Resource and Energy Economics 33 (2011) 231–246

Contents lists available at ScienceDirect

Resource and Energy Economics

journal homepage: www.elsevier.com/locate/ree

Green tax reforms and habits

Carlos de Miguel *, Baltasar Manzano

Universidad de Vigo and rede, Lagoas-Marcosende, s/n, 36200 Vigo, Spain

ARTICLE INFO

Article history:
Received 10 November 2008
Received in revised form 6 May 2010
Accepted 6 May 2010
Available online 31 May 2010

JEL classification:
E62
Q43
H23

Keywords:
Green tax reform
Habit formation
General equilibrium

ABSTRACT

Using a dynamic general equilibrium model, we explore the role of habit formation when analyzing green tax reforms under the double dividend hypothesis. We assume increases in energy taxes and adjust capital taxation in a revenue-neutral framework to evaluate the effects on welfare. Since the existence of an environmental dividend is uncontroversial, we mainly focus on the efficiency dividend. Our findings show that, when taxes on household energy consumption increase, habits and transitional dynamics alter household decisions, and change the efficiency dividend. However, when the tax increase is on energy used as an input, reform always induces a welfare cost in terms of efficiency. In this case, habits play a less important role.

1. Introduction

In recent years, green tax reforms have become an essential instrument in environmental policies (see, for example Pearce, 1991). These reforms are based on the double dividend hypothesis that supports the idea that environmental taxes improve welfare through two different channels: first, by improving the environment (first dividend or environmental dividend); second, by reducing the pre-existing distortionary taxes (second dividend or efficiency dividend).[1]

However, while the validity of the environmental dividend remains unquestioned, the existence of an efficiency dividend is controversial (see, for example, Bovenberg and Goulder, 2002). Thus, De Mooij (2000) shows how the efficiency dividend depends on the net effect of two factors: the revenue recycling factor and the tax base factor. The first one allows for a cut on pre-existing distortionary

* Corresponding author.
E-mail addresses: cmiguel@uvigo.es (C. de Miguel), bmanzano@uvigo.es (B. Manzano).

[1] The double dividend hypothesis has been addressed in many papers. See, for example, Oates (1991) and Bovenberg and De Mooij (1994).

0928-7655/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.reseneeco.2010.05.001

taxes; the second is the effect of the reform on the bases of the other existing taxes. The balance of these two effects may (or may not) lead to a second dividend.

The aim of this paper is to analyze green tax reforms in a model where individual preferences are subject to habit formation. A green tax reform can generate a double dividend, because, on the one hand it reduces the consumption of pollutant goods and, on the other, it allows the substitution of taxes thereby reducing the pre-existing distortionary taxation. However, if individuals have habits on consumption, these dividends can be affected. If the reform consists in increasing the tax on a pollutant good with habits, the environmental gain in welfare could become smaller because individuals are now more reluctant (at least in the short run) to reduce their consumption of this good. This could reduce the environmental dividend. Moreover, a good with habits has a more inelastic demand; literature indicates that taxing this type of goods produces less distortions. So, the green tax reform may imply efficiency improvements and positively affect the second dividend. In sum, considering habits could be potentially important when assessing the implications of a green tax reform.

Duesenberry (1949) was the first economist to propose the idea of "habit formation": the utility from current consumption can be affected by the level of past consumption. In fact, there is a strand of the literature that provides evidence of the existence of habit formation in consumption decisions (see, for example, De la Croix and Urbain, 1998; Houthakker et al., 2001; Carrasco et al., 2005 among others). Moreover, several recent papers have introduced habit formation in order to explain some empirical facts that cannot be reconciled with the traditional models that display time-separable preferences.[2] However, to our knowledge, habit formation as such has never been introduced in studies of green tax reforms.

In our model, we consider time non-separability in preferences by assuming habit formation in consumption in such a way that consumers' utility depends both on their own current consumption as well as on a reference level. This reference can be viewed as a (time varying) standard of living determined by individuals' own past consumption. The introduction of habit formation implies that the individual derives utility from the comparison of the current level of their own consumption with their consumption in the previous period. The point is that, confronted with a fiscal reform, individuals with habits will take into account how the reform affects their standard of living and thus, how it conditions their future levels of consumption. So, they will react differently than would an individual without habits. This is an important and untreated issue in the green tax reform literature.

Our goal is to shed light on how habits can influence the existence of an efficiency dividend. We address the question by simulating green tax reforms in a dynamic general equilibrium model calibrated to the Spanish economy. Such reforms consist in increasing taxation on energy, adjusting capital taxes and keeping total tax revenues constant. Given that habit formation affects intertemporal substitution, we choose to adjust capital taxes which also alter it and thereby potentially affects the efficiency dividend even more. Another reason to use a capital tax is its distortionary effect. Thus, beginning with the seminal work of Chamley (1986) and following Zhu (1992), Jones et al. (1993) and Chari et al. (1994), a robust result emerges whereby optimal capital tax is zero in the long run. Also, from Lucas (1990) and Cooley and Hansen (1992), we know that capital taxes have strong distortionary effects on welfare. As we are interested in looking for efficiency gains, a capital tax reduction seems appropriate.[3]

The main result of the paper indicates that the existence of an efficiency dividend depends both on transitional dynamics considerations and habit formation when the green tax reform increases taxes on household energy consumption. We need to bear in mind transitional dynamics to appropriately account for welfare changes because a large part of welfare gains can be lost in the adjustment process towards a new equilibrium. When we increase the tax on household energy, capital tax rates decrease and an incentive for savings emerges. With habits, the household is more willing to decrease leisure in order to keep current consumption, and more willing to decrease current leisure by working more

[2] See, among many others, Constantinides (1990), Abel (1990), Carroll et al. (2000), and Fuhrer (2000).

[3] Although in general the double dividend literature considers tax revenues to be recycled through a decrease in labor taxes (because labor is often the only primary production input), there are papers like Glomm et al. (2008) that also analyze a revenue-neutral green tax reform using the extra revenue to reduce capital taxes.

hours and increasing savings, to increase leisure and consumption in the future. The result can be viewed as a mix of a *persistent consumption effect* and a *flexible labor effect*, because habits make the individual more prone to reacting to a policy change by adjusting leisure rather than consumption.

When the reform increases the tax on energy used by firms, the result is dominated by the contractive effect that this tax has on the economy. So, in this case, the efficiency dividend becomes a cost. Here, habit formation plays a less important role because the incentives to intertemporal substitution are more restricted.

Finally, along the lines of the literature, we always find an environmental dividend based on the decrease in pollution that the energy reduction in these reforms have brought about.

The paper is organized as follows. In Section 2, we present the model. In Section 3, the calibration of the parameters is discussed. Section 4 presents the results of the green tax reforms carried out. Finally, in Section 5 we summarize the main conclusions.

2. The model

The economy is represented by a dynamic general equilibrium model consisting in a large number of identical, infinitely lived households and firms and a government that finances an exogenous flow of spending through tax collecting. An important feature of the model is the use of energy both for consumption (*eh*) and for production (*ef*). The prices associated with both uses of energy are different because data show that the energy mix used by households and firms is different. We consider energy prices to be exogenous.

