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Abstract

In this paper we explore the proposition that, in economies with imperfect competitive markets, the optimal capital income tax is negative and the optimal tax on firms profits is confiscatory. We show that if the total factor productivity as well as the measure of firms or varieties are endogenous instead of fixed, then the optimal fiscal policy can lead to different results. The government faces a trade-off between the fixed costs that the society pays for the introduction of a new firm and the productivity gains associated to the introduction of a new variety. We show that both the optimal capital income tax and the optimal profits tax depend on the relationship between the index of market power, the returns to specialization and the government ability to control entry.

Keywords: Optimal taxation, returns to specialization, monopolistic competition.
J.E.L. classification codes: H21, H30, E62.

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1. Introduction

In this paper we explore the proposition that, in economies with imperfect competitive markets, the optimal capital income tax is negative and the optimal tax on firms profits is confiscatory. The main contribution of the paper is to show that once we consider an endogenous number of firms or varieties, the optimal fiscal policy can lead to different results. In contrast with Judd (1997), we identify some additional sources and parameters, in particular an index of market power and an index of returns to specialization, that affect the sign of both the capital income tax and the profits tax. The rationale is that the government faces a trade-off between the fixed costs that the society pays for the introduction of a new firm and the productivity gains associated to the introduction of a new variety.[1] Nevertheless, we find some cases where the optimal capital income tax is zero.

The empirical evidence shows that any source of capital income, profits or rents, is taxed in most of the OECD countries. This fact has generated an important theoretical discussion in order to find the sign and the magnitude of the optimal capital income tax. According to Judd (1985) and Chamley (1986), in an economy with competitive markets and infinitely-lived consumers, the optimal capital income tax in steady-state should be zero. Moreover, Jones, Manuelli and Rossi (1993) show that there are large welfare gains associated to implement this optimal policy.

In a recent set of papers, Judd (1997, 2002) uses a representative-agent model with a fixed number of goods produced by monopolistic competitive firms, and he finds that the optimal fiscal policy implies a negative capital income tax and a 100% tax rate on firms profits. The basic intuition works as follows. Since the market price exceeds the marginal cost, the government uses a capital subsidy to counterbalance the market power and, thus, the efficient capital-labor ratio is recovered. Moreover, given that pure profits do not affect any agent decision at the margin, the government finds optimal to tax them at a confiscatory rate and lower the tax burden on other margins. According to Judd (1997), the estimates of the welfare gains associated to implement the optimal fiscal policy can be misleading if one takes into account that the prescribed policy implies an investment subsidy rather than zero.[2]

In this paper we depart from the seminal work of Dixit and Stiglitz (1977) and consider an endogenous number of firms or varieties. The environment considers two production sectors: intermediate and final goods. Firms that produce intermediate goods have monopoly power that can be characterized by a single parameter: the mark-up. However, we follow the original formulation that Ethier (1982) proposed which clearly separates returns to specialization (or returns to variety, as in Kim, 2004) and the monopolistic mark-up. The modeling choice has two advantages. First, the set-up embeds the standard monopolistic competition with a fixed number of firms as a special case. Second, and in contrast with Judd (1997), the introduction of free entry eliminates pure profits in equilibrium. As a result, the optimal fiscal policy does not depend on the government ability to distinguish between profits and other forms of capital income, but it does on the capacity to

[1] Throughout the paper we assume that the government can commit to the optimal policy ignoring time-consistency issues. Clearly this is an important restriction that can change the results. However, the analysis of the time-consistent policy goes beyond the scope of this paper.

[2] In a related paper, Schmitt-Grohé and Uribe (2004) show that if the government has no access to a 100% tax rate on monopoly profits, then the Friedman rule is not optimal and the government resorts to a positive nominal interest rate as an indirect way to tax profits.

control the entry and exit of firms.[3,4] In this sense, the findings with restricted entry describes the short-run equilibrium. Besides, the entry of new firms can be interpreted as R&D in the production of new inputs, which increases the total productivity of the economy, as in the endogenous growth literature. However, our specification of the final goods production function, based on Benassy (1996), differs from the conventional endogenous growth model of Romer (1996). While Benassy (1996) shows that the market equilibrium can generate too much innovation or entry (the number of intermediate goods is higher than in the social optimum equilibrium), the resources devoted to R&D are inefficiently low in the models based on the Romer framework. Therefore, we can have two possible situations: in the first the government has to subsidize the entry of new firms in order to foster innovation, whereas in the second situation the government has to tax profits in order to restrict the entry of new firms, since the entry of new firms represents a social waste of resources.

