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**Second-Best Optimal
Taxation of Oil and
Capital in a Small Open
Economy**

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Economics, LUISS University

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Summary

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Keywords: Optimal Factor Taxation, Oil, Capital Income, Residence-based System, Source-Based System

JEL Classification: E62, H21, Q43, Q48

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Second-Best Optimal Taxation of Oil and Capital in a Small Open Economy

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October 2009

Abstract

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1 Introduction

It is widely recognized that the non-environmental efficiency costs associated with taxation of oil (energy, in general) used as a factor of production are very large. This is because taxes on productive oil distort, directly or indirectly, three margins: the labor-leisure margin, the intertemporal margin and the intermediate-good choice margin.¹ The non-environmental efficiency losses of taxes imposed on oil used by households as a consumer good are, instead, much smaller, as they only affect the labor-leisure and the consumer-good choice margins. See, for example, Goulder (1994) and Newbury (2005) for thorough discussions of the consequences of the two types of oil taxation on the resource allocation.

As distortions are minimized by those taxes that only affect the intratemporal margins,² the previous considerations have immediate normative implications in a world with no environmental externalities: The optimal tax rate on productive oil should be zero, while the tax rate on household consumption of oil should be positive.

The elegant doctrinary support of such tax prescriptions is offered by the Diamond and Mirrlees (1971) principle of public finance: Production efficiency requires that taxes are levied only on final goods (oil used for consumption) as intermediate goods (oil used for production) should be exempted from taxation, when the product market is perfectly competitive and the technology is constant-returns-to-scale.³

The optimality of the zero tax rate on productive oil is invalidated when there are externalities associated with the use of oil or restrictions on the choice of tax instruments. See, among the others, Goulder (1994), Bovenberg and Goulder (2002), and De Miguel and Manzano (2005). By studying

¹These margins regard the labor market, the capital market and the intermediate-good market, respectively.

²See Diamond and McFadden (1974).

³Under such circumstances, the optimal tax rate on oil used for consumption should be equal to the other consumption good tax rates as prescribed by the Atkinson and Stiglitz (1972) principle of uniform taxation of consumption goods. This principle – a corollary of the intermediate-goods result – is satisfied when preferences are homothetic and weakly separable in consumption goods and leisure.

the second-best taxation of oil in a perfectly competitive small open economy that imports oil and faces perfect capital mobility, De Miguel and Manzano (2005) show, for example, that the zero-tax result for productive oil is violated when a uniform taxation of oil employed by firms and oil used by households is imposed, and a consumption tax is the only additional source of government revenue. If labor, in addition to consumption, were also taxed at an optimal rate, the uniform oil taxation would become zero as the competitive equilibrium from incomplete (that is, when there are more equations than independent tax instruments) becomes complete.⁴

There are strong analogies between a tax on oil used for production and a capital income tax. By affecting the intertemporal margin, a tax on capital income is highly distortionary too. As capital represents an intermediate good (since it does not enter the utility function), the Diamond and Mirrlees (1971) prescription also applies to capital taxation: Capital income, like productive oil, should be exempted from taxation from a second-best perspective. This result, discovered by Chamley (1986) for a closed economy, holds asymptotically.⁵

The Chamley (1986) tax rule is also valid for an open economy financially integrated with the rest of the world; see, for example, Correia (1996a), Atkeson, Chari and Kehoe (1999), and Chari and Kehoe (1999). This open economy result does not depend on the type of international capital tax system implemented.

The zero capital tax rule is based on the hypotheses of perfect competition in the product market and no limitations on the choice of tax instruments. The removal of one of such supporting assumptions implies that the optimal capital tax rate differs from zero since the Diamond and Mirrlees (1971) principle is invalidated.⁶ This is shown, for example, by Jones, Manuelli and Rossi (1993, 1997), Correia (1996b), Guo and Lansing (1999) and Judd

⁴See Chari and Kehoe (1999).

⁵The optimal capital tax rate may differ from zero outside the steady state. If however a CRRA utility function is assumed, it is optimal to tax capital income only in the initial period (Chamley, 1986).

⁶Stiglitz and Dasgupta (1971), and Munk (1980) analyze the consequences of these hypotheses on optimal commodity taxation.

(2002).⁷

In the literature of dynamic public economics developed so far, the implications of firms with market power or a tax code that is not sufficiently rich have been unexplored in the analysis of the joint normative taxation of oil and capital. As the effects of these assumptions for the second-best factor tax results are quite complicated to figure out on a simple intuitive basis, the aim of this paper is to study them theoretically within an oil-importing open economy peopled by immortal agents. The implications of imperfections in the product market and limitations on tax setting are analyzed separately. Issues related to the environmental dimension of oil and therefore to the externality correcting role of factor taxation are not addressed in this paper.

Particular attention is devoted to the analysis of the international regime of capital income taxation. Two international systems of capital taxation are considered: the residence-based (also called worldwide) system and the source-based (often denominated territorial) system. The residence-based principle prescribes that taxation is levied on capital income of domestic residents regardless of the country where income has originated. Source-based capital income taxes are, instead, imposed on all capital income obtained in a particular jurisdiction regardless of the country of residence of savers.

The optimal analysis developed here assumes that the government has access to a commitment technology. This hypothesis guarantees the sustainability of second-best plans by eliminating problems of time inconsistency.

We depart substantially from the results obtained with perfect competition and free tax choice. In fact, in the cases studied – one with monopolistic competition and no limitations on the tax choice, and one with perfect competition and tax restrictions – we discover that the optimal taxation of oil and capital income strictly depend on the international tax system implemented; in addition, it depends on the degree of market power, the extent

⁷Also the consideration of a technology that exhibits constant-returns-to-scale with respect to all the inputs is at the base of the Chamley (1986) result. When a production function having constant-returns-to-scale with respect to the reproducible inputs alone is, instead, considered, the zero capital tax result is no longer valid; see Jones, Manuelli and Rossi (1993), and Judd (1999). Such a case can be seen as a combination of the hypotheses of product market imperfections (because of pure profits) and tax restrictions (because of the absence of monopoly power distortions).

to which monopoly profits are taxed, the type of tax restrictions and the different uses of oil (whether for production or consumption).