The preferences of households are represented by a utility function given by:

$$U(A_t, n_t, H_t) = \frac{\left[A_t^{1-\mu}(1-n_t)^{\mu} H_t^{\phi}\right]^{\sigma}}{\sigma},$$
$$A_t(c_t, eh_t, c_{t-1}, eh_{t-1}) = \left[(1-\gamma)(c_t - bc_{t-1})^{\alpha} + \gamma(eh_t - beh_{t-1})^{\alpha}\right]^{1/\alpha}, \tag{1}$$

where A_t is the effective aggregate good that combines non-energy effective consumption $(c_t - bc_{t-1})$ and energy effective consumption $(eh_t - beh_{t-1})$[4]. The elasticity of substitution between energy and non-energy effective consumptions is $1/(1-\alpha)$. Parameter $b \in [0, 1)$ denotes the intensity of habit formation and introduces non-separability of preferences over time. Moreover, n_t is the fraction of time devoted to work, and H_t is a negative externality (let us say, pollution) that represents the negative impact on welfare caused by the use of energy (*eh* and *ef*). We assume *H* will be given by:

$$H_t = eh_t + ef_t. \tag{2}$$

The utility function (1) implies that past consumption reduces current utility in such a way that, to improve welfare, the household needs to increase consumption above the habits stock in both energy (beh_{t-1}) and non-energy (bc_{t-1}) consumption goods. Therefore, the habit-forming households are averse to large fluctuations in both consumption goods: the optimal consumption paths become smoother than the ones predicted by a model with time-separable utility.

The consumer's problem is to maximize an intertemporal flow of utility subject to the budget constraint:

$$\begin{aligned} &\underset{c_t, eh_t, n_t, k_{t+1}}{\text{Max}} \sum_{t=0}^{\infty} \beta^t U(A_t(c_t, eh_t, c_{t-1}, eh_{t-1}), n_t, H_t) \\ &s.t.: \quad (1+\tau^c)c_t + (1+\tau^h)\,p^h eh_t + k_{t+1} - (1-\delta)k_t = (1-\tau^w)w_t n_t + (1-\tau^k)r_t k_t - T_t \end{aligned},$$

where $0 < \beta < 1$ is the discount factor, *k* is capital stock, δ is the capital depreciation rate, and *w*, *r* and p^h respectively denote wages, interest rate and the relative price of household energy consumption.

[4] Following Ravn et al. (2006), we assume deep habit formation. Thus, agents form habits over individual goods as opposed to a composite consumption good.

Finally, τ^c, τ^h, τ^w and τ^k represent tax rates on the non-energy consumption good, on household consumption of energy, on labor income and on capital income, respectively, and T is a lump-sum tax.

The conditions that solve the consumer's problem are:

$$
\begin{aligned}
c_t &: \frac{\partial U(A_t(c_t, eh_t, c_{t-1}, eh_{t-1}), n_t, H_t)}{\partial A_t}\frac{\partial A_t(c_t, eh_t, c_{t-1}, eh_{t-1})}{\partial c_t} - \lambda_t(1+\tau^c) \\
&\quad + \beta\frac{\partial U(A_{t+1}(c_{t+1}, eh_{t+1}, c_t, eh_t), n_{t+1}, H_{t+1})}{\partial A_{t+1}}\frac{\partial A_{t+1}(c_{t+1}, eh_{t+1}, c_t, eh_t)}{\partial c_t} = 0, \\
eh_t &: \frac{\partial U(A_t(c_t, eh_t, c_{t-1}, eh_{t-1}), n_t, H_t)}{\partial A_t}\frac{\partial A_t(c_t, eh_t, c_{t-1}, eh_{t-1})}{\partial eh_t} - \lambda_t(1+\tau^h)p^h \\
&\quad + \beta\frac{\partial U(A_{t+1}(c_{t+1}, eh_{t+1}, c_t, eh_t), n_{t+1}, H_{t+1})}{\partial A_{t+1}}\frac{\partial A_{t+1}(c_{t+1}, eh_{t+1}, c_t, eh_t)}{\partial eh_t} = 0, \\
n_t &: \frac{\partial U(A_t(c_t, eh_t, c_{t-1}, eh_{t-1}), n_t, H_t)}{\partial n_t} + \lambda_t(1-\tau^w)w_t = 0, \\
k_{t+1} &: -\lambda_t + \beta\lambda_{t+1}[1-\delta+(1-\tau^k)r_{t+1}] = 0.
\end{aligned}
$$

Firms produce output by a constant return-to-scale technology that combines labor (n), capital (k) and energy (ef). The production function is given by:

$$F(n_t, k_t, ef_t) = n_t^{\theta}[(1-a)k_t^{-\upsilon} + a ef_t^{-\upsilon}]^{-(1-\theta)/\upsilon}. \tag{3}$$

The representative firm solves:

$$\underset{n_t, k_t, ef_t}{\text{Max}}\; F(n_t, k_t, ef_t) - w_t n_t - r_t k_t - (1+\tau^f)p^f ef_t,$$

where τ^f is the tax on energy used in production and p^f denotes the relative price of the energy input.

First-order conditions for the firm are:

$$
\begin{aligned}
w_t &= \frac{\partial F(n_t, k_t, ef_t)}{\partial n_t}, \\
r_t &= \frac{\partial F(n_t, k_t, ef_t)}{\partial k_t}, \\
(1+\tau^f)p^f &= \frac{\partial F(n_t, k_t, ef_t)}{\partial ef_t}.
\end{aligned}
$$

The government finances an exogenous flow of spending (G_t) by using taxes. Government budget constraint is:

$$G_t = \tau^c c_t + \tau^h p^h eh_t + \tau^f p^f ef_t + \tau^w w_t n_t + \tau^k r_t k_t + T_t. \tag{4}$$

Finally, the aggregate resources constraint is:

$$c_t + k_{t+1} - (1-\delta)k_t + G_t + p^h eh_t + p^f ef_t = F(n_t, k_t, ef_t). \tag{5}$$

A *competitive equilibrium* for this economy is a set of paths of allocations, prices and policies that satisfy the following conditions:

(i) $\{c_t, eh_t, n_t, k_{t+1}\}$ solve the consumer's problem given prices $\{w_t, r_t, p^h\}$ and policies $\{\tau^c, \tau^h, \tau^w, \tau^k, T_t\}$.
(ii) $\{n_t, ef_t, k_t\}$ solve the firm's problem given prices $\{w_t, r_t, p^f\}$ and the policy $\{\tau^f\}$.
(iii) The government budget constraint holds at each period.
(iv) Goods, labor, capital and energy markets clear.

Appendix A describes how to solve the competitive equilibrium.

In order to keep the model description as simple as possible, we represent it so the difference between a model with or without habits depends only on the value of b ($b>0$ versus $b=0$). Although this is a very useful way to present the model, there is an important difference when considering habits or non-habits. Along with capital, habits make the past level of energy and non-energy consumption become state variables too. Even though this issue is not relevant for the steady state

Table 1
Parameter values.

Preferences		
Subjective discount factor	β	0.96
Energy consumption share	γ	0.036
Elasticity of substitution between effective energy and non-energy consumption	$1/(1-\alpha)$	0.85
Preference for leisure	μ	2/3
Risk aversion	σ	−1
Disutility of pollution	ϕ	−0.5
Technology		
Labor share	θ	0.64
Rate of depreciation	δ	4%
Parameter of the production function	υ	0.7
Fiscal parameters		
Non-energy consumption tax	τ^c	7.36%
Labor tax	τ^w	31.52%
Capital tax	τ^k	18.41%
Energy consumption tax, standard deviation of energy consumption tax	τ^h	62.56%, 23%
Energy used by firms tax, standard deviation of energy used by firms tax	τ^f	24.77%, 11%
Government spending/GDP		16.49%

that can be solved for any value of habits (b), it is very important when transitional dynamics is considered. The reason for this is that the number of state variables affects the computation of the dynamics.[5]

3. Calibration

The theoretical model presented does not allow us to obtain analytical solutions, so we must employ numerical methods to approach a solution (see Appendix A for details). In this section, we describe the calibration process carried out. The structural parameters have been chosen so that, in the steady state, the model without habits reproduces some of the more relevant long-run characteristics of the Spanish economy for the period 1978–2005. The time period is one year. Table 1 summarizes the parametric values used.

