Optimal Oil Taxation in a Small Open Economy*

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Abstract

The international oil market has been very volatile over the past three decades. In industrialized economies, especially in Europe, taxes represent a large fraction of oil prices and governments do not seem to react to oil price shocks by using oil taxes strategically. The aim of this paper is to analyze optimal oil taxation in a dynamic stochastic general equilibrium model of a small open economy that imports oil. We obtain that in general it is not optimal to distort the oil price paid by firms with taxes. Extending the model in several ways this result could be reversed depending on environmental considerations and available fiscal instruments.

Key words: Optimal oil taxation, general equilibrium, small open economies.

JEL: H21, Q48

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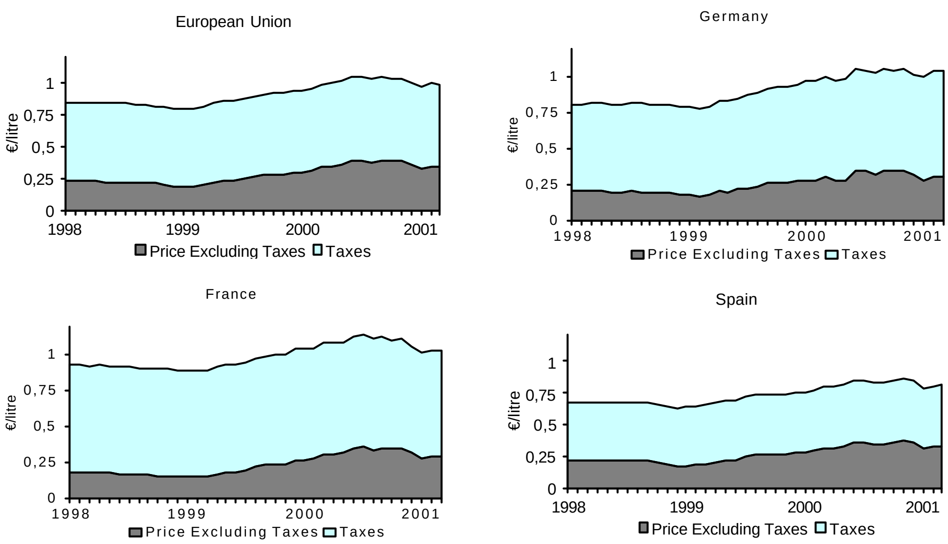
1 Introduction

The international oil market has been very volatile over the past three decades. In 1999 and 2000 significant increases in oil prices have been observed, due to restrictions in oil supply by OPEC, prompting economic agents to advocate government policies to mitigate the effects of oil price increases by cutting taxes. Figure 1 represents the evolution of gasoline prices with and without taxes [see International Energy Agency (2000)]. We observe that both series follow similar paths; so we can conclude that governments do not seem to react to oil price shocks by using oil taxes strategically. Given that taxes represent a large fraction of oil prices in industrialized economies (especially in Europe), governments have significant scope to use taxes to accommodate oil price shocks.

Figure 1: Unleaded Gasoline Prices (1998:1 - 2001:3).



The purpose of this paper is to examine the role of oil taxes in small economies that import oil and take as given the international oil price, for example as in Spain. A fundamental question in this framework is, How should oil taxes be set over the long run and over the business cycle? To address this question we combine two different strands of the literature: the macroeconomic incidence of oil price shocks on one hand and optimal taxation on the other hand.

The effects of energy price shocks on economic activity have long been recognized in the literature. Finn (1991) and Kim and Loungani (1992) focus on the analysis of energy price shocks, finding that this kind of shocks can contribute to economic fluctuations. Rotemberg and Woodford (1996) argue that modifying the standard neoclassical growth model by assuming imperfect competition makes it easier to explain the size of the declines in output and real wages that follow increases in the price of oil. Atkeson and Kehoe (1999) explore implications of considering alternative models of energy use, finding different implications for how capital and output respond to permanent differences in energy prices.