We begin by studying the role of product market imperfections.⁸ We find that the capital income tax is zero when a system of residence-based taxation is adopted. Tariffs on oil used as an input should be zero too if monopoly profits are tax free. If, instead, firm profits were fiscally confiscated, oil should be subsidized. Therefore, government spending is solely (or mainly, when profits are taxed at the 100% rate) financed through labor taxation. Because of perfect capital mobility, it is the taxation of foreign assets (constrained to be equal to that of domestic capital) that is driving to zero capital income and, in the case of untaxed profits, oil taxes.

Under the source-based system of taxation, the optimal factor tax structure is more articulated.⁹ Capital and oil should be both subsidized (but at different rates) when monopoly profits are either tax free or taxed at the 100% rate. In both cases, capital should be subsidized more than oil. If profits are instead taxed as capital income, the capital tax rate could be positive, while the oil tax rate should be unambiguously negative provided that capital and oil are Edgeworth complementary.

Furthermore, we analyze the role of tax restrictions on the optimal factor tax structure in models with perfect competition.¹⁰ Two sub-cases are investigated: one in which the tax burden only falls on capital and oil since labor cannot be taxed, and one in which the tax rates on oil used for production and oil used for consumption are constrained to be the same.

When labor is untaxed, productive oil should bear the burden of taxation under the worldwide system as the optimal capital tax rate is zero. In the territorial system, instead, the second-best tax load should be distributed

⁸Guo and Lansing (1999), and Judd (2002) show that the consideration of firms with market power leads to the invalidity of the Chamley (1986) prescription on capital taxation in a closed economy. In a setup that incorporates imperfect competition, the efficiency costs of oil taxes are exacerbated; this is shown by Rotemberg and Woodford (1994), who however do not investigate the optimal taxation of oil.

⁹Note that the findings obtained under the territorial tax regime correspond to those that would be registered with financial autarky.

¹⁰The implications of the richness of the tax code for the second-best taxation of capital are studied by Jones, Manuelli and Rossi (1993, 1997), and Correia (1996b).

over oil and capital.

In the case of uniform taxation of oil used by firms and households, optimality prescribes that oil and labor should be jointly taxed. Under the residence-based system, capital income should be entirely lifted from taxation, while, under the source-based system, capital income should be subsidized.

The rest of the paper is structured as follows. Section 2 develops an imperfectly competitive model of an oil-importing small open economy and studies the normative properties of factor taxation. Section 3 examines the implications of tax restrictions on the optimal tax structure under perfect competition. Section 4 summarizes the results and concludes.

2 An imperfectly competitive economy with free tax choices

2.1 The model

Consider a small open economy that imports oil from the rest of the world and operates in a globalized financial market. The world interest rate and the international oil price are given. This economy, populated by monopolistic firms, produces a single tradable good, perfectly substitutable with the foreign produced good. Without implicating the generality of the results, we assume that oil is only used for production.¹¹

Product market imperfections are incorporated into the analysis by using the Benhabib and Farmer (1994) supply-side apparatus. There are two sectors in the economy: a final good sector, which is perfectly competitive, and an intermediate good sector, which is monopolistically competitive. The perfectly competitive sector produces a unique final good by using differentiated intermediate goods. The imperfectly competitive sector, instead, produces intermediate goods by using physical capital, labor and oil.

¹¹It is not difficult to show that the consideration of household oil consumption would not affect our normative findings for capital and productive oil taxation; it would only additionally imply a positive tax rate on oil used by consumers.

The final good y is produced through the linearly homogeneous production function

$$y = \left(\int_0^1 y_i^{1-\mu} di \right)^{\frac{1}{1-\mu}}, \quad (1)$$

where y_i represents the i th intermediate good, and i is continuous in the interval $[0,1]$; $\mu \in [0, 1)$ is the reciprocal of the elasticity of substitution among intermediate inputs. Final good producing firms maximize profits by choosing the optimal quantity of each intermediate good. Profit maximization yields the following input demand

$$\frac{y_i}{y} = p_i^{-\frac{1}{\mu}}, \quad (2)$$

where p_i is the price of the i th intermediate good and the price of the final good, taken to be the numeraire, has been normalized to one. Since the final sector is perfectly competitive, firms' profits should be zero. This requires that $\int_0^1 p_i^{\frac{\mu-1}{\mu}} di = 1$.

The technology used in the intermediate goods sector is given by

$$y_i = F(k_i, l_i, e_i), \quad (3)$$

where k_i , l_i and e_i represent capital, labor and oil used for producing intermediate good i th, respectively. $F(\cdot)$ satisfies the neoclassical properties of regularity and is constant-returns-to-scale. In the absence of clear empirical evidence, we assume – as in Svensson (1984), and Rotemberg and Woodford (1994, 1996) – that all factors of production are Edgeworth complementary; that is, the three cross-partial derivatives of $F(\cdot)$ are positive.

After using (2) for p_i , the i th firm's profit in the intermediate sector (measured in terms of the final good) can be expressed as $\Pi_i = y^\mu y_i^{1-\mu} - Rk_i - wl_i - (1 + \tau_e)p_e^* e_i$, where R is the real rental price of capital, w the real wage, p_e^* the international price of oil (expressed in terms of domestic output) and τ_e the *ad valorem* tariff/tax rate on imported oil. The i th intermediate good producer maximizes Π_i by taking into account the production function (3). The first-order conditions for maximum profits are

$$(1 - \mu) \left(\frac{y}{y_i} \right)^\mu F_{k_i}(k_i, l_i, e_i) = R, \quad (4a)$$

$$(1 - \mu) \left(\frac{y}{y_i} \right)^\mu F_{l_i}(k_i, l_i, e_i) = w, \quad (4b)$$

$$(1 - \mu) \left(\frac{y}{y_i} \right)^\mu F_{e_i}(k_i, l_i, e_i) = (1 + \tau_e) p_e^*. \quad (4c)$$

We consider a situation of symmetric equilibrium in which $k_i = k$, $l_i = l$, $e_i = e$, $y_i = y$ and $p_i = 1$. In this situation, the input demands become

$$(1 - \mu) F_k(k, l, e) = R, \quad (4a')$$

$$(1 - \mu) F_l(k, l, e) = w, \quad (4b')$$

$$(1 - \mu) F_e(k, l, e) = (1 + \tau_e) p_e^*. \quad (4c')$$

Profits in the intermediate good sector are positive and equal to $\Pi = \mu F(k, l, e)$. μ measures the degree of market power in the economy; $\mu = 0$ describes a perfectly competitive intermediate-good sector and hence an economy with no product market imperfections.