With respect to the preferences, parameters $\{\beta, \mu, \sigma\}$ take standard values in the literature and parameter α is taken to obtain the elasticity of substitution reported by Goulder et al. (1999). For technology, we use, following Thompson and Taylor (1995) estimations, an elasticity of substitution between capital and energy equal to 0.76. The labor share parameter, θ, is standard.

We assume that the depreciation rate for capital is 0.04. This value is chosen to be consistent with the ratio of consumption of fixed capital to the GDP observed in the data.

Concerning energy parameters, we construct measures of energy prices and energy uses for households and firms by using International Energy Agency (IEA) statistics. We consider seven sources of primary energy, all measured in tons of oil equivalent (toe). These types of energy are natural gas, liquefied petroleum gases (LPG), light fuel oil, heavy fuel oil, motor gasoline, motor diesel and electricity.[6] The relative energy price indexes for households (p^h) and for firms (p^f) are constructed as a weighted average of the prices of each type of energy. The weights represent the average shares of expenditure of each form of energy over total energy expenditure for both households and firms. The indexes obtained are deflated with the Spanish GDP deflator to obtain relative prices.

Furthermore, data show that the ratio of household energy consumption to total household consumption is 6.2% and the ratio of household energy expenditure to total energy expenditure is 52%. The parameters $\{\gamma, a\}$ are chosen to approximate those shares.

[5] Solving the model, we use a log–linear approximation of the equations system of the economy to obtain the stable transition path to the steady state. This stable transition path has to do with the number of state variables of the model.

[6] With respect to motor diesel, we cannot distinguish between the amount used by households and the amount used by firms from the data. To solve this limitation, we assume that 25% of motor diesel is consumed by households. The results are robust to consider that the motor diesel consumed by households is 50%.

Regarding the fiscal parameters, we use the average effective tax rates on capital (τ^k) and labor (τ^w) reported for the Spanish economy by Boscá et al. (2005) for the period 1978–2001. Additionally, we construct an effective non-energy consumption tax rate (τ^c) by using data on total household consumption expenditure from OECD statistics and household energy expenditure by using IEA statistics. The effective tax rates on energy used by households (τ^h) and by firms (τ^f) have been calculated by using data on energy expenditure with and without taxes from the IEA statistics. The government spending parameter, G, is calibrated to reproduce the average ratio of government spending over GDP in the Spanish economy. Finally, the lump-sum tax is chosen to balance the government budget constraint.

For the disutility of pollution, we assume an intermediate value, $\phi = -0.5$, throughout the simulations. The size of the environmental dividend is driven by such a parameter, but it does not affect the efficiency dividend, in which we are mainly interested.

4. Green tax reform experiments

In this section, we present the main results of the different simulation exercises carried out. These exercises consist in changes in fiscal policy through an increase in energy taxation, in particular by increasing taxes on energy consumption by households (τ^h) or energy used by firms (τ^f), and reducing pre-existing capital taxes (τ^k) in a revenue-neutral framework. We focus on analyzing the role of habit formation, so the simulations were carried out for different scenarios, defined by the values of the parameter of habits (b). Although we have included labor and consumption taxes in the model, we focus on tax reforms that recycle extra-revenues to diminish capital taxes for all of the reasons aforementioned in the introduction.

We evaluate the impact of those reforms on the welfare of households computing the welfare gain associated with these policies. The effect of any policy on the welfare can be divided into an efficiency dividend and an environmental dividend.

The efficiency dividend takes into account changes in effective aggregate consumption (A) and leisure ($1-n$) due to the tax reform, keeping the externality (H) constant at the initial steady state level. The environmental dividend will be associated only with changes in the externality, keeping effective aggregate consumption and leisure constant at the pre-reform steady state level.

We computed both dividends with the comparison between steady states and taking into account the transitional dynamics, as follows:

(i) The efficiency dividend and the environmental dividend in the steady state comparisons are given respectively through the x_F and x_E variables that solve the following equations:

$$U(\bar{A}, \bar{n}, \bar{H}) = U(\tilde{A}(1-x_F), \tilde{n}, \bar{H}), \tag{6}$$

$$U(\bar{A}, \bar{n}, \bar{H}) = U(\bar{A}(1-x_E), \bar{n}, \tilde{H}), \tag{7}$$

where $\{\bar{A}, \bar{n}, \bar{H}\}$ is the level of allocations in steady state before the tax reform, while $\{\tilde{A}, \tilde{n}, \tilde{H}\}$ represents allocations in the new steady state after the tax reform. Variables x_F and x_E indicate the percentage reduction in effective aggregate consumption required so that individuals enjoy the same level of pre-tax reform welfare.

(ii) We also compute efficiency and environmental dividends, taking into account the transition between steady states:

$$\sum_{t=0}^{\infty} \beta^t \{U(\tilde{A}_t(1-x_F), \tilde{n}_t, \bar{H}) - U(\bar{A}, \bar{n}, \bar{H})\} = 0, \tag{8}$$

$$\sum_{t=0}^{\infty} \beta^t \{U(\bar{A}(1-x_E), \bar{n}, \tilde{H}_t) - U(\bar{A}, \bar{n}, \bar{H})\} = 0. \tag{9}$$

$x_F > 0$ ($x_F < 0$) imply an efficiency dividend (cost), while $x_E > 0$ ($x_E < 0$) represent an environmental dividend (cost), due to the reform. Dividends are always expressed in terms of percentages of GDP.

Table 2
Energy consumption tax: efficiency and environmental dividends.

	Steady state comparisons	Transitional dynamics
Efficiency dividend		
Non-habits (b=0)	0.475	0.030
Low (b=0.1)	0.476	−0.067
Medium (b=0.5)	0.479	−0.056
High (b=0.9)	0.506	0.063
Environmental dividend		
Non-habits (b=0)	1.878	2.361
Low (b=0.1)	1.878	2.765
Medium (b=0.5)	1.875	2.638
High (b=0.9)	1.848	1.659

These dividends are computed as the values of x_F and x_E that solve Eqs. (6)–(9) and are expressed as a percentage of GDP in terms of effective aggregate consumption.

Table 3
Energy used by firms' tax: efficiency and environmental dividends.

	Steady state comparisons	Transitional dynamics
Efficiency dividend		
Non-habits (b=0)	−0.015	−0.021
Low (b=0.1)	−0.015	−0.023
Medium (b=0.5)	−0.015	−0.023
High (b=0.9)	−0.008	−0.025
Environmental dividend		
Non-habits (b=0)	0.976	0.983
Low (b=0.1)	0.976	0.988
Medium (b=0.5)	0.975	0.989
High (b=0.9)	0.968	0.975

These dividends are computed as the values of x_F and x_E that solve Eqs. (6)–(9) and are expressed as a percentage of GDP in terms of effective aggregate consumption.

In the following subsections, we show the results of the tax reforms. We consider that the energy tax increases by one standard deviation of both the effective tax rate on energy consumption by households (τ^h) and the effective tax on energy used by firms (τ^f) described in the calibration section. Those deviations imply a change of 23% in τ^h and a change of 11% in τ^f.[7]

Tables 2 and 3 show the value of environmental and efficiency dividends for four different habit scenarios. Figs. 1 and 2 show the evolution of the efficiency and the environmental dividends both in steady state as in transitional dynamics in an economy with habits, for a range of habit parameter values ($b \in (0,0.95]$). The non-habits economy (b=0) is considered in Tables 2 and 3, but not in Figs. 1 and 2. The reason for this is the discontinuity between habit and non-habit economies that emerges in the dynamics of both the efficiency and environmental dividends. This is due to the different number of state variables already pointed out in Section 2. In the transitional dynamics, even for a very small b, dividends do not converge with those obtained in the non-habit economy (see Tables 2 and 3).

