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On the environmental, economic and budgetary impacts of fossil fuel prices: A dynamic general equilibrium analysis of the Portuguese case ☆

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ABSTRACT

This paper examines the influence of fossil fuel prices on carbon dioxide emissions, economic activity, and the public sector account in Portugal. It uses a dynamic general equilibrium model which highlights the mechanisms of endogenous growth and includes a detailed modeling of the public sector. Fuel price scenarios are based on forecasts by the US Department of Energy (DOE-US), the International Energy Agency (IEA-OECD) and IHS Global Insight Inc. The differences in relative fuel prices among the three scenarios lead to substantially different environmental impacts. Higher fuel prices in the DOE-US scenario lead to a 10.2% reduction in the policy effort required to meet the EU 2020 emission targets, while relative price changes in the IEA-OECD scenario result in a 19.2% increase in the required policy effort and decreasing fuel prices increase the emissions deficit by 95.9% under the IHS scenario. In terms of the long term economic impacts, our results suggest a 2.2% reduction in GDP in the DOE-US scenario and 1.9% in the IEA-OECD scenario and an increase of 1.4% in the IHS scenario. As to the budgetary impact, higher fuel prices lead to lower tax revenues, which, coupled with a reduction in public spending translates to lower public deficits. From a methodological perspective, our results highlight the importance of the mechanisms of endogenous growth. A scenario of higher fuel prices would, under exogenous economic growth assumptions, result in larger baseline emissions growth, substantially smaller economic effects, and rather different budgetary effects. From a policy perspective, our results highlight the importance of fossil fuel prices in defining the level of policy intervention required for compliance with international and domestic climate change legislation.

1. Introduction

This paper addresses the impact of fossil fuel prices on energy consumption, carbon dioxide (CO_2) emissions, economic activity, and the public sector account using a dynamic general equilibrium model of the Portuguese economy, an economy dependent on foreign energy sources. It has two main purposes: to assess the role of fuel prices as drivers of CO_2 emissions and to explore the dynamic relationship between fuel prices, economic activity, and the public sector account. These allow us to determine the impact of fuel prices on climate policy efforts.

Fuel prices are important in climate policy due to their impact on CO_2 emissions. Fuel prices directly affect emissions through their impact on energy costs, energy demand, and as drivers in the adoption of new energy technologies. High fossil fuel prices reduce energy demand and can stimulate energy efficiency and the adoption of renewable energy technologies, leading to a reduction in emissions [see Martinsen et al. (2007)]. Relative price levels, however, may favor a greater use of coal in electric power and synthetic fuels in transportation, increasing emissions [see van Ruijven and van Vuuren (2009)]. As a consequence, fuel price forecasts are a key input for emission projections [see Brecha (2008), Nel and Cooper (2009), Verbruggen and Marchohi (2010), and UK Department of Energy and Climate Change (n.a.)].

Fuel prices also indirectly affect emissions through their impact on economic growth and its dynamic feedbacks with energy demand [see van Ruijven and van Vuuren (2009)], an impact that is not typically considered in applied climate policy analysis. Still, a great deal of empirical research highlights the dynamic relationship between energy prices, consumption and growth [see Hamilton (2009), He et al. (2010), Korhonen and Ledyaeva (2010), and Balcilar et al. (2010)]. As a result, energy prices are considered an important input for macroeconomic forecasting [see Esteves and Neves (2004), Roeger (2005), and European Commission (2010b)].

The fact that fuel prices affect economic activity is itself important [see Backus and Crucini (2000) and Schubert and Turnovsky (2010)]. The effect of fuel prices on economic growth and the subsequent dynamic feedbacks with the public sector account directly correlate with the most important policy constraints faced by many energy-importing countries in their pursuit of sound climate policies: the need to enact policies that promote long-term growth and budgetary

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consolidation. These constraints are particularly relevant for less developed energy-importing economies in the European Union (EU), countries such as Ireland, Greece, and Portugal, where growing public spending and, more recently, declining tax revenues have contributed to high levels of public debt and a sharp need for budgetary consolidation.

The wide ranging economic and environmental impacts of energy prices highlight the need for an integrated assessment of the economic and environmental impact of fuel prices. In this paper, we examine the impact of different fuel price scenarios using a dynamic general equilibrium model. We focus on primary energy demand by firms and CO_2 emissions from fossil fuel combustion activities because these are a linear function of the quantity of fossil fuels consumed. Fossil fuels are imported while investment in wind energy is privately financed.

The fuel price scenarios are based on forecasts by the US Department of Energy (DOE-US), the OECD International Energy Agency (IEA-OECD) and IHS Global Insight Inc. (IHS), which are widely used in policy analysis and macroeconomic forecasting exercises. Naturally, the US government commonly uses the DOE-US forecasts while the EU commonly uses the IEA-OECD forecasts. These fuel price forecasts vary substantially from each other, allowing us to examine the impact of changes in both relative and absolute fuel prices.