Consumers are identical and in a fixed number. The representative consumer maximizes the following intertemporal utility function

$$\int_0^\infty U(c, x) e^{-\rho t} dt, \quad (5)$$

where c is consumption, x leisure and ρ the fixed rate of time preference. The instantaneous utility function $U(\cdot)$ is strictly increasing and is concave in its arguments. Consumption and leisure are normal goods. Leisure is given by the fixed time endowment, normalized to one, less hours worked; that is, $x = 1 - l$.

Consumers accumulate financial wealth, a , by holding capital, foreign assets, b , and government bonds, d ; that is, $a = k + b + d$.

The consumer budget constraint should be specified according to the international tax regime implemented. In an open economy, two regimes of

capital taxation can be considered: the worldwide or residence-based system and the territorial or source-based system. Under the *residence-based system* of international taxation, incomes from domestic and foreign wealth are taxed equally. Therefore, the household flow budget constraint is given by

$$c + \dot{k} + \dot{b} + \dot{d} = (1 - \tau_k)[(R - \delta)k + r^*b] + rd + (1 - \tau_l)wl + (1 - \omega\tau_k)\psi\Pi, \quad (6)$$

where τ_k represents a proportional worldwide capital tax rate, δ the capital depreciation rate, r^* the world interest rate, r the real return on government debt, τ_l the *ad valorem* labor tax rate, and ω and ψ are non-negative parameters that capture (by taking alternatively values 0 and 1) different tax treatments of monopoly profits.

Dividends enter (6) as consumers are the owners of firms. As pure profits only exert income effects, their separate taxation would prescribe the confiscatory 100% rate from a normative standpoint. Since tax authorities may be unable to distinguish capital income from dividends or consumers may evade taxes by concealing profits to the fiscal administration, such an optimal taxation of profits is difficult to implement in practice. Therefore, we consider the following three alternative cases of profit taxation:¹²

- i) confiscatory taxation of pure profits; that is, $\psi = 0$;
- ii) tax free monopoly profits; that is, $\omega = 0$ and $\psi = 1$;
- iii) pure profits that are taxed at the same rate as income from capital; that is, $\omega = \psi = 1$.

The maximization of (5) subject to (6) yields the following first-order conditions

$$U_c = \xi, \quad (7a)$$

$$\frac{U_x}{\xi} = (1 - \tau_l)w, \quad (7b)$$

$$\rho - \frac{\dot{\xi}}{\xi} = (1 - \tau_k)r^*, \quad (7c)$$

¹²Identical hypotheses are considered by Guo and Lansing (1999), who in addition postulate different fiscal treatments of depreciation allowances.

$$R - \delta = r^* = r/(1 - \tau_k), \quad (7d)$$

together with the proper transversality conditions on k , b and d . ξ , the Lagrange multiplier on the flow budget constraint (6), represents the shadow value of financial wealth.

Equations (7) are fairly standard. Perfect capital mobility along with the residence tax system implies that the before-tax rates of return on domestic and foreign assets are equalized; this is contemplated by (7d).

Consider the *source-based regime* of taxation. In this case, income from capital is taxed at a proportional rate τ_k , while income from foreign assets is untaxed. The consumer instantaneous budget constraint is

$$c + \dot{k} + \dot{b} + \dot{d} = (1 - \tau_k)(R - \delta)k + r^*b + rd + (1 - \tau_l)wl + (1 - \omega\tau_k)\psi\Pi. \quad (6')$$

Also in this case, the different regimes of profit taxation, described above, are captured by assigning different values to ω and ψ .

Now the representative consumer maximizes (5) subject to (6'). The first-order conditions for this problem are given by (7a), (7b) and the following relationships

$$\rho - \frac{\dot{\xi}}{\xi} = r^*, \quad (7c')$$

$$(1 - \tau_k)(R - \delta) = r^* = r. \quad (7d')$$

Under the source-based regime, the after-tax rate of return on capital is equal to the world interest rate, from (7d').

The government budget deficit is financed by issuing government debt. In the case of the worldwide regime, the government budget constraint is given by

$$\dot{d} + \tau_k[r^*(k + b) + \omega\psi\Pi] + \tau_lwl + \tau_e p_e^* e + (1 - \psi)\Pi = rd + g, \quad (8)$$

where g is unproductive government spending.

When the territorial principle of capital income taxation is considered, the government budget constraint becomes

$$\dot{d} + \tau_k[(R - \delta)k + \omega\psi\Pi] + \tau_lwl + \tau_e p_e^* e + (1 - \psi)\Pi = rd + g. \quad (8')$$

In the Ramsey policy experiments developed below, we will assume that the government follows a budget balanced policy – i.e., the stock of government debt is constant – and g is exogenously given.

The excess of national income over aggregate demand and oil imports gives the rate of accumulation of foreign assets; that is,

$$\dot{b} = y + r^*b - c - \dot{k} - \delta k - g - p_e^* e. \quad (9)$$

This is the feasibility constraint of our small open economy.

2.2 Second-best optimal policy

The residence-based system

The efficient tax structure is determined by solving the 'Ramsey problem', which prescribes the maximization of the utility of the representative consumer once the competitive equilibrium with distortionary taxes and the constraint that a given amount of revenue has to be raised are taken into account.

We employ the 'primal approach' to optimal taxation developed by Lucas and Stokey (1983), which combines the consumer intertemporal budget constraint with the optimal conditions of utility maximization.¹³ This method is based on the implementability constraint, which summarizes such a combination.