The literature on optimal taxation suggests that the government should raise revenue by using the tax instruments with the lowest efficiency cost [Diamond and McFadden (1974)]. Many authors, such as Bizer and Stuart (1987) and Goulder (1994) point out that energy taxes have high efficiency cost, which becomes even larger under the imperfect competition assumption [Rotemberg and Woodford (1994)]. If environmental damage is taken into account, the efficiency cost of energy taxes decreases by reducing pollution [Goulder (1994)].

The framework used in this paper is a dynamic stochastic general equilibrium model of a small open economy that imports oil. The economy consists of consumers and firms that behave competitively and a government that finances an exogenous flow of public spending by using consumption and oil taxes. The government chooses taxes optimally by maximizing welfare and taking as given the behavior of private agents.

We establish that, in general, the government should not distort the oil price paid by firms with taxes, even when consumption of oil is considered and the government distinguishes between the taxes paid by the households and the firms. These results also hold over the business cycle: in general, in a small open economy it is not optimal to use oil taxes paid by firms to accommodate shocks. In such cases, consumption and household oil taxes would be the optimal fiscal instruments that the government uses in response to shocks. This result could change depending on environmental issues and available tax instruments.

The paper is organized as follows. In the second section we present the baseline model of a small open economy that imports oil. In the third section we extend the model assuming that imported oil is also used by households as a consumption good. Finally, in the fourth section we summarize the conclusions.

2 A simple oil dependent small open economy

Consider a small open economy that needs to import oil to produce. We assume that this economy is small in the sense that its actions do not affect the rest of the world. In particular, the price of oil is taken as given. There are two sources of fluctuations in this economy: technology shocks and oil price shocks.

The economy is populated by a large number of identical infinite-lived households and firms. A constant return to scale technology is available to transform labor (n_t), capital (k_t) and oil (e_t) into output (y_t):

$$y_t = F(n_t, k_t, e_t; z_t), \tag{1}$$

where z_t represents an exogenous stochastic productivity shock.

Output can be used for consumption (c_t), new capital (k_{t+1}), oil purchases ($p_t e_t$), government spending (g_t) and non-oil net exports (tb_t):

$$c_t + k_{t+1} - (1-\delta)k_t + g_t + p_t e_t + tb_t = y_t, \tag{2}$$

where δ is the depreciation rate of capital and p_t is the exogenous oil price that follows a given stochastic process. Agents in this economy can buy and sell foreign bonds (b_t) in the international capital market at the international real rate of return (r_t^*):

$$tb_t = b_{t+1} - (1 + r_t^*)b_t. \tag{3}$$

The consumer's problem is to maximize the expected lifetime utility subject to the budget constraint:

$$Max \qquad E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, n_t)$$

$s.t:$

$$(1+\tau_t^c)c_t + k_{t+1} - (1-\delta)k_t + b_{t+1} = w_t n_t + r_t k_t + (1+r_t^*)b_t,$$

where β is the discount factor, τ^c is a consumption tax, w_t is the wage and r_t is the capital rate of return. The first-order conditions are:

$$U_{n_t} + \frac{U_{c_t}}{1+\tau_t^c} w_t = 0, \tag{4}$$

$$\frac{U_{c_t}}{(1+\tau_t^c)} = E_t\beta\frac{U_{c_{t+1}}}{(1+\tau_{t+1}^c)}(1-\delta+r_{t+1}), \tag{5}$$

$$\frac{U_{c_t}}{(1+\tau_t^c)} = E_t\beta\frac{U_{c_{t+1}}}{(1+\tau_{t+1}^c)}(1+r_{t+1}^*), \tag{6}$$

$$(1+\tau_t^c)c_t + k_{t+1} - (1-\delta)k_t + b_{t+1} = w_t n_t + r_t k_t + (1+r_t^*)b_t. \tag{7}$$