Our model incorporates dynamic optimization behavior, endogenous growth, and detailed modeling of the public sector. Previous versions of this model have been used to evaluate the impact of tax policy [see Pereira and Rodrigues (2002, 2004)], social security reform [see Pereira and Rodrigues (2007)] and environmental fiscal reform [see Pereira and Pereira, forthcoming]. This model brings together two important strands of the taxation literature. On one hand, it follows in the footsteps of computable general equilibrium modeling in its ability to consider the tax system in great detail. This is important because existing tax distortions influence the costs and effectiveness of climate policies [see Goulder (1995), Goulder et al. (1999) and Goulder and Parry (2008)]. On the other hand, it incorporates insights from the endogenous growth literature as it recognizes that public policies have the potential to not simply generate temporary level effects but, more importantly, affect the fundamentals of long-term growth [see Xepapadeas (2005)].

The key distinguishing feature of our model in the applied climate policy literature is our focus on endogenous growth and the associated treatment of public sector optimization behavior [see Conrad (1999) and Bergman (2005) for literature surveys]. Investment in public capital and human capital, which have been largely overlooked in applied climate policy (Carraro et al., 2009), are, in addition to private investment, the drivers of endogenous growth. Indeed, few climate policy models consider endogenous growth mechanisms, with the notable exception of the computable DICE model and several analytical models (Bovenburg and de Mooij, 1997; Gerlagh et al., 2002; Fullerton and Kim, 2008; Glomm et al., 2008). Furthermore, the analysis of the interaction between fiscal policies, public capital, economic growth, and environmental performance has received little attention and then only in a theoretical framework (Greiner, 2005; Gupta and Barman, 2009).

2. The dynamic general equilibrium model

In this section we present the dynamic general equilibrium model of the Portuguese economy in very general terms. Complete model documentation with detailed descriptions of the model equations, parameters, data, calibration, and numerical implementation, can be found in Pereira and Pereira (2012).

We consider a decentralized economy in a dynamic general-equilibrium framework. All agents are price-takers and have perfect foresight. With money absent, the model is framed in real terms. There are four sectors in the economy—the production sector, the household sector, the public sector and the foreign sector. The first three have an endogenous behavior but all four sectors are interconnected through competitive market equilibrium conditions, as well as the evolution of the stock variables and the relevant shadow prices. All markets are assumed to clear.

The trajectory for the economy is described by the optimal evolution of eight stock and five shadow price variables—private capital, wind energy capital, public capital, human capital, and public debt together with their shadow prices, and foreign debt, private financial wealth, and human wealth. In the long term, endogenous growth is determined by the optimal accumulation of private capital, public capital and human capital. The last two are publicly provided.

2.1. The production sector

Aggregate output is produced with a Constant Elasticity of Substitution (CES) technology, linking value added and primary energy demand. Value added is produced according to a Cobb–Douglas technology exhibiting constant returns to scale in the reproducible inputs–effective labor inputs, private capital, and public capital. Only the demand for labor and private capital is directly controlled by the firm, meaning that if public investment is absent then decreasing returns set in. Public infrastructure and the economy-wide stock of knowledge are publicly financed and are positive externalities. Primary energy demand is produced according to a CES technology using crude oil inputs and non-transportation energy sources. The production of non-transportation energy is defined according to a Cobb–Douglas technology using coal, natural gas and wind energy inputs. Fig. 1 presents the firms' production structure.

Private capital accumulation is characterized by a dynamic equation of motion where physical capital depreciates. Gross investment is dynamic in nature with its optimal trajectory induced by the presence of adjustment costs. These costs are modeled as internal to the firm – a loss in capital accumulation due to learning and installation costs – and are meant to reflect rigidities in the accumulation of capital towards its optimal level. Adjustment costs are assumed to be non-negative, monotonically increasing, and strictly convex. In particular, we assume adjustment costs to be quadratic in investment per unit of installed capital.

The firms' net cash flow represents the after-tax position when revenues from sales are net of wage payments, energy expenditure and investment spending. After-tax net revenues reflect the presence of private investment and wind energy investment tax credits, taxes on corporate profits, and social security contributions paid by the firms on gross salaries.

Buildings are a fraction of private investment expenditure. This fraction is subject to value-added and other excise taxes, the remainder is exempt. The corporate income tax base is calculated as revenues net of total labor costs and net of fiscal depreciation allowances over past and present capital investments. A straight-line fiscal depreciation method over the periods allowed for depreciation allowances is used and investment is assumed to grow at the same rate at which output grows. Under these assumptions, depreciation allowances simplify to a proportion of the difference of two infinite geometric sums.

Optimal production behavior consists in choosing the levels of investment and labor that maximize the present value of the firms' net cash flows subject to the equation of motion for private capital accumulation. The demands for labor and investment are obtained from the current-value Hamiltonian function, where the shadow price of private capital evolves according to the respective co-state equation. Finally, with regard to the financial link of the firm with the rest of the economy, we assume that at the end of each operating period the net cash flow is transferred to the consumers.

2.2. The energy sector

The energy sector is an integral component of the firms' optimization decisions. We consider primary energy consumption of crude oil,