The implementability constraint in the case of the *worldwide system* of taxation is obtained as follows. Plugging (7d) into the flow budget constraint (6) and integrating forward (after the transversality conditions are incorporated), the intertemporal budget constraint is obtained

¹³A paradigmatic application of the 'primal method' in a continuous-time setup is provided by Lucas (1990).

$$\int_0^{\infty} [c - (1 - \tau_l)wl - (1 - \omega\tau_k)\psi\Pi]e^{-\int_0^t(1-\tau_k)(R-\delta)du} dt = a_0, \quad (10)$$

where a_0 is nonhuman wealth at time 0. From (7c) and (7d), the shadow value of wealth can be expressed as $\xi = \xi_0 e^{\rho t - \int_0^t(1-\tau_k)(R-\delta)du}$, where $\xi_0 = U_c(c_0, x_0)$. Plugging (7b) into (10) and using the previous expression for ξ as well as the time allocation constraint, the implementability constraint is derived; that is,

$$\int_0^{\infty} \{c\xi - U_x(1-x) - (1 - \omega\tau_k)\psi\xi\Pi\}e^{-\rho t} dt = \xi_0 a_0. \quad (11)$$

Because of the different tax treatments of profits, the Ramsey problem has to be devised in such a way as to consider the possibility that income from wealth and profits are taxed at the same rate. Therefore, the efficient second-best tax structure is found by maximizing the utility functional (5) subject to the implementability constraint (11) – with $\Pi = \mu F(k, 1-x, e)$ –, the feasibility constraint (9) – with $F(k, 1-x, e)$ that replaces y – and the Euler equation (7c), once the static efficiency condition (7a) is taken into account.¹⁴

The conceptual characterization of the efficient tax structure is

Proposition 1 *In a monopolistically competitive oil-dependent economy facing perfect capital mobility, in which the residence-based tax system is applied, optimality calls for a zero capital tax rate. Oil taxation should be zero too when monopoly profits are untaxed. If, instead, dividends are taxed at the 100% rate, oil should be subsidized. Regardless of the profit tax treatment, labor cannot be exempted from the burden of taxation.*

Proof. The Hamiltonian for the Ramsey problem is

$$\begin{aligned} H = & W(c, x, e, k, \xi, \tau_k) + \Gamma [F(k, 1-x, e) + r^*b - c - \delta k - g - p_e^*e] + \\ & + \Omega \xi [\rho - (1 - \tau_k)r^*] + \Delta(\xi - U_c), \end{aligned}$$

¹⁴The additional constraints (7c) and (7a) are to be considered in the Ramsey problem since τ_k enters the implementability constraint when pure profits are taxed as capital income (that is, $\omega = \psi = 1$).

where $W(\cdot)$ is the pseudo-welfare function of the planner, given by

$$W(c, x, e, k, \xi, \tau_k) = U(c, x) + \Phi[c\xi - U_x(1-x) - (1-\omega\tau_k)\psi\xi\mu F(k, 1-x, e)],$$

and Γ , Ω , Δ and Φ are the Lagrange multipliers associated with (9), (7c), (7a) and (11), respectively.

The first-order conditions of the second-best problem are

$$W_c = \Gamma + \Delta U_{cc}, \quad (12a)$$

$$W_x = \Gamma F_l + \Delta U_{cx}, \quad (12b)$$

$$-\Phi(1-\omega\tau_k)\psi\xi\mu F_e + \Gamma(F_e - p_e^*) = 0, \quad (12c)$$

$$-\dot{\Gamma} + \Gamma\rho = -\Phi(1-\omega\tau_k)\psi\xi\mu F_k + \Gamma(F_k - \delta), \quad (12d)$$

$$-\dot{\Gamma} + \Gamma\rho = \Gamma r^*, \quad (12e)$$

$$-\dot{\Omega} + \rho\Omega = \Phi[c - (1-\omega\tau_k)\psi\mu F] + \Omega[\rho - (1-\tau_k)r^*] + \Delta, \quad (12f)$$

$$\Omega = -\frac{\omega\psi\Phi\mu F}{r^*}, \quad (12g)$$

where $W_c \equiv U_c[1 + \Phi(1 + \eta_c)]$ and $W_x \equiv U_x[1 + \Phi(1 + \eta_x)]$.¹⁵

In a steady state equilibrium, the Ramsey plan requires, from (12e), that $r^* = \rho$. When this relationship is contrasted with (7c), we get $\tilde{\tau}_k = 0$.¹⁶

After using (4a'), (7c) and (7d) into the long-run version of (12d) and taking into account $\tilde{\tau}_k = 0$, we obtain that $\Gamma = \xi\Phi$ when profits are not

¹⁵ η_c and η_x represent general equilibrium elasticities. They are given by the expressions:
 $\eta_c = -(1-x)\frac{U_{xc}}{U_c}$ and $\eta_x = -(1-x)\frac{U_{xx}}{U_x} + \frac{(1-\omega\tau_k)\psi U_c \mu F_l}{U_x}$.

¹⁶Tax rates with tilde denote the second-best efficient tax rates.

taxed (that is, $\psi = 1$). Once this condition is used into (12c) together with (4c'), we obtain $\tilde{\tau}_e = 0$.

If, instead, profits are taxed at a confiscatory rate – i.e., $\psi = 0$ – the condition (12c), combined with (4c') and $\tilde{\tau}_k = 0$, implies that $\tilde{\tau}_e = -\mu$.

The efficient labor income tax rate is unambiguously positive.¹⁷ \square

Product market imperfections do not alter the prescription of a zero capital tax under the worldwide system, obtained in a competitive setup by Correia (1996a). This is because the tax rates of domestic capital and net claims on foreigners are constrained to be the same and net foreign assets do not appear in the pseudo-welfare function of the social planner. Therefore, the assumption of perfect capital mobility is driving the zero capital result as profits entering the intertemporal budget constraint of consumers play no role in the optimal capital tax structure.

Our results on capital taxation are, however, surprising, as they differ substantially from the closed economy ones. In a monopolistically competitive closed economy, capital subsidization is necessary from a normative standpoint to cure the distortionary effects of firms' market power.¹⁸

The regime of profit taxation, which is inconsequential for capital taxation, affects oil taxation. If profits are confiscatorily taxed, oil used by firms must be subsidized; otherwise, oil for production, like capital, should be tax free.

The source-based system

In the case of the *territorial system* of capital taxation, as the after-tax return on capital is equal to the world interest rate, the consumer intertemporal budget –obtained from (6') and (7d')– is given by (10).