Figs. 3 and 4 show how the main variables respond to the policy changes, focusing in four different scenarios: non-habits (b=0), low habits (b=0.1), medium habits (b=0.5) and high habits (b=0.9).

4.1. Household energy consumption tax (τ^h)

The first green tax reform considered is the increase on the tax on energy consumed by households (τ^h), using the additional tax revenue to decrease capital taxes (τ^k).

[7] We have conducted simulations for tax reforms of two standard deviations on τ^h and τ^f, with no qualitative changes in the results.

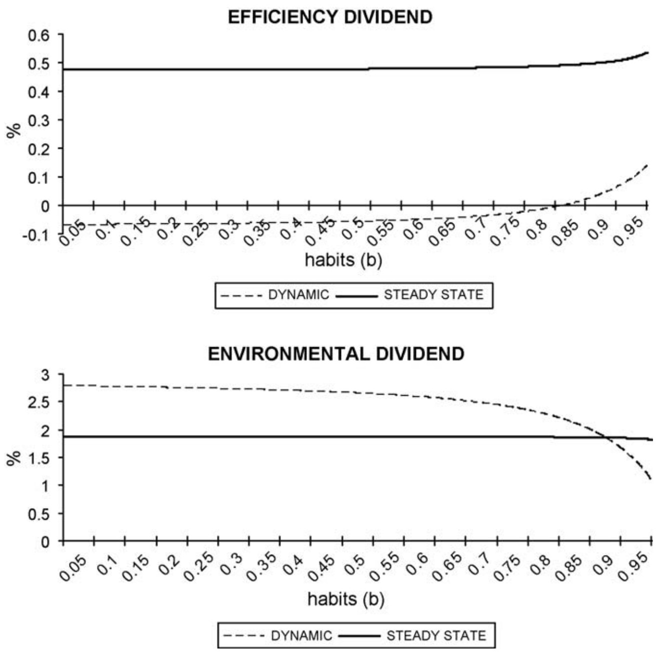

Fig. 1. Energy consumption tax. Habits and the efficiency and environmental dividends.

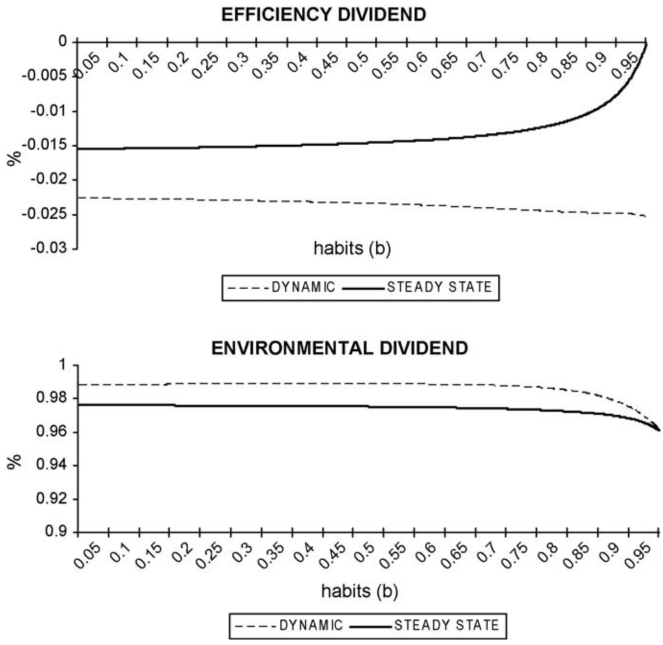

Fig. 2. Energy used by firms' tax. Habits and the efficiency and environmental dividends.

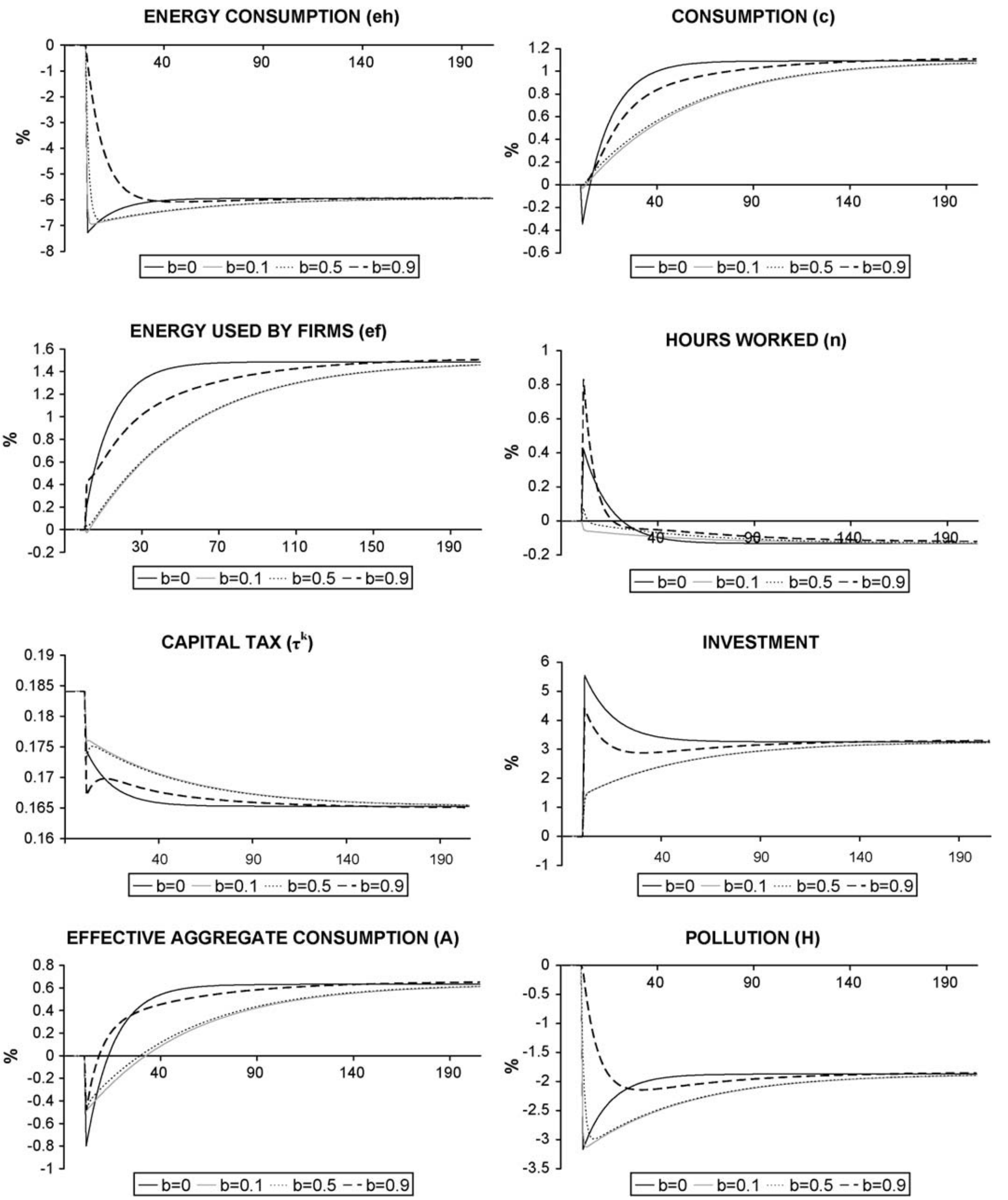

Fig. 3. Energy consumption tax. Deviations from the initial steady state (except capital tax). Time period is one year.