The representative firm solves:

$$Max\ F(n_t, k_t, e_t; z_t) - w_t n_t - r_t k_t - (1+\tau_t^e)p_t e_t,$$

where τ_t^e is an oil tax. Marginal productivities equalize input prices:

$$w_t = F_{n_t}, \tag{8}$$

$$(1+\tau_t^e)p_t = F_{e_t}, \tag{9}$$

$$r_t = F_{k_t}. \tag{10}$$

The government finances an exogenous flow of government spending (g_t) by using consumption and oil taxes. The government budget constraint is:

$$g_t = \tau_t^c c_t + \tau_t^e p_t e_t. \tag{11}$$

A *competitive equilibrium* is a set of paths of allocations $\{c_t,\ n_t,\ k_{t+1},\ e_t,\ b_{t+1}\}$, prices $\{w_t, p_t, r_t, r_t^*\}$ and policies $\{\tau_t^c, \tau_t^e, g_t\}$ that satisfy the following: (i) the allocations $\{c_t, n_t, k_{t+1}, b_{t+1}\}$ solve consumer problem given $\{w_t, r_t, r_t^*\}$ and τ_t^c, (ii) the allocations $\{n_t, k_t, e_t\}$ solve the firm problem given $\{w_t, r_t, p_t\}$, z_t and τ_t^e, (iii) the government budget constraint holds at each period, (iv) the goods, labor, capital, bonds and oil markets clear.

In the competitive equilibrium the government policies are arbitrary. We now consider a government that chooses its fiscal instruments optimally, taking as given the behavior of the private agents. The government problem can be divided in such a way that the optimal allocations can be obtained independently of the policies [see for example Chari and Kehoe (1999)].

The government solves:

$$Max \qquad E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, n_t)$$

$s.t:$

$$E_0 \sum_{t=0}^{\infty} \beta^t [U_{c_t} c_t + U_{n_t} n_t] = \frac{U_{c_0}}{(1+\tau_0^c)} [(1 + r_0^*) b_0 + (1 - \delta + r_0) k_0]$$

$$c_t + k_{t+1} - (1-\delta) k_t + g_t + p_t e_t + b_{t+1} - (1 + r_t^*) b_t = F(n_t, k_t, e_t; z_t).$$

The first restriction is the implementability constraint, that is the infinite horizon household budget constraint where consumer and firm first-order conditions have been used to substitute out prices and policies.

The implementability constraint is included in the objective function in order to solve the government problem easily:

$$E_0 \sum_{t=0}^{\infty} \beta^t W(c_t, n_t, \lambda) - \lambda \frac{U_{c_0}}{(1 + \tau_0^c)} [(1 + r_0^*) b_0 + (1 - \delta + r_0) k_0], \qquad (12)$$

where $W(c_t, n_t, \lambda) = U(c_t, n_t) + \lambda [U_{c_t} c_t + U_{n_t} n_t]$, with λ representing the Lagrange multiplier that discounts the implementability constraint. Optimal allocations are the result of maximizing this objective function subject to the feasibility condition:

$$c_t + k_{t+1} - (1-\delta) k_t + g_t + p_t e_t + b_{t+1} - (1 + r_t^*) b_t = F(n_t, k_t, e_t; z_t).$$

Given the optimal allocations, we can obtain the taxes that support these allocations as a competitive equilibrium outcome by using the optimal rules of private agents. The consumption tax is obtained combining (4) and (8):

$$U_{n_t} + \frac{U_{c_t}}{1 + \tau_t^c} F_{n_t} = 0, \qquad (13)$$

and the oil tax is pinned down from (9).

Because of the time inconsistency problem, we assume that the government can commit itself to follow the optimal fiscal policy plan.

The objective function is an increasing function of τ_0^c. Therefore the government has incentives to set the initial consumption tax as high as possible. The reason is that τ_0^c changes the marginal value of the initial stocks of capital and bonds for the household by rising the effective price of the consumption good, and the individual cannot react to the tax by changing the capital or bond stocks.