By substituting the static efficiency condition (7b) into (10) (in order to express prices and taxes in terms of quantities) and using the expression $\xi = \xi_0 e^{\rho t - \int_0^t (1 - \tau_k)(R - \delta) du}$ – derived from (7c') and (7d') – we get the implementability constraint, which corresponds to (11).

Now the second-best problem is

¹⁷Obviously, when the taxation of profits is confiscatory, the tax burden on labor is partly lifted.

¹⁸See, for example, Judd (2002). Guo and Lansing (1999) obtain different results with imperfect competition because of the diversified tax treatment of depreciation allowances and monopoly profits.

$$\max \int_0^{\infty} W(c, x, e, k, \tau_k) e^{-\rho t} dt \quad (13a)$$

subject to

$$\dot{k} + \dot{b} = F(k, 1 - x, e) + r^*b - c - \dot{k} - \delta k - g - p_e^*e, \quad (13b)$$

and

$$(1 - \tau_k)[(1 - \mu)F_k - \delta] = r^*, \quad (13c)$$

where

$$W(c, x, e, k, \tau_k) = U(c, x) + \Phi[cU_c - U_x(1 - x) - (1 - \omega\tau_k)\psi U_c\mu F(k, 1 - x, e)],$$

and $\Phi > 0$ is the multiplier on equation (11). The constraint (13c), imposed on the Ramsey problem, is necessary for realizing the possibility that capital income and pure profits can be taxed at the same rate.

In this case, we can state that

Proposition 2 *When the source-based system of capital taxation is implemented in an oil-dependent small open economy with monopolistic competition, the optimal structure of factor taxation strictly depends on the extent to which pure profits are taxed. The optimal tariff on oil used for production and tax on capital are negative when monopoly profits are either untaxed or taxed confiscatorily. When profits are taxed at the same rate as capital income, the capital tax rate is ambiguous, while the tax rate on productive oil remains negative (provided that oil and capital are Edgeworth complementary).*

Proof. The necessary and sufficient conditions of the 'Ramsey optimum' are

$$W_c = \Gamma, \quad (14a)$$

$$W_x = \Gamma F_l + \Sigma(1 - \tau_k)(1 - \mu)F_{kl}, \quad (14b)$$

$$-\Phi(1 - \omega\tau_k)\psi U_c \mu F_e + \Gamma(F_e - p_e^*) + \Sigma(1 - \tau_k)(1 - \mu)F_{ke} = 0, \quad (14c)$$

$$-\dot{\Gamma} + \Gamma\rho = -\Phi(1 - \omega\tau_k)\psi U_c \mu F_k + \Gamma(F_k - \delta) + \Sigma(1 - \tau_k)(1 - \mu)F_{kk}, \quad (14d)$$

$$-\dot{\Gamma} + \Gamma\rho = \Gamma r^*, \quad (14e)$$

$$\Sigma = \frac{\omega\psi\Phi U_c \mu F}{[(1 - \mu)F_k - \delta]} \geq 0, \quad (14f)$$

where $W_c \equiv U_c[1 + \Phi(1 + \varepsilon_c)]$, and $W_x \equiv U_x[1 + \Phi(1 + \varepsilon_x)]$;¹⁹ Γ and Σ denote multipliers associated with (13b) and (13c), respectively.

The joint use of (4a'), (7c') and (7d') implies that, in the steady state, $(1 - \tau_k)[(1 - \mu)F_k - \delta] = \rho$. By plugging this equation into (14d) it yields the efficient capital income tax rate, which is given by

$$\tilde{\tau}_k = -\frac{[\mu F_k(\Gamma - \psi\Phi U_c) + \Sigma(1 - \mu)F_{kk}]}{\{\Gamma[(1 - \mu)F_k - \delta] + \omega\psi\Phi U_c \mu F_k - \Sigma(1 - \mu)F_{kk}\}}. \quad (15a)$$

With the aid of (14b), the Ramsey condition for oil (14c) can be solved, after employing (6d), for the optimal oil tax rate as follows

$$\tilde{\tau}_e = -\frac{\left\{ \mu F_e[\Gamma - \Phi\psi U_c(1 - \omega\tilde{\tau}_k)] + \Sigma(1 - \tilde{\tau}_k)(1 - \mu)F_{ke} \right\}}{\left\{ F_e[\Gamma - \mu\Phi\psi U_c(1 - \omega\tilde{\tau}_k)] + \Sigma(1 - \tilde{\tau}_k)(1 - \mu)F_{ke} \right\}}. \quad (15b)$$

The optimal capital and oil tax rates have to be discussed by taking into account the different hypotheses on the tax treatment of profits;²⁰ it is instead

¹⁹ ε_c and ε_x denote general equilibrium elasticities, whose expressions are: $\varepsilon_c = \frac{U_{cc}}{U_c}[c - (1 - \omega\tau_k)\psi\mu F] - (1 - x)\frac{U_{xc}}{U_c}$ and $\varepsilon_x = \frac{U_{cx}}{U_x}[c - (1 - \omega\tau_k)\psi\mu F] - (1 - x)\frac{U_{xx}}{U_x} + \frac{(1 - \omega\tau_k)\psi U_c \mu F_l}{U_x}$.