This exercise illustrates how considering only long-run welfare analysis (steady state comparisons) can lead to wrong policy recommendations. Thus, we show how the existence of an efficiency dividend depends on the short-run effects of the tax reform; it is very important to take into account transitional dynamics because much of the gain in welfare can be lost in the transition between steady states. Moreover, we point out the important role of habit formation in such transitional dynamics, where it actually changes the way in which agents make decisions.

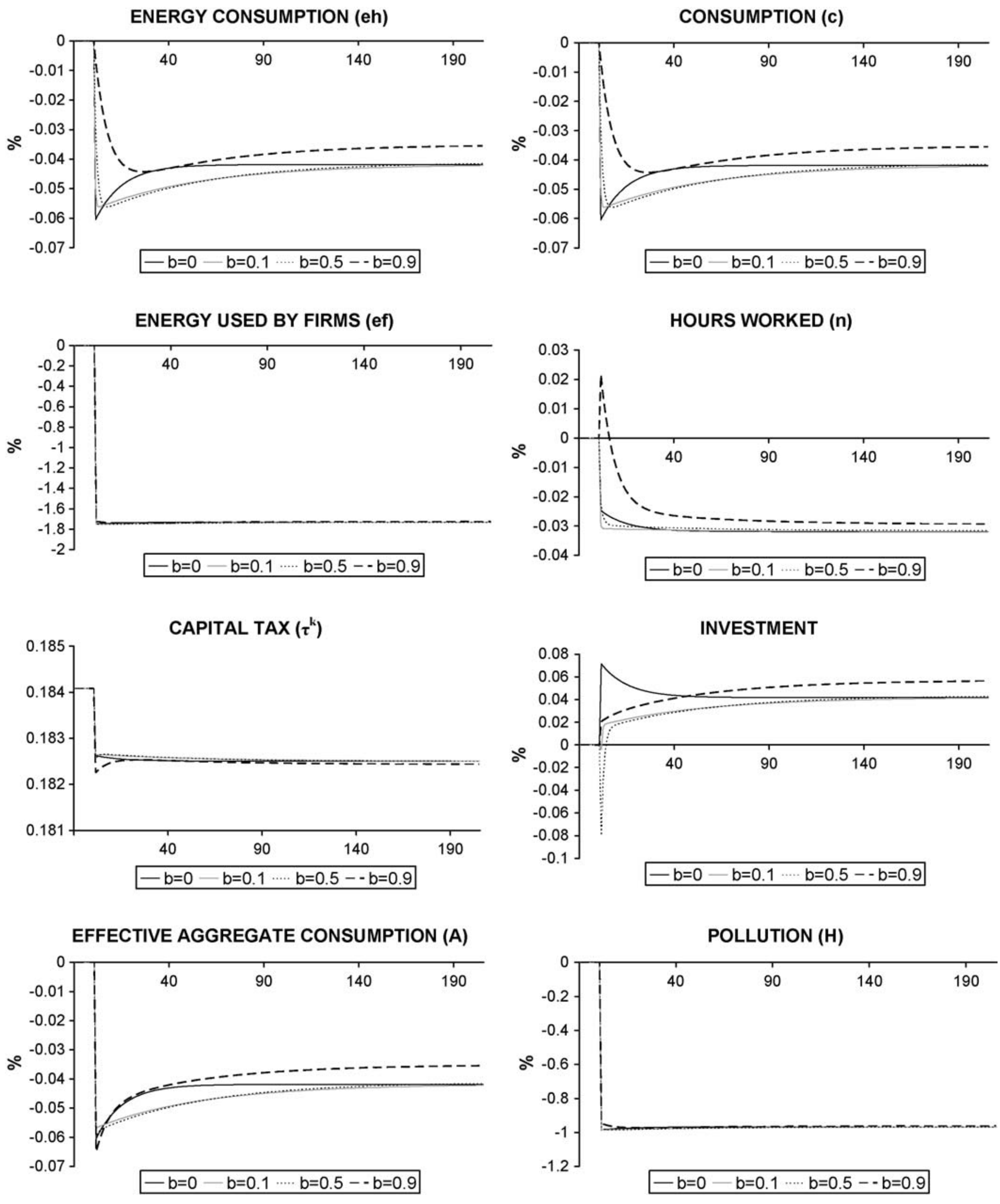

Fig. 4. Energy used by firms' tax. Deviations from the initial steady state (except capital tax). Time period is one year.

Fig. 1 shows how when considering only steady state comparisons, the efficiency dividend is about 0.5% of GDP in terms of effective aggregate consumption. The size of the dividend hardly varies in the presence of habit formation. In the same way, the environmental dividend does not change significantly with habits. However, in the same figure we can see that when transitional dynamics and habit formation are kept in mind, those results change. Thus, the efficiency dividend becomes a welfare cost when we compute the transitional dynamics, although for high enough value of habits (0.82 is the threshold for our model) a welfare gain is obtained. Taking into account transitional dynamics, the environmental dividend is greater than steady state comparisons. Although as habits increase, that difference decreases. Even from a high enough value of b, the environmental dividend is comparatively lower than those in steady state.

These results are due to the different dynamic reaction of economic variables to the policy reform with or without habits. For the sake of understanding, we focus on the response of the variables to the green tax reform, in four different scenarios: non-habits (b=0), low habits (b=0.1), medium habits (b=0.5) and high habits (b=0.9) depicted in Fig. 3.

Let us start by considering an economy without habit formation (b=0). The tax reform considered will bring about two simultaneous effects on the economy. A first effect is the increase of τ^h reduces household energy consumption (eh) drastically and this will make the individual want to compensate this fall with an increase in non-energy consumption (c). However, as the reduction in eh dominates the rise of c, the effective aggregate consumption (A) decreases. The household will try to offset that negative effect by substituting effective aggregate consumption with leisure, causing an increase in leisure and, therefore, a drop in time worked.

Nevertheless, as reform implies a decrease in capital tax rate (τ^k), we will have a second effect which will be set off by the reduction of the price of future consumption relative to current consumption. Such reduction gives incentives to the household to transfer consumption to the future; this implies that the household raises savings by decreasing energy and non-energy consumption, and working more.

As we can see, the tax reform induces two opposite effects in terms of non-energy consumption and leisure. Fig. 3 displays how the reduction in both energy and non-energy consumption and the increase in hours worked dominate in the short run, thereby producing a loss in welfare during the first post-reform periods. In the long run, non-energy consumption recovers, increasing from the initial steady state along with an increase in leisure. Table 2 shows how the initial welfare loss reduces the efficiency dividend relative to the steady state comparison, although this reduction is not enough to produce an efficiency cost (the efficiency dividend is around 0.03% of GDP). The environmental dividend is always found because of the important drop in energy consumption (eh), which is larger than the increase in energy used by firms (ef), following a reduction of pollution.

The economy with habits is different from the previous one. The presence of habit formation not only changes the short-run response of households to the reform, but also changes the transition path to the new steady state. As we consider habits both in energy and non-energy consumption, the response in both consumptions is different to that of non-habits. Let us recall that habit formation implies that the individual derives utility from the comparison of the current level of their own consumption with that of their previous period. Thus, to improve welfare, households need to increase consumption above the stock of habits in both energy (beh_{t-1}) and non-energy (bc_{t-1}) consumption goods. On the one hand, increasing current consumption makes it more difficult to improve welfare in the future. This explains why here, in comparison to a non-habit economy, habits penalize brusque consumption reactions and make households choose smoother consumption paths. This is called *persistent consumption effect*. On the other hand, because we do not consider habits in leisure, it is much less costly in terms of welfare for individuals to react by adjusting leisure and hours worked (*flexible labor effect*).