The economy with imperfect competitive markets and free entry has two sources of inefficiencies. The first inefficiency is the price-marginal cost distortion or mark-up distortion: the monopoly power in the intermediate goods sector reduces the wage and the interest rate below the marginal productivity of labor and capital. There exists a second inefficiency: the market equilibrium can generate an inefficient level of firms, since when a firm has to decide if entering into the market, it only considers if the monopoly profits are higher than the fixed cost, and it ignores the productivity gains generated by the introduction of a new intermediate good. Hence, the private benefits from entry (monopoly profits) can be different than the social benefits (productivity increase).

The introduction of a new firm in the market is determined by two opposite effects: a complementary effect and a business-stealing effect. The complementary effect tends to generate an inefficiently low number of firms, since firms do not take into account the positive effect on total productivity when they enter into the market. The business-stealing effect tends to produce an excessive entry of firms, since new firms enter into the market attracted by high profits but they do not take into account the negative effect on the incumbent firms due to the fact that the existing firms in the market have to share the demand with the new firm although this new firm produces a differentiated product and it does not compete directly with the incumbent firms. Consequently, if the government does not control the entry, the market could generate a number of firms too low (high) relative to the social optimum when the monopoly profits are too low (high).

We show that in the first-best solution, the mark-up distortion does not depend on the number of firms in the market. Consequently, the optimal policy ensures that the private return and the social return coincide and then, as in Judd (1997), the distortion associated to the monopoly power is effectively eliminated. However, taxation on gross profits can be positive, negative or zero, and is used to determine the efficient number of firms.

In the second-best, the optimal fiscal policy is characterized by the fact that the government could or not dispose of enough fiscal instruments to control the firms entry.[5] We consider three different cases. In the first case the government disposes of a complete set of fiscal instruments and, therefore, it can directly control entry through the profits tax. We show that the optimal capital income tax is negative regardless of the relative magnitude of the returns to specialization with respect to the mark-up. By implementing the optimal capital income tax, the government recovers

[3] Guo and Lansing (1999) introduce physical capital depreciation, depreciation tax allowances and endogenous government expenditure in Judd's (1997) imperfect competition model. They show that if the government can fully confiscate profits, then the steady-state capital income tax is negative. However, in the case that the tax authority cannot differentiate between capital income and profits, they find that the optimal capital income tax in steady-state can be negative, positive or zero, depending on the degree of monopoly power, the size of the depreciation allowances and the magnitude of the government expenditure.

[4] Judd (1997) considers the returns to specialization or "taste for variety" as Grossman and Helpman (1991).

[5] In this formulation, exit would not occur in equilibrium. However, in the presence of technology shocks there could be exit in equilibrium.

the efficient capital-labor ratio. The optimal profits tax depends on the relationship between the mark-up and the returns to specialization, whereas the labor tax bears the tax burden.

In the second case we assume that the government cannot differentiate monopoly profits from capital income and, as a result, both are taxed at the same rate. Hence, the government levies a corporate tax on any source of income generated by the firms. While Guo and Lansing (1999) consider the optimal corporate tax in an economy without entry and where the corporate tax is used by the government as an indirect way to tax the monopoly profits, in our case the government can indirectly control the firms' entry through the corporate tax. We find that the optimal corporate tax depends not only on the magnitude of the returns to specialization and the mark-up, but also on the fixed cost and the curvature degree of the production function. This curvature degree captures the trade-off between the fixed costs that society pays for the introduction of a new firm (business-stealing effect) and the productivity gains associated to the introduction of a new variety (complementary effect).