²⁰ Also Guo and Lansing (1999) show that when a common tax rate on capital income and profits is considered in an intertemporal optimizing closed economy model with imperfect competition, the optimal tax rate on capital income can be either positive or negative.

quite straightforward to show that the labor tax rate is always positive. We have the following cases:

i) confiscatory taxation of monopoly profits: $\psi = 0$

In this case, as $\psi = \Sigma = 0$, we have

$$\tilde{\tau}_k = -\frac{\mu F_k}{[(1-\mu)F_k - \delta]} < 0, \quad (15a')$$

and

$$\tilde{\tau}_e = -\mu < 0. \quad (15b')$$

When monopoly profits are fiscally confiscated, it is optimal to subsidize capital and, to a lesser extent, oil. Capital and oil taxes should be used to cure the inefficiency associated with private market imperfections.

ii) no taxation of monopoly profits: $\omega = 0$ and $\psi = 1$

When dividends are tax free, $\Sigma = 0$ from (14f). Therefore, the optimal tax rates on capital and oil are respectively given by

$$\tilde{\tau}_k = -\frac{\mu F_k (\Gamma - \Phi U_c)}{\Gamma [(1-\mu)F_k - \delta]}, \quad (15a'')$$

and

$$\tilde{\tau}_e = -\frac{\mu (\Gamma - \Phi U_c)}{(\Gamma - \mu \Phi U_c)}. \quad (15b'')$$

Thus, we have that $\tilde{\tau}_k < 0$ and $\tilde{\tau}_e < 0$ as $\Gamma > \Phi U_c$.²¹ Capital subsidization should be larger than the oil one.

iii) uniform taxation of pure profits and capital income: $\omega = \psi = 1$

In this circumstance, $\tilde{\tau}_k$ is ambiguous as the numerator of (15a) has an unclear sign. This is because two effects are at work: the underinvestment

²¹This latter inequality holds because

$$\Gamma - \Phi U_c = U_c(1 + \Phi \varepsilon_c) = U_c \left\{ \frac{U_x(1 + \varepsilon_x) - F_l U_c [1 + (1 - \tilde{\tau}_l) \varepsilon_c]}{U_x(1 + \varepsilon_x) - F_l U_c(1 + \varepsilon_c)} \right\} > 0,$$

where the expression $\Phi = \frac{\tilde{\tau}_l F_l U_c}{[U_x(1 + \varepsilon_x) - F_l U_c(1 + \varepsilon_c)]} > 0$ has been used.

effect, due to the distortionary implications of market power, and the pure profit effect, due to the nondistortionary effect of profit taxation. $\tilde{\tau}_k$ oscillates from the case of capital subsidization, required from a second-best standpoint to alleviate the distortionary role of market imperfections (as suggested by Judd, 2002), to the one of profit taxation, that has no distortive role as it only exerts income effects (this is an aspect emphasized by Guo and Lansing, 1999).

The analytical expressions for the optimal tax rates are

$$\tilde{\tau}_k = \frac{\left\{ -\mu F_k \Gamma + \mu F_k \Phi U_c \left[1 - \frac{(1-\mu) F F_{kk}}{[(1-\mu) F_k - \delta] F_k} \right] \right\}}{\left\{ \Gamma [(1-\mu) F_k - \delta] - \mu F_k \Phi U_c \left[1 - \frac{(1-\mu) F F_{kk}}{[(1-\mu) F_k - \delta] F_k} \right] \right\}}, \quad (15a'')$$

$$\tilde{\tau}_e = - \frac{\left\{ \mu F_e [\Gamma - \Phi U_c (1 - \tilde{\tau}_k)] + \frac{(1 - \tilde{\tau}_k) \mu (1 - \mu) \Phi F U_c F_{ke}}{[(1 - \mu) F_k - \delta]} \right\}}{\left\{ F_e [\Gamma - \mu \Phi U_c (1 - \tilde{\tau}_k)] + \frac{(1 - \tilde{\tau}_k) \mu (1 - \mu) \Phi F U_c F_{ke}}{[(1 - \mu) F_k - \delta]} \right\}}. \quad (15b'')$$

While it is not unambiguously clear whether the second-best capital tax rate is positive or negative or zero, the optimal oil tax rate is clearly negative since capital and oil are assumed to be Edgeworth complementary (that is, $F_{ke} > 0$). \square

The analysis conducted here demonstrates that the Diamond and Mirrlees (1971) principle is invalid because of positive profits, as shown by Stiglitz and Dasgupta (1971).

At the end of the various experiments performed with monopolistic competition, a general comment on taxation of oil as a consumer good is in order. If oil were simultaneously used as a consumer good and productive input, and oil were taxed at different rates according to the different uses, no substantial changes would be obtained for the optimal fiscal policy. The normative taxation of productive oil would follow the prescriptions obtained above, while oil used as a consumer good should be positively taxed along with labor.

3 A perfectly competitive economy with tax restrictions

In this Section, we analyze the optimal taxation of oil and capital when there are restrictions on the capacity of the planner to choose tax rates. In order to avoid confusing the implications of government limitations on tax setting with those of product market imperfections studied above, we consider a perfectly competitive economy. Two cases of tax restrictions are discussed: one in which labor cannot be taxed, and one in which the tax rate imposed on oil used for production is equal to the tax rate on oil used for consumption.

3.1 No taxation of labor

3.1.1 The model

Consider the model developed in Section 2 and assume that there is perfect competition in the intermediate-good market (i.e., $\mu = 0$). As labor cannot be taxed, only two tax instruments can be used to finance the exogenous stream of government spending: productive oil and capital income taxes.²²

Under the hypothesis that labor is tax free, the standard Ramsey problem, obtained by maximizing the utility integral of the representative agent subject to the implementability and the feasibility constraints, is incomplete. This is because an additional constraint has to be incorporated into the normative analysis: the competitive equilibrium of the labor market; that is,

$$U_x = F_l U_c. \tag{16}$$

Without the imposition of such a constraint, the second-best problem cannot be decentralized as a competitive solution since the resulting Ramsey plan would not respect equation (16).²³

It is not difficult to show that the implementability constraint, independently of the international tax system adopted, is now given by

²²For simplicity and without any loss of generality, the assumption that oil is only used by firms for production is retained.

²³See Correia (1996b), and Chari and Kehoe (1999).

$$\int_0^{\infty} [cU_c - U_x(1-x)]e^{-\rho t} dt = U_{c0}a_0. \quad (17)$$

The Ramsey problem is obtained by maximizing (5) subject to (9), (16) and (17).

3.1.2 Optimal tax policy

The residence-based system

In this case, the first-order condition of the Ramsey problem for b is still given by (12e), which is not affected by the imposition of the constraint (16) and the hypothesis $\mu = 0$. Therefore, from (7c), the result $\tilde{\tau}_k = 0$ is obtained. This implies that oil taxation remains the only available source for raising the revenue necessary to finance government spending.