These two effects make for the fact that the greater the habits, the more willing the individuals are to renounce to current leisure and to work more to keep current consumption and enjoy more leisure and consumption in the future. This behavior is consistent with the results of Seckin (2001) which find that the existence of habits increases the marginal rate of intratemporal substitution between consumption and leisure (in which the individual is more willing to renounce to current leisure in favor of current consumption) as well as the marginal rate of intertemporal substitution between current and future leisure (which explains why the individual is willing to renounce to current leisure in favor of increased future leisure).

These effects help us understand the response of the main variables to this green tax reform when there are habits. Fig. 3 shows how the increase in household energy consumption tax triggers a minor reaction in the short run both in energy and non-energy consumption as well as a smoother adjustment to the new steady state as the habits become greater (persistent consumption effect). Adjusting consumption becomes more costly and households react by adjusting leisure thus increasing hours worked (flexible labor effect). Besides, the subsequent falling taxes on capital make current consumption more costly in terms of future consumption and thereby incentivize savings. Habits make individuals more reluctant to modify their consumption and they will give work more hours in lieu of enjoying leisure which will allow them to accumulate more capital to enable them to work less and consume more in the future.

These reactions are the ones that produce changes in the efficiency dividend, as we can see in Fig. 1 and Table 2. For low ($b=0.1$) or medium ($b=0.5$) levels of habit formation, the smoother the transition of aggregate effective consumption (A) to the new steady state is, the longer it lasts and the greater the cost is. As a result and relative to the non-habits economy, the efficiency dividend diminishes and becomes a welfare cost.

However, for a high enough degree of habit formation, reducing current consumption is very harmful to the household. Given this high habit stock, the household has to exceed a large percentage of past energy and non-energy consumption to increase welfare. Therefore, consumption of both goods hardly varies because habits increase the persistent consumption effect. To take advantage of the reduction of capital taxes, the household can only transfer income to the future by temporarily working a lot more (flexible labor effect). Thus, with high habits ($b=0.9$), the initial decrease of effective aggregate consumption is lower than it is in the low and medium levels of habit cases, and the transition to the new steady state is very fast. As we can see in Table 2 and Fig. 1, there is an efficiency dividend, due both to the faster convergence to the new steady state and the lower initial decrease in consumption.

The environmental dividend is always found because of the great fall in energy consumption, which, in turn, reduces pollution.

To summarize, both habits and transitional dynamics can play a significant role in determining an efficiency dividend in a green tax reform consisting in an increase in τ^h and a decrease in τ^k.

4.2. Energy used by firms tax (τ^f)

The second reform increases the tax on the use of energy as an input (τ^f) while adjusting, as in the previous exercise, the pre-existing capital tax (τ^k), maintaining total tax revenue constant. Fig. 4 shows the response of the main variables to the tax reform.[8]

The result of the tax reform is dominated by the contractive effect that the increase of τ^f has on the economy. As we can see in Table 3 and Fig. 2, the reform implemented only has positive welfare effects on the environment, because households and firms both decrease their energy consumption and the result of this is less pollution. So, we find in all cases, that the contraction in the economy explains the environmental dividend. However, in terms of the efficiency dividend, we can see that the reform always produces a slight welfare cost.

The way the tax reform works is straightforward. The increase in τ^f reduces the energy input (ef), and negatively affects the marginal productivity of other inputs, and all of this results in a reduction in both capital and labor. There is a decrease in output and disposable income, which reduces both energy and non-energy household consumption. The decrease in the marginal productivity of capital tends to reduce the incentives for savings produced by the reduction in capital tax. In the long run, these variables recover slightly but converge to a lower steady state. Although leisure increases (labor diminishes), in terms of welfare it cannot offset the fall in effective aggregate consumption that results in an efficiency cost which is either computed through steady state comparisons or bearing transitional dynamics in mind. The decrease in both uses of energy (eh and ef) reduces pollution, causing an environmental dividend.

As in the previous reform, the presence of habits induces lower decreases in both energy and non-energy consumption. The higher the strength of habits are, the lower the decreases in those consumptions and the smoother the response to the policy shock. However, in this specific case, habits play a less important role because the incentives for intertemporal substitution are lower. In fact,

[8] Notice that deviations from the initial steady state for energy consumption, consumption, hours worked, investment and effective aggregate consumption are minor. The magnitude of these deviations is less than 0.1%.

when we compute the efficiency dividend taking into account transitional dynamics, a change in habits hardly makes a difference.

5. Conclusions

Welfare-enhancing effects of Pigouvian environmental taxes and the possibility of having a double dividend following a green tax reform have long been discussed in the literature. The double dividend hypothesis would imply not only a welfare gain from the reduction of pollution following the setting of an environmental tax, but also an increase in welfare derived from recycling the extra-revenues to reduce distortionary taxes, thereby improving the overall efficiency of the tax system.

The existence of a second dividend is important for green tax reforms because it implies that the environment can be improved at no cost for the economy. However, literature is not conclusive in terms of the existence of such an efficiency dividend. Moreover, this dividend arises only under fairly unusual circumstances.

This paper introduces a novelty in the analysis of double dividend by considering habits in consumption. We also address the question in a dynamic setting, while most papers in the literature consider a static framework.

We specify and simulate a calibrated dynamic general equilibrium model with habits, by assessing the effects of two types of reforms. These reforms increase either the tax on household energy consumption or the tax on energy used by firms, and adjust capital taxation in a revenue-neutral framework.

We evaluate the impact of the tax reforms on welfare by computing the welfare gain associated with these policies and mainly focus on the existence of an efficiency dividend.

The results show that habit formation is relevant in evaluating the costs and benefits of the tax reform, when household energy consumption taxes increase. We find that habits introduce a significant change in household decisions and that the dynamic framework is also important to appropriately account for welfare changes relative to steady state analysis.

In the second reform analyzed (the increase in the tax on energy used by firms) the large contractive effect this tax has on the economy dominates, thus making both habit formation and the dynamic framework less relevant. In this case, we find an efficiency cost.

Acknowledgements

The authors would like to thank Jaime Alonso, the editor and two anonymous referees for their valuable suggestions as well as the participants at the 31st IAEE International Conference. Financial support from the Spanish Ministry of Science and Innovation and FEDER through grant ECO2008-02752/ECON is gratefully acknowledged.

Appendix A

The competitive equilibrium for this economy can be found by carrying out a standard optimization problem for households and firms jointly with the aggregate resources constraint and the government budget constraint.

From the consumer's optimization problem:

$$\underset{c_t, eh_t, n_t, k_{t+1}}{\text{Max}} \sum_{t=0}^{\infty} \beta^t \frac{\left[[(1-\gamma)(c_t - bc_{t-1})^{\alpha} + \gamma(eh_t - beh_{t-1})^{\alpha}]^{(1-\mu)/\alpha}(1-n_t)^{\mu} H_t^{\phi}\right]^{\sigma}}{\sigma}$$
$$s.t.: \quad (1+\tau^c)c_t + (1+\tau^h)p^h eh_t + k_{t+1} - (1-\delta)k_t = (1-\tau^w)w_t n_t + (1-\tau^k)r_t k_t - T_t,$$

we define the Lagrangian associated with this problem:

$$L = \sum_{t=0}^{\infty} \beta^t \left\{ \frac{1}{\sigma}\left[[(1-\gamma)(c_t - bc_{t-1})^{\alpha} + \gamma(eh_t - beh_{t-1})^{\alpha}]^{(1-\mu)/\alpha}(1-n_t)^{\mu} H_t^{\phi}\right]^{\sigma} \right.$$
$$\left. -\lambda_t[(1+\tau^c)c_t + (1+\tau^h)p^h eh_t + k_{t+1} - (1-\delta)k_t - (1-\tau^w)w_t n_t - (1-\tau^k)r_t k_t + T_t] \right\},$$

where $\boldsymbol{\lambda}$ represents the Lagrange multiplier.

