is that I use a model of endogenous innovation without the scale effect to study the welfare effects of energy taxes.

[3] These models have profound implications for the analysis of taxation [21,15].

[4] This result is derived under the restriction that the government uses only one instrument in an environment where the optimal policy would, in fact, require several.

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