These findings can be summarized as

Proposition 3 *In an infinite-lived small open economy with perfect competition, elastic labor-leisure choices and the worldwide regime of capital taxation, the Ramsey optimality prescribes the taxation of oil and the exemption of capital from taxation when labor cannot be taxed.*

The source-based system

When the competitive equilibrium on the labor market – i.e., the condition (16) – is imposed under the territorial capital tax regime, the first-order conditions of the second-best problem with respect to k and e are respectively given by

$$-\dot{\Gamma} + \Gamma\rho = \Gamma(F_k - \delta) - \Xi U_c F_{lk}, \quad (18a)$$

$$\Gamma(F_e - p_e^*) = \Xi U_c F_{le}, \quad (18b)$$

where $\Xi > 0$ is the Lagrange multiplier associated with the constraint (16).

By using the input demands (4') together with the assumption $\mu = 0$, the following optimal tax rates on capital and oil are obtained

$$\tilde{\tau}_k = \frac{\Xi U_c F_{lk}}{\Gamma(F_k - \delta)}, \quad (19a)$$

$$\tilde{\tau}_e = \frac{\Xi U_c F_{le}}{(\Gamma F_e - \Xi U_c F_{le})}. \quad (19b)$$

$\tilde{\tau}_k$ and $\tilde{\tau}_e$ are both positive since $F_{lk} > 0$ and $F_{le} > 0$ by Edgeworth complementarity.

Our discoveries can be expressed compactly as follows

Proposition 4 *If a factor of production cannot be taxed, the minimization of the excess burden of taxation in an oil-dependent small open economy that operates under the territorial tax system requires the distribution of taxation over the taxable inputs that are Edgeworth complementary with the untaxed factor.*

When the tax code is not sufficiently rich, also highly distortive taxes become unavoidable from a second-best standpoint in order to raise a given flow of revenue; such taxes represent *de facto* an indirect way to tax what cannot be taxed.

The normative findings obtained here, due to the existence of limitations to the optimal tax policy, are imputable to the invalidity of the Diamond and Mirrlees (1971) result, as pointed out, in a static setting, by Munk (1980) and, in a dynamic setting, by Correia (1996b) and Jones, Manuelli and Rossi (1993, 1997). The mechanical motivation of our results is based on the fact that, when additional constraints are imposed on the Ramsey problem because of the tax restrictions, the cross-partial derivatives of the production function with respect to labor and capital as well as labor and oil enter the first-order conditions of the planner problem. This fact undermines the optimality of the zero taxation of capital and oil in a model with perfect competition.

3.2 Uniform taxation of productive and consumption oil

3.2.1 The model

Consider a perfectly competitive economy by postulating $\mu = 0$ in the model of Section 2. Suppose that there are two uses of oil: one for production, and

one for consumption. Assume that the tax rates on productive oil and oil consumed by households are constrained to be equal.²⁴

If oil used for production is denoted by e^f and the oil tax rate paid by firms by τ_e^f , the input demand system is given by (4') when $\mu = 0$ and a small adjustment in the notation is used; that is,

$$F_k(k, l, e^f) = R, \quad (20a)$$

$$F_l(k, l, e^f) = w, \quad (20b)$$

$$F_{e^f}(k, l, e^f) = (1 + \tau_e^f)p_e^*. \quad (20c)$$

Denote household oil consumption by e^h . Now the representative agent maximizes the integral utility

$$\int_0^\infty U(c, x, e^h)e^{-\rho t} dt, \quad (21)$$

subject to, in the case of the residence-based system, the following flow budget constraint

$$c + (1 + \tau_e^h)p_e^*e^h + \dot{k} + \dot{b} + \dot{d} = (1 - \tau_k)[(R - \delta)k + r^*b] + rd + (1 - \tau_l)wl, \quad (22)$$

where τ_e^h is the *ad valorem* tax rate on oil consumption. $U(\cdot)$ is well-behaved and c , x and e^h are normal goods.

The dynamic utility maximization yields, as first-order conditions, equations (7) and

$$U_{e^h} = U_c(1 + \tau_e^h)p_e^*. \quad (23)$$

Under the territorial tax regime, the instantaneous budget constraint is

²⁴The case of distinct oil tax rates will not be considered here, since it is not difficult to ascertain that in such a circumstance – independently of the international tax regime implemented – the optimal tax on capital and productive oil would be zero, while the tax rate on oil used as a consumer good and the labor tax rate would instead be positive.

$$c + (1 + \tau_e^h)p_e^*e^h + \dot{k} + \dot{b} + \dot{d} = (1 - \tau_k)(R - \delta)k + r^*b + rd + (1 - \tau_l)wl. \quad (22')$$

In this case, the first-order conditions of the consumer problem are given by (7a), (7b), (7c'), (7d') and (23).

In the government budget constraints (8) and (8'), $\Pi = \psi = \omega = 0$ and the item $\tau_e^f p_e^* e^f + \tau_e^h p_e^* e^h$ replaces $\tau_e p_e^* e$ on the revenue side.

Finally, the current account dynamics are described by

$$\dot{b} = F(k, l, e^f) + r^*b - c - \dot{k} - \delta k - g - p_e^*(e^f + e^h). \quad (24)$$

3.2.2 Optimal fiscal policy

The residence-based system

The Ramsey problem is

$$\max \int_0^\infty W(c, x, e^h, \Phi) e^{-\rho t} dt \quad (25a)$$

subject to (24) and

$$U_{e^h} = U_c F_{e^f}, \quad (25b)$$

where

$$W(c, x, e^h, \Phi) = U(c, x, e^h) + \Phi[cU_c + e^h U_{e^h} - U_x(1 - x)].$$

The constraint (25b) guarantees that the tax rate on oil used for production and the tax rate on oil employed for consumption are equal, i.e. $\tau_e^h = \tau_e^f = \tau_e$.

The first-order conditions for the Ramsey optimum with respect to e^f and b are

$$\Gamma(F_{e^f} - p_e^*) - \Lambda U_c F_{e^f e^f} = 0, \quad (26a)$$

$$-\dot{\Gamma} + \Gamma\rho = \Gamma r^*, \quad (26b)$$

where Λ is the Lagrange multiplier on the constraint (25b).