Proposition 1 *At the optimum the government should not distort the oil price paid by the firm with taxes* $\{\tau_t^e = 0\}_{t=0}^{\infty}$.

Proof. Given that the government objective function is different at $t = 0$ from $t > 0$, the proof must be divided in two stages:

1) $t > 0$.

Solving the government problem, we obtain the following first-order condition for e_t:

$$-W_{c_t}(p_t - F_{e_t}) = 0.$$

Under standard assumptions, interiority can be assured, so $W_{c_t} \neq 0$, and:

$$p_t - F_{e_t} = 0. \tag{14}$$

Since optimal allocations must satisfy the competitive equilibrium conditions, (9) and (14) must hold simultaneously. Consequently $\tau_t^e = 0$, for all $t > 0$.

2) $t = 0$.

Solving the government problem, we obtain the following first-order condition for e_0:

$$-\lambda \frac{U_{c_0}}{(1+\tau_0^c)} F_{k_0 e_0} k_0 - \\ - \left(W_{c_0} - \lambda \frac{U_{c_0 c_0}}{(1+\tau_0^c)} [(1+r_0^*) b_0 + (1 - \delta + r_0) k_0] \right) (p_0 - F_{e_0}) = 0.$$

Rearranging:

$$(p_0 - F_{e_0}) = \frac{-\lambda \frac{U_{c_0}}{(1+\tau_0^c)} F_{k_0 e_0} k_0}{W_{c_0} - \lambda \frac{U_{c_0 c_0}}{(1+\tau_0^c)} [(1+r_0^*) b_0 + (1 - \delta + r_0) k_0]}.$$

As we have discussed above, the government has incentives to set an initial consumption tax as high as possible, and:

$$\lim_{\tau_0^c \to \infty} (p_0 - F_{e_0}) = 0. \tag{15}$$

Then, as in the first stage, it follows that $\tau_0^e = 0$. ■

The result presented above implies that the government should not tax oil purchases not only not in the long run, but also not in the short run, because is not optimal to use oil taxes in response to shocks[1]. Therefore, proposition 1 does not support the claims of private agents in many European countries that advocate for cuts in oil taxes to accommodate changes in the international oil prices.

Proposition 1 is equivalent to the result on intermediate good taxation of Diamond and Mirrlees (1971) insofar as oil can be reinterpreted as an intermediate good in this economy. This result implies that the tax on intermediate goods should be zero since an optimal tax system must maintain aggregate production efficiency.

Proposition 2 *In the presence of externalities, the optimal oil tax could be different from 0.*

Proof. We assume that the use of oil reduces welfare. We therefore introduce oil as a negative externality into the utility function:

$$U(c_t, n_t, e_t), \qquad with \qquad U_{e_t} < 0. \tag{16}$$

Proceeding as above, we obtain an objective function that depends also on oil: $W(c_t, n_t, e_t, \lambda)$. Solving the government problem with this specification of the utility function yields the following first-order conditions on oil:

$$W_{e_t} - W_{c_t}(p_t - F_{e_t}) = 0, \ \forall t > 0,$$

$$W_{e_0} - \lambda \frac{U_{c_0}}{(1+\tau_0^c)} F_{k_0 e_0} k_0 - \\ - \left(W_{c_0} - \lambda \frac{U_{c_0 c_0}}{(1+\tau_0^c)} [(1+r_0^*)b_0 + (1-\delta+r_0)k_0] \right) (p_0 - F_{e_0}) = 0.$$

Comparing with the first order condition (9) it follows that $\tau_t^e \neq 0$ for all $t \geq 0$. ■

[1] Unless an upper bound is imposed on the initial tax rate on consumption, the optimal tax on oil would be 0 in the first period.

This proposition explains the existence of optimal oil taxes when environmental damage is considered. The oil tax acts as a pigouvian tax in the sense that attempts to correct the negative externality. Optimal taxes involve a compromise between the positive effect of oil in the production function and the negative effect in the utility function, so as both effects are equal at the margin (see Baumol and Oates (1988) for a general reference).