The third case assumes that the number of firms or varieties cannot be affected by the fiscal authority. In this scenario the number of firms is pinned-down by the zero-profit condition in the market equilibrium, which is taken as a constraint by the government. In comparison with the previous two cases, we find that the optimal capital income tax only depends on the returns to specialization. Surprisingly, in the absence of returns to specialization the implied value is zero. This result is consistent with some theoretical findings in the industrial organization literature (see Benassy, 1998, de Groot and Nahuis, 1998, or Jones and Williams, 2000), that show that when the returns to specialization are not present, a tax or a subsidy leads to a socially inefficient number of firms. Moreover, the optimal number or measure of firms is one, as in Judd (1997). However, the threat of endogenous entry makes the prescribed capital income tax to be zero instead of negative. Finally, we show when these results can be extended to the transition path.

The remainder of the paper is organized as follows. In the next section we describe the basic framework and derive the market equilibrium. In section 3 we compare the market allocation with the social optimum in order to identify the main source of inefficiencies. This comparison is useful to understand the trade-off's that the government faces when choosing the optimal policy, which is discussed in section 4, where we analyze the optimal fiscal policy depending on the fiscal instruments available to the government. Finally, section 5 concludes.

2. Market equilibrium

We consider an infinite-horizon production economy with imperfect competitive product markets. The government finances an exogenous stream of purchases by levying distortionary taxes. There is a unique final good Y which is produced by competitive firms through the following technology (as in Benassy, 1996)[6]:

$$Y = \left(z^{v(1-\eta)-\eta} \int_0^z x_i^{1-\eta} di \right)^{\frac{1}{1-\eta}}, \quad \eta \in [0,1)\,,\ v \in [0,1)\,, \tag{1}$$

where the inputs are a continuum of intermediate goods x_i, $i \in [0, z]$, being z the total number of intermediate goods at t. Since intermediate goods are not perfect substitutes, firms in the intermediate goods sector face a downward slopping demand curve which confers to them some degree of market power. Thus, η is the inverse of the elasticity of the demand for each intermediate good and measures the degree of market power. In a symmetric equilibrium, all the firms in the intermediate goods sector produce the same output level x and, thus, $Y = z^{v+1}x$. Then, the elasticity of output

[6] The time subscripts of the production side of the economy have been eliminated to keep notation simple.

with respect to the number of firms z is given by the "degree of returns to specialization" v, as in Ethier (1982). This parameter measures the degree to which society benefits from specializing production between a large number of intermediate goods z. As a result an increase in the variety of inputs improves the total factor productivity of the final goods technology. This formulation of the production function allows us to separate the effect of both the mark-up and the economies of scale in the optimal government policy. Since there is free entry in the intermediate goods sector, at the aggregate level the number of varieties z is determined by the zero profit condition. However, the representative firm in the final goods sector takes this value as given. From its profit maximization problem, given by

$$\max_{\{x_i\}} Pz^{\frac{v(1-\eta)-\eta}{1-\eta}} \left(\int_0^z x_i^{1-\eta} di \right)^{\frac{1}{1-\eta}} - \int_0^z p_i x_i di, \tag{2}$$

where p_i is the price of the ith intermediate good and P is the price of the final output, we obtain the inverse demand function for each intermediate input

$$x_i = \left(\frac{p_i}{P} \right)^{-\frac{1}{\eta}} z^{v\frac{(1-\eta)}{\eta}-1} Y. \tag{3}$$

At each period, in the intermediate goods sector new firms can enter and produce a new variety. Each firm produces at most one input for which it has market power. In order to operate, each firm has to pay a fixed cost $P\phi$ (measured in units of the final good). For sake of simplicity, we assume there is no capital depreciation. All the firms produce the intermediate good according to a constant returns to scale production function

$$x_i = F(k_i, l_i), \tag{4}$$

where k_i and l_i denote capital and labor input, respectively, for firm i. The technology is assumed to be strictly concave, C^2, and satisfies the Inada conditions. Each firm solves

$$\max_{\{k_i, l_i\}} \pi_i = (1 - \tau^\pi) [p_i x_i - r k_i - w l_i] - P\phi, \tag{5}$$