Therefore, using (7c), (7d) and (26), we get

$$\tilde{\tau}_k = 0, \quad (27a)$$

and

$$\tilde{\tau}_e = \frac{\Lambda U_c F_{e^f e^f}}{(\Gamma F_{e^f} - \Lambda U_c F_{e^f e^f})} > 0. \quad (27b)$$

since $\Lambda < 0$.²⁵

$\tilde{\tau}_k$ is zero because of perfect capital mobility. $\tilde{\tau}_e$ is, instead, positive as we are constraining two taxes with different efficiency costs to be equal.

The following proposition synthesizes our findings:

Proposition 5 *A uniform taxation of oil used as an input and a consumer good in a perfectly competitive model under a worldwide regime implies a zero capital income tax as well as positive oil and labor taxes.*

The source-based system

When the international tax regime is of the territorial type, the optimal conditions of the Ramsey plan for e^f , b and k , are given by (26) and

$$-\dot{\Gamma} + \Gamma \rho = \Gamma(F_k - \delta) - \Lambda U_c F_{e^f k}. \quad (28)$$

²⁵ Λ is obtained as follows. The optimal Ramsey conditions for c and x are

$$W_c = \Gamma - \Lambda(U_{e^h c} - F_{e^f} U_{cc}), \quad (i)$$

$$W_x = \Gamma F_l - \Lambda(U_{e^h x} - F_{e^f} U_{cx} - U_c F_{e^f l}), \quad (ii)$$

where $W_c = U_c[1 + \Phi(1 + \eta_c)]$, $W_x = U_x[1 + \Phi(1 + \eta_x)]$, $\eta_c = \frac{cU_{cc}}{U_c} + e^h \frac{U_{e^h c}}{U_c} - (1-x) \frac{U_{xc}}{U_c}$ and $\eta_x = \frac{cU_{cx}}{U_x} + e^h \frac{U_{e^h x}}{U_x} - (1-x) \frac{U_{xx}}{U_x}$.

By using (i) and (ii) to eliminate Γ , we get

$$\Lambda = \frac{\{\Phi(\eta_x - \eta_c) - \tilde{\tau}_l[1 + \Phi(1 + \eta_x)]\}}{[F_l(U_{e^h c} - F_{e^f} U_{cc}) + F_{e^f} U_{cx} + U_c F_{e^f l} - U_{e^h x}]} < 0.$$

From (28), (7c') and (7d'), in the long-run, we get

$$\tilde{\tau}_k = \frac{\Lambda U_c F_{e^f k}}{\Gamma(F_k - \delta)} < 0, \quad (29)$$

and (27b).

As $\Lambda < 0$,²⁶ $\tilde{\tau}_k < 0$ and $\tilde{\tau}_e > 0$ from (29) and (27b). The high efficiency costs connected with the taxation of e^f are compensated by a subsidy imposed on k .

Therefore, the following statement summarizes our discoveries

Proposition 6 *In a perfectly competitive small open economy, oil and labor have to be taxed under the territorial tax system, when oil used by firms and household oil consumption are taxed equally. The second-best tax rate on capital income should, instead, be negative.*

4 Concluding remarks

This paper has analyzed the efficient taxation of oil and capital income in an infinitely lived small open economy facing perfect capital mobility when there are either product market imperfections or restrictions on the feasible set of tax policies. These elements, previously unexplored in terms of second-best factor taxation within oil using economies, undermine the Diamond and Mirrlees (1971) principle, which supports the optimality of exempting oil used by firms and capital income from taxation.

In order to better understand and therefore corroborate the didascalical message of the paper, the implications of market imperfections and tax restrictions have been investigated separately. In particular, we have studied an economy with imperfect competition and no tax limitations on the one side, and an economy with perfect competition and tax restrictions on the other.

Our findings stem from the invalidity of the prohibition against the intermediate goods taxation, pointed out in static models by Stiglitz and Dasgupta (1971) – when markets are monopolistically competitive – and Munk

²⁶See footnote 25.

(1980) – when there are restrictions to the optimal choice of taxes. Product market power and limitations in the ability of the planner to optimally choose taxes can be seen as forms of imperfection. We have discussed circumstances in which, by taking into account efficiency considerations, oil and capital taxes have to correct these imperfections. We have discovered that the optimal tax structure depends, among other factors, on the international tax system chosen (residence-based versus source-based) and, in the imperfectly competitive case, on the fiscal treatment of monopoly profits.

The synopsis of the results of the paper is as follows:

(1) *Monopolistic competition with no tax restrictions*

When a residence-based system is implemented, second-best optimality prescribes the removal of the distortion of capital income taxation. Productive oil taxation should be zero when monopoly profits are tax free, while it should be negative if instead profits are fiscally confiscated. Labor bears the burden of taxation.

Under a source-based system, the degree of profit taxation determines the structure of the optimal tax policy. The optimal taxes on oil used by firms and capital are negative when monopoly profits are either untaxed or taxed confiscatorily. When profits are taxed at the same rate as capital income, the optimal tax rate on productive oil remains negative, while the efficient capital tax rate may be positive or negative.

(2) *Perfect competition with tax restrictions*

2.a) In a perfectly competitive economy operating under the worldwide regime, the Ramsey optimality calls for a tax on productive oil and no capital taxation if labor is tax free. The minimization of the excess burden of taxation within an economy that operates under the territorial system requires, instead, the distribution of the tax burden over capital and oil used by firms.

2.b) A uniform taxation of oil used by firms and households implies, under the worldwide regime, a Ramsey plan characterized by a zero capital income tax as well as positive oil and labor taxes. Under the territorial tax system, oil and labor should be taxed, while the optimal tax rate on capital should instead be negative.

To conclude, we can notice, from a methodological point of view, that the optimality of zero taxation of oil as an input is denied when: i) oil enters

the implementability constraint and therefore the pseudo-welfare function of the planner; ii) there are additional constraints, faced by the planner that private agents do not face, involving the production function. These conditions, which are parallel to those emphasized by Jones, Manuelli and Rossi (1997, pp. 105-6) for the zero capital tax result,²⁷ further demonstrate the analogies between a tax on productive oil and a tax on capital income.

²⁷One exception to this parallelism is obtained here under the residence-based system when markets are imperfectly competitive and monopoly profits are fiscally confiscated.

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