3 Household oil consumption

We extend the model assuming that imported oil (e_t) is used not only by firms (e_t^f) as an input, but also by households (e_t^h) as a consumption good:

$$e_t = e_t^f + e_t^h. \tag{17}$$

We allow the government to tax e_t^f and e_t^h at rates τ_t^f and τ_t^h, respectively.

Solving the firm problem, we set marginal productivities equal to prices:

$$w_t = F_{n_t}, \tag{18}$$

$$(1+\tau_t^f)p_t = F_{e_t^f}, \tag{19}$$

$$r_t = F_{k_t}. \tag{20}$$

Now the consumers also obtain satisfaction from the consumption of oil. The consumer's problem is to maximize utility subject to the budget constraint:

$$Max \qquad E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, e_t^h, n_t)$$

$s.t:$

$$(1+\tau_t^c)c_t + k_{t+1} - (1-\delta)k_t + (1+\tau_t^h)p_t e_t^h + b_{t+1} =$$
$$= w_t n_t + r_t k_t + (1+r_t^*)b_t.$$

The conditions that solve the consumer's problem are:

$$U_{n_t} + \frac{U_{c_t}}{1+\tau_t^c} w_t = 0, \tag{21}$$

$$U_{n_t} + \frac{U_{e_t^h}}{(1+\tau_t^h)p_t} w_t = 0, \tag{22}$$

$$\frac{U_{c_t}}{(1+\tau_t^c)} = E_t \beta \frac{U_{c_{t+1}}}{(1+\tau_{t+1}^c)} (1-\delta+r_{t+1}), \tag{23}$$

$$\frac{U_{c_t}}{(1+\tau_t^c)} = E_t \beta \frac{U_{c_{t+1}}}{(1+\tau_{t+1}^c)} (1+r_{t+1}^*), \tag{24}$$

$$\begin{aligned}(1+\tau_t^c)c_t + k_{t+1} - (1-\delta)k_t + (1+\tau_t^h)p_t e_t^h + b_{t+1} = \\ = w_t n_t + r_t k_t + (1+r_t^*) b_t.\end{aligned} \tag{25}$$

The government finances public spending using consumption and oil taxes:

$$g_t = \tau_t^c c_t + \tau_t^h p_t e_t^h + \tau_t^f p_t e_t^f. \tag{26}$$

Finally market clearing requires:

$$\begin{aligned}c_t + k_{t+1} - (1-\delta)k_t + g_t + p_t(e_t^h + e_t^f) + b_{t+1} - \\ - (1+r_t^*)b_t = F(n_t, k_t, e_t^f; z_t).\end{aligned} \tag{27}$$

A *competitive equilibrium* is a set of paths of allocations $\{c_t,\ n_t,\ k_{t+1},\ e_t^h,\ e_t^f,\ b_{t+1}\}$, prices $\{w_t, p_t, r_t, r_t^*\}$ and policies $\{\tau_t^c, \tau_t^h, \tau_t^f, g_t\}$ that satisfy the following: (i) the allocations $\{c_t, n_t, e_t^h, k_{t+1}, b_{t+1}\}$ solve consumer problem given $\{w_t, r_t, r_t^*, p_t\}$ and $\{\tau_t^c, \tau_t^h\}$, (ii) the allocations $\{n_t, k_t, e_t^f\}$ solve the firm problem given $\{w_t, p_t, r_t\}$, z_t and τ_t^f, (iii) the government budget constraint holds at each period, (iv) the goods, labor, capital, bonds and oil markets clear.

The government problem is solved following the strategy described in the previous section, that is, by dividing the problem in such a way that optimal allocations are obtained independently of policies.