The first-order conditions for this problem are:

$$c_t : (1-\mu)(1-\gamma)(1-n_t)^{\mu\sigma}H_t^{\phi\sigma}[(1-\gamma)(c_t-bc_{t-1})^{\alpha}+\gamma(eh_t-beh_{t-1})^{\alpha}]^{(1-\mu)\sigma/(\alpha)-1}$$
$$\times (c_t-bc_{t-1})^{\alpha-1}-\lambda_t(1+\tau^c)-\beta(1-\mu)b(1-\gamma)(1-n_{t+1})^{\mu\sigma}H_{t+1}^{\phi\sigma}$$
$$\times [(1-\gamma)(c_{t+1}-bc_t)^{\alpha}+\gamma(eh_{t+1}-beh_t)^{\alpha}]^{(1-\mu)\sigma/(\alpha)-1}(c_{t+1}-bc_t)^{\alpha-1}=0,$$
$$eh_t : (1-\mu)\gamma(1-n_t)^{\mu\sigma}H_t^{\phi\sigma}[(1-\gamma)(c_t-bc_{t-1})^{\alpha}+\gamma(eh_t-beh_{t-1})^{\alpha}]^{(1-\mu)\sigma/(\alpha)-1}$$
$$\times (eh_t-beh_{t-1})^{\alpha-1}-\lambda_t(1+\tau^h)p^h-\beta(1-\mu)b\gamma(1-n_{t+1})^{\mu\sigma}H_{t+1}^{\phi\sigma}$$
$$\times [(1-\gamma)(c_{t+1}-bc_t)^{\alpha}+\gamma(eh_{t+1}-beh_t)^{\alpha}]^{(1-\mu)\sigma/(\alpha)-1}(eh_{t+1}-beh_t)^{\alpha-1}=0,$$
$$n_t : -\mu(1-n_t)^{\mu\sigma-1}H_t^{\phi\sigma}[(1-\gamma)(c_t-bc_{t-1})^{\alpha}+\gamma(eh_t-beh_{t-1})^{\alpha}]^{(1-\mu)\sigma/(\alpha)}+\lambda_t(1-\tau^w)w_t=0,$$
$$k_{t+1} : -\lambda_t+\beta\lambda_{t+1}[1-\delta+(1-\tau^k)r_{t+1}]=0.$$

The representative firm solves:

$$\underset{n_t,k_t,ef_t}{\text{Max}}\ n_t^{\theta}[(1-a)k_t^{-\upsilon}+aef_t^{-\upsilon})]^{-(1-\theta)/\upsilon}-w_tn_t-r_tk_t-(1+\tau^f)p^f ef_t,$$

First-order conditions for the firm are:

$$w_t=\theta n_t^{\theta-1}[(1-a)k_t^{-\upsilon}+aef_t^{-\upsilon}]^{-(1-\theta)/\upsilon},$$
$$r_t=(1-a)(1-\theta)k_t^{-\upsilon-1}n_t^{\theta}[(1-a)k_t^{-\upsilon}+aef_t^{-\upsilon}]^{-(1-\theta)/(\upsilon)-1},$$
$$(1+\tau^f)p^f=a(1-\theta)ef_t^{-\upsilon-1}n_t^{\theta}[(1-a)k_t^{-\upsilon}+aef_t^{-\upsilon}]^{-(1-\theta)/(\upsilon)-1}.$$

Thus, the competitive equilibrium is defined by:

$$(1-\mu)(1-\gamma)(1-n_t)^{\mu\sigma}H_t^{\phi\sigma}[(1-\gamma)(c_t-bc_{t-1})^{\alpha}+\gamma(eh_t-beh_{t-1})^{\alpha}]^{(1-\mu)\sigma/(\alpha)-1}$$
$$\times (c_t-bc_{t-1})^{\alpha-1}-\lambda_t(1+\tau^c)-\beta(1-\mu)b(1-\gamma)(1-n_{t+1})^{\mu\sigma}H_{t+1}^{\phi\sigma}$$
$$\times [(1-\gamma)(c_{t+1}-bc_t)^{\alpha}+\gamma(eh_{t+1}-beh_t)^{\alpha}]^{(1-\mu)\sigma/(\alpha)-1}(c_{t+1}-bc_t)^{\alpha-1}=0,$$
$$(1-\mu)\gamma(1-n_t)^{\mu\sigma}H_t^{\phi\sigma}[(1-\gamma)(c_t-bc_{t-1})^{\alpha}+\gamma(eh_t-beh_{t-1})^{\alpha}]^{(1-\mu)\sigma/(\alpha)-1}$$
$$\times (eh_t-beh_{t-1})^{\alpha-1}-\lambda_t(1+\tau^h)p^h-\beta(1-\mu)b\gamma(1-n_{t+1})^{\mu\sigma}H_{t+1}^{\phi\sigma}$$
$$\times [(1-\gamma)(c_{t+1}-bc_t)^{\alpha}+\gamma(eh_{t+1}-beh_t)^{\alpha}]^{(1-\mu)\sigma/(\alpha)-1}(eh_{t+1}-beh_t)^{\alpha-1}=0,$$
$$-\mu(1-n_t)^{\mu\sigma-1}H_t^{\phi\sigma}[(1-\gamma)(c_t-bc_{t-1})^{\alpha}+\gamma(eh_t-beh_{t-1})^{\alpha}]^{(1-\mu)\sigma/(\alpha)}+\lambda_t(1-\tau^w)w_t=0,$$
$$-\lambda_t+\beta\lambda_{t+1}[1-\delta+(1-\tau^k)r_{t+1}]=0,$$
$$w_t-\theta n_t^{\theta-1}[(1-a)k_t^{-\upsilon}+aef_t^{-\upsilon}]^{-(1-\theta)/\upsilon}=0,$$
$$r_t-(1-a)(1-\theta)k_t^{-\upsilon-1}n_t^{\theta}[(1-a)k_t^{-\upsilon}+aef_t^{-\upsilon}]^{-(1-\theta)/(\upsilon)-1}=0,$$
$$(1+\tau^f)p^f-a(1-\theta)ef_t^{-\upsilon-1}n_t^{\theta}[(1-a)k_t^{-\upsilon}+aef_t^{-\upsilon}]^{-(1-\theta)/(\upsilon)-1}=0,$$
$$c_t+k_{t+1}-(1-\delta)k_t+G_t+p^heh_t+p^fef_t-n_t^{\theta}[(1-a)k_t^{-\upsilon}+aef_t^{-\upsilon}]^{-(1-\theta)/\upsilon}=0,$$
$$G_t-\tau^cc_t-\tau^hp^heh_t-\tau^fp^fef_t-\tau^ww_tn_t-\tau^kr_tk_t-T_t=0,$$
$$H_t-eh_t-ef_t=0.$$