The government solves:

$$Max \qquad E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, e_t^h, n_t)$$

$s.t:$

$$E_0 \sum_{t=0}^{\infty} \beta^t [U_{c_t} c_t + U_{n_t} n_t + U_{e_t^h} e_t^h] =$$
$$= \frac{U_{c_0}}{(1+\tau_0^c)} [(1 + r_0^*) b_0 + (1 - \delta + r_0) k_0]$$
$$c_t + k_{t+1} - (1 - \delta) k_t + g_t + p_t(e_t^h + e_t^f) + b_{t+1} -$$
$$-(1 + r_t^*) b_t = F(n_t, k_t, e_t^f; z_t).$$

When the implementability constraint is included into the objective function, the allocations are obtained by solving:

$$Max \qquad E_0 \sum_{t=0}^{\infty} \beta^t W(c_t, e_t^h, n_t, \lambda) - \lambda \frac{U_{c_0}}{(1+\tau_0^c)} [(1 + r_0^*) b_0 + (1 - \delta + r_0) k_0]$$

$s.t:$

$$c_t + k_{t+1} - (1 - \delta) k_t + g_t + p_t(e_t^h + e_t^f) + b_{t+1} - (1 + r_t^*) b_t = F(n_t, k_t, e_t^f; z_t),$$

where $W(c_t, n_t, \lambda) = U(c_t, n_t) + \lambda [U_{c_t} c_t + U_{n_t} n_t + U_{e_t^h} e_t^h]$.

In next subsections we study optimal taxation for two different cases: the case of different taxes on oil ($\tau_t^h \neq \tau_t^f$) and the case of uniform taxation on oil ($\tau_t^h = \tau_t^f$).

3.1 Differentiated oil taxes

Given optimal allocations, the taxes that support these allocations as a competitive equilibrium outcome are obtained by using the optimal rules of private agents. The consumption tax is obtained combining (18) and (21):

$$U_{n_t} + \frac{U_{c_t}}{1 + \tau_t^c} F_{n_t} = 0, \tag{28}$$

and household oil tax is pinned down combining (18) and (22):

$$U_{n_t} + \frac{U_{e_t^h}}{(1 + \tau_t^h) p_t} F_{n_t} = 0, \tag{29}$$

and finally, firm oil tax is obtained from (19).

Proposition 3 *In the optimum the government should not distort the oil price paid by the firm with taxes* $\{\tau_t^f = 0\}_{t=0}^{\infty}$.

Proof. Similar to proof in proposition 1. ■

Adding household oil consumption to the model does not change proposition 1, and the Diamond and Mirrlees (1971) result still holds. Moreover, under the assumption that government can distinguish between oil taxes paid by consumers and firms, it is optimal to tax oil only as a consumption good. Consumption and household oil taxes would be the fiscal instruments that the government uses in response to shocks.

Proposition 4 *If utility is weakly separable between consumption goods* $\{c_t, e_t^h\}$ *and labor* $\{n_t\}$ *and is homothetic in consumption, then consumption and household oil taxation is uniform in the sense that optimal taxes satisfy* $\tau_t^c = \tau_t^h$ *across time.*

Proof. Combining equations (28) and (29) we obtain:

$$\frac{1+\tau_t^c}{(1+\tau_t^h)} = \frac{U_{c_t}}{U_{e_t^h}} p_t. \tag{30}$$

Thus, $\tau_t^c = \tau_t^h$ if and only if $U_{c_t}/U_{e_t^h} = 1/p_t$.

Let consider the utility function $U(c_t, e_t^h, n_t) = V(Q(c_t, e_t^h), n_t)$ with Q homothetic in consumption. This utility function satisfies:

$$U_{e_t^h}[c_t U_{c_t c_t} + e_t^h U_{c_t e_t^h}] = U_{c_t}[c_t U_{e_t^h c_t} + e_t^h U_{e_t^h e_t^h}]. \tag{31}$$

To see this, notice that from homotheticity, it follows that:

$$\frac{U_{c_t}(\alpha\widetilde{c}_t, n_t)}{U_{e_t^h}(\alpha\widetilde{c}_t, n_t)} = \frac{U_{c_t}(\widetilde{c}_t, n_t)}{U_{e_t^h}(\widetilde{c}_t, n_t)} \text{ with } \widetilde{C}_t = (c_t, e_t^h). \tag{32}$$

Differentiating equation (32) with respect to α and evaluating it at $\alpha = 1$, we obtain (31).

Consider now the first-order conditions for c_t and e_t^h from the government problem:

$$U_{c_t} + \lambda[c_t U_{c_t c_t} + U_{c_t} + e_t^h U_{e_t^h c_t}] - \mu_t = 0, \tag{33}$$

$$U_{e_t^h} + \lambda[c_t U_{c_t e_t^h} + U_{e_t^h} + e_t^h U_{e_t^h e_t^h}] - \mu_t p_t = 0, \tag{34}$$

where μ_t represents the Lagrangian multiplier on the aggregate resource constraint. Combining equations (33) and (34) we obtain:

$$\frac{(1+\lambda)U_{c_t} - \mu_t}{(1+\lambda)U_{e_t^h} - \mu_t p_t} = \frac{c_t U_{c_t Ct} + e_t^h U_{e_t^h c_t}}{c_t U_{c_t e_t^h} + e_t^h U_{e_t^h e_t^h}}. \tag{35}$$

Finally, using equation (31):

$$\frac{U_{c_t}}{U_{e_t^h}} = \frac{1}{p_t}.$$

■

Under the assumptions of proposition 4, the government would tax consumption and household oil at the same rate across time. This proposition reflects the validity of the classic result on uniform commodity taxation of Atkinson and Stiglitz (1972) in the dynamic stochastic setting we consider.

3.2 Uniform oil taxes

In this subsection household and firm oil are forced to be taxed at the same rate ($\tau_t^h = \tau_t^f = \tau_t^e$). Competitive equilibrium conditions in which taxes are involved represent an incomplete tax system [see Chari and Kehoe (1999)] in the sense that we have more equations than fiscal instruments. These equations are:

$$U_{n_t} + \frac{U_{c_t}}{1+\tau_t^c} F_{n_t} = 0, \tag{36}$$

$$U_{n_t} + \frac{U_{e_t^h}}{(1+\tau_t^e)p_t} F_{n_t} = 0, \tag{37}$$

$$(1+\tau_t^e)p_t = F_{e_t^f}, \tag{38}$$

and the fiscal instruments are (τ_t^c, τ_t^e). An incomplete tax system implies that a new condition on the allocations must hold to implement it as a competitive equilibrium outcome. This condition is obtained by combining equations (37) and (38):

$$-\frac{U_{e_t^h}}{U_{n_t}} = \frac{F_{e_t^f}}{F_{n_t}}. \tag{39}$$

Equation (39) represents the competitive equilibrium condition that equates marginal rate of substitution between oil and leisure with marginal rate of technical substitution between oil and labor, representing the compatibility between household and firm plans. So equation (39) must be added as a restriction into the government problem:

$$Max \qquad E_0 \sum_{t=0}^{\infty} \beta^t W(c_t, e_t^h, n_t, \lambda) - \lambda \tfrac{U_{c0}}{(1+\tau_0^c)}[(1+r_0^*)b_0 + (1-\delta+r_0)k_0]$$

$s.t:$

$$c_t + k_{t+1} - (1-\delta)k_t + g_t + p_t(e_t^h + e_t^f) + b_{t+1} - \\ -(1+r_t^*)b_t = F(n_t, k_t, e_t^f; z_t)$$

$$-\tfrac{U_{e_t^h}}{U_{n_t}} = \tfrac{F_{e_t^f}}{F_{n_t}}.$$

Proposition 5 *In this economy with an incomplete tax system, optimal oil tax is not zero.*