The steady state of this economy is characterized by:

$$(1-\beta b)(1-\mu)(1-\gamma)(1-\tilde{n})^{\mu\sigma}\tilde{H}^{\phi\sigma}(1-b)^{(1-\mu)\sigma-1}[(1-\gamma)\tilde{c}^{\alpha}+\gamma\tilde{eh}^{\alpha}]^{(1-\mu)\sigma/(\alpha)-1}\tilde{c}^{\alpha-1}$$
$$-\tilde{\lambda}(1+\tau^c)=0, \tag{A1}$$

$$(1-\beta b)(1-\mu)\gamma(1-\tilde{n})^{\mu\sigma}\tilde{H}^{\phi\sigma}(1-b)^{(1-\mu)\sigma-1}[(1-\gamma)\tilde{c}^{\alpha}+\gamma\tilde{eh}^{\alpha}]^{(1-\mu)\sigma/(\alpha)-1}\tilde{eh}^{\alpha-1}$$
$$-\tilde{\lambda}(1+\tau^h)p^h=0, \tag{A2}$$

$$-\mu(1-\tilde{n})^{\mu\sigma-1}\tilde{H}^{\phi\sigma}(1-b)^{(1-\mu)\sigma}[(1-\gamma)\tilde{c}^{\alpha}+\gamma \widetilde{eh}^{\alpha}]^{(1-\mu)\sigma/(\alpha)}+\tilde{\lambda}(1-\tau^{w})\tilde{w}=0, \tag{A3}$$

$$-1+\beta[1-\delta+(1-\tau^{k})\tilde{r}]=0, \tag{A4}$$

$$\tilde{w}-\theta\tilde{n}^{\theta-1}[(1-a)\tilde{k}^{-\upsilon}+a\tilde{f}^{-\upsilon}]^{-(1-\theta)/\upsilon}=0, \tag{A5}$$

$$\tilde{r}-(1-a)(1-\theta)\tilde{k}^{-\upsilon-1}\tilde{n}^{\theta}[(1-a)\tilde{k}^{-\upsilon}+a\widetilde{ef}^{-\upsilon}]^{-(1-\theta)/(\upsilon)-1}=0, \tag{A6}$$

$$(1+\tau^{f})p^{f}-a(1-\theta)\widetilde{ef}^{-\upsilon-1}\tilde{n}^{\theta}[(1-a)\tilde{k}^{-\upsilon}+a\widetilde{ef}^{-\upsilon}]^{-(1-\theta)/(\upsilon)-1}=0, \tag{A7}$$

$$\tilde{c}+\delta\tilde{k}+G+p^{h}\widetilde{eh}+p^{f}\widetilde{ef}-\tilde{n}^{\theta}[(1-a)\tilde{k}^{-\upsilon}+a\widetilde{ef}^{-\upsilon}]^{-(1-\theta)/\upsilon}=0, \tag{A8}$$

$$G-\tau^{c}\tilde{c}-\tau^{h}p^{h}\widetilde{eh}-\tau^{f}p^{f}\widetilde{ef}-\tau^{w}\tilde{w}\tilde{n}-\tau^{k}\tilde{r}\tilde{k}-\tilde{T}=0, \tag{A9}$$

$$\tilde{H}-e\tilde{h}-\widetilde{ef}=0 \tag{A10}$$

where "∼" represents the steady state variable, that is to say $c_{t+1}=c_t=\tilde{c}$ and so on with the rest of the variables.

Eqs. (A1)–(A10) show the steady state of the variables $\{\tilde{c},\widetilde{eh},\tilde{n},\tilde{k},\widetilde{ef},\tilde{w},\tilde{r},\tilde{H},\tilde{T},\tilde{\lambda}\}$, given the prices $\{p^h,p^f\}$, the policies $\{\tau^c,\tau^h,\tau^f,\tau^w,\tau^k\}$ and the exogenous government spending $\{G\}$.

To characterize the effects of a policy change along the transition between steady states, we use the equations that define the competitive equilibrium and the stability conditions of a log–linear approximation of the equations system. This approach is used to compute the transitional dynamics. For a general reference on computational methods for dynamic macroeconomic models see, for example, Marimon and Scott (1999).

References

Abel, A.B., 1990. Assets prices and the habit formation and catching up with the Joneses. American Economic Review Papers and Proceedings 80, 38–42.

Boscá, J. E., García, J.R., Taguas, D., 2005. La fiscalidad en la OCDE: 1965–2001. Documento de Trabajo D-2005-06. Dirección General de Presupuestos. Ministerio de Economía y Hacienda.

Bovenberg, A.L., De Mooij, R.A., 1994. Environmental levies and distortionary taxation. American Economic Review 84 (4), 1085–1089.

Bovenberg, L., Goulder, L., 2002. Environmental taxation and regulation. In: Auerbach, A.J., Feldstein, M. (Eds.), Handbook of Public Economics. Elsevier, Dordrecht, pp. 1471–1545.

Carrasco, R., Labeaga, J.M., López-Salido, J.D., 2005. Consumption and habits: evidence from panel data. The Economic Journal 115 (January), 144–165.

Carroll, C., Overland, J., Weil, D., 2000. Saving and growth with habit formation. American Economic Review 90 (3), 341–355.

Chamley, C., 1986. Optimal taxation of capital income in general equilibrium with infinite lives. Econometrica 54, 607–622.

Chari, V.V., Christiano, L.J., Kehoe, P.J., 1994. Optimal fiscal policy in a business cycle model. Journal of Political Economy 102, 617–652.

Constantinides, G.M., 1990. Habit formation. A resolution of the equity premium puzzle. Journal of Political Economy 98, 519–543.

Cooley, T.F., Hansen, G.D., 1992. Tax distortions in a neoclassical monetary economy. Journal of Economic Theory 58, 290–316.

De la Croix, D., Urbain, J.P., 1998. Intertemporal substitution in import demand and habit formation. Journal of Applied Econometrics 13, 589–612.

De Mooij, R.A., 2000. Environmental Taxation and the Double Dividend. Contributions to Economic Analysis, North Holland, Amsterdam, The Netherlands.

Duesenberry, J., 1949. Income, Saving, and the Theory of Consumption Behavior. Harvard University Press, Cambridge, MA.

Fuhrer, J., 2000. Habit formation in consumption and its implications for monetary policy. American Economic Review 90 (3), 367–390.

Glomm, G., Kawaguchi, D., Sepulveda, F., 2008. Green taxes and double dividends in a dynamic economy. Journal of Policy Modelling 30, 19–32.

Goulder, L.H., Parry, I.W.H., Williams III, R.C., Burtraw, D., 1999. The cost-effectiveness of alternative instruments for environmental protection in a second-best setting. Journal of Public Economics 72, 329–360.

Houthakker, H.S., Verleger Jr., P.K., Sheehan, D.P., 2001. Dynamic demand analyses for gasoline and residential electricity. American Journal of Agricultural Economics 56 (2), 412–418.

Jones, L.E., Manuelli, R.E., Rossi, P.E., 1993. Optimal taxation in models of endogenous growth. Journal of Political Economy 101, 458–517.

Lucas Jr., R.E., 1990. Supply-side economics: an analytical review. Oxford Economics Papers 42 (2), 293–316.
Marimon, R., Scott, A. (Eds.), 1999. Computational Methods for the Study of Dynamic Economics. Oxford University Press, Oxford.
Oates, W.E., 1991. Pollution charges as a source of public revenues. Discussion Paper No. OE92-05, Resources for the Future, Washington, DC.
Pearce, D.W., 1991. The role of carbon taxes in adjusting to global warming. The Economic Journal 101, 938–948.
Ravn, M., Schmitt-Grohe, S., Uribe, M., 2006. Deep habits. Review of Economic Studies 73 (1), 195–218.
Seckin, A., 2001. Consumption-leisure choice with habit formation. Economics Letters 70, 115–120.
Thompson, P., Taylor, T.G., 1995. The capital-energy substitutability debate: a new look. The Review of Economics and Statistics 77, 565–569.
Zhu, X., 1992. Optimal fiscal policy in a stochastic growth model. Journal of Economic Theory 58, 250–289.