Proof. Solving the government problem, we obtain the following first-order condition for e_t^f:

$$-\mu_t(p_t - F_{e_t^f}) - \gamma_t(F_{e_t^f e_t^f} U_{n_t} + F_{n_t e_t^f} U_{e_t^h}) = 0, \quad \forall t > 0,$$

$$-\mu_0(p_0 - F_{e_0^f}) - \gamma_0(F_{e_0^f e_0^f} U_{n_0} + F_{n_0 e_0^f} U_{e_0^h}) - \lambda \frac{U_{c_0}}{(1+\tau_0^c)} F_{k_0 e_0^f} k_0 = 0,$$

where μ_t and γ_t are the Lagrange multipliers on the constraints of the government problem. Comparing these conditions to the firm oil condition (38), we obtain $\tau_t^e \neq 0$, for all $t \geq 0$. ■

Proposition 6 *If the tax system is completed by adding a labor tax, a zero optimal oil tax is found.*

Proof. The inclusion of a labor tax (τ_t^w) modifies the household budget constraint:

$$(1+\tau_t^c)c_t + k_{t+1} - (1-\delta)k_t + (1+\tau_t^h)p_t e_t^h + b_{t+1} =$$

$$= (1-\tau_t^w)w_t n_t + r_t k_t + (1+r_t^*)b_t. \tag{40}$$

Competitive equilibrium conditions in which taxes are involved are now:

$$\frac{U_{n_t}}{1-\tau_t^w} + \frac{U_{c_t}}{1+\tau_t^c}F_{n_t} = 0, \tag{41}$$

$$\frac{U_{n_t}}{1-\tau_t^w} + \frac{U_{e_t^h}}{(1+\tau_t^e)p_t}F_{n_t} = 0, \tag{42}$$

$$(1+\tau_t^e)p_t = F_{e_t^f}, \tag{43}$$

which represents a complete tax system.

Optimal allocations arise from the problem:

$$Max \qquad E_0 \sum_{t=0}^{\infty} \beta^t W(c_t, e_t^h, n_t, \lambda) - \lambda \frac{U_{c_0}}{(1+\tau_0^c)}[(1+r_0^*)b_0 + (1-\delta+r_0)k_0]$$

$s.t:$

$$c_t + k_{t+1} - (1-\delta)k_t + g_t + p_t(e_t^h + e_t^f) + b_{t+1} - (1+r_t^*)b_t = F(n_t, k_t, e_t^f; z_t),$$

and the proposition can be proved similarly to proposition 1. ■

When the government cannot distinguish between agents that purchase oil, optimal oil taxes depend on the tax system available. In this sense, proposition 5 points out that in a fiscal system that consists of taxes on consumption and oil, the classic rule of no intermediate good taxation is broken and the optimal oil tax is not zero. To maintain Diamond and Mirrlees' (1971) result, a new fiscal instrument is required. In this framework a labor tax would complete the tax system.

4 Conclusions

In this paper we analyze optimal taxation in oil dependent economies. Using a dynamic stochastic general equilibrium model that includes oil as an input, we study how oil taxes should be in both the long and the short run. The standard literature points out that energy taxes have greater efficiency costs than other kinds of taxes. In a general framework, this result holds, and the government should not distort with taxes the oil price paid by the firm over the long run or over the business cycle. When environmental damages are considered, this result is reversed and a non-zero oil tax is optimal.

Extending the model by including oil consumption by households, two different situations arise. When the government can distinguish between oil taxes paid by the household and the firm, it is optimal to tax the two different uses of oil at different rates. Thus, whereas the zero taxation result holds for oil used by firms, the government sets household oil taxes jointly with consumption taxes to raise revenue and to accommodate shocks. Moreover, under suitable assumptions on preferences, the government would tax consumption and household oil at the same rate across time. When it is not possible to tax oil at different rates, an incomplete tax system problem arises, and it is optimal to distort the oil price paid by the firm. Otherwise a new tax instrument is required and oil should not be taxed.

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