subject to the final goods sector demand, Eq.(3), and the production function, Eq.(4), where r is the rental price of capital, w is the wage rate and τ^π is a proportional tax on profits. The associated first-order conditions of the firm problem yield

$$r = p_i (1 - \eta) F_k (k_i, l_i), \tag{6}$$

$$w = p_i (1 - \eta) F_l (k_i, l_i). \tag{7}$$

We consider the symmetric equilibrium in which all the firms produce the same output $x_i = x$ with the same quantities of capital and labor, $k_i = k$ and $l_i = l$, set the same price $p_i = p$ and have the same profits $\pi_i = \pi$. The aggregate stock of capital is $K = zk$ and the aggregate employment is $L = zl$. Thus, in equilibrium, using Eq.(6) and Eq.(7), we can write the interest rate and the wage as a function of total employment and capital[7]

$$r = p (1 - \eta) F_K (K, L), \tag{8}$$

$$w = p (1 - \eta) F_L (K, L). \tag{9}$$

[7]Note that the homogeneity of degree one of the production function implies that the partial derivatives are homogenous functions of degree zero. Therefore, $z_t^{v+1} F(k_t, l_t) = z_t^v F(K_t, L_t)$ and $F_j(k,l) = F_j(zk, zl) = F_j(K, L)$ for $j = K, L$.

Moreover, at the symmetric equilibrium, the final output is equal to

$$Y = z^{v} F(K, L), \tag{10}$$

and the price, by substituting Eq.(4) and Eq.(10) into Eq.(3), is

$$P = p z^{-v}. \tag{11}$$

The free entry assumption, for which each intermediate firm makes zero after-tax profits, i.e. $\pi = 0$, endogenously determines the equilibrium number of firms. Therefore,

$$\frac{(1-\tau^{\pi}) p \eta F(K, L)}{z} = P\phi. \tag{12}$$

From Eq.(11) and Eq.(12), the total number of firms is equal to

$$z = \left[\frac{(1-\tau^{\pi}) \eta F(K, L)}{\phi} \right]^{\frac{1}{1-v}}. \tag{13}$$

Since the final cost is defined in terms of the final output, the entry of any firm reduces the relative price between the final output and the intermediate goods $P/p = z^{-v}$, and thus makes entry more profitable. Finally, we consider as the numéraire the final good and normalize its price to one, $P = 1$. Hence, the relative price of the intermediate goods becomes $p = z^{v}$.

The entry of new firms can be interpreted as R&D in the production of new inputs, which increases the total productivity of the economy, as in the endogenous growth literature. However, our specification of the final goods production function, based on Benassy (1996), differs from the conventional endogenous growth model of Romer (1996). While Benassy (1996) shows that the market equilibrium can generate too much innovation or entry (the number of intermediate goods z is higher than in the social optimum equilibrium), the resources devoted to R&D are inefficiently low in the models based on the Romer framework.[8] Therefore, we can have two possible situations: in the first the government has to subsidize the entry of new firms in order to foster innovation, whereas in the second situation the government has to tax profits in order to restrict the entry of new firms, since the entry of new firms represents a social waste of resources. Note that in our model we obtain the standard formulation where $p = P$ when $v = 0$. In particular, the model used by Judd (1997) corresponds to the particular case of $v = 0$ and $\phi = 0$, where the total number of firms is fixed and normalized to one, $z_t = 1$ for all t. In this particular formulation aggregate returns to specialization are absent.

We consider a stand-in consumer that each period chooses consumption c_t, savings s_{t+1}, and the allocation of their one unit of time endowment between work L_t, and leisure $(1 - L_t)$. We assume there is no population growth. Formally, the consumers solve

$$V(s_0) = \max_{\{c_t, L_t, s_{t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t U(c_t, L_t) \tag{14}$$

$$s.to \quad c_t + s_{t+1} = w_t(1-\tau_t^{l}) L_t + s_t \left[1 + r_t(1-\tau_t^{k}) \right] + \Pi_t + T_t^{c}, \tag{15}$$

$$c_t \geq 0, \; L_t \in [0, 1], \; s_{t+1} \geq -B$$

[8] The standard formulation generally assumed in most of the endogenous growth and international trade literatures corresponds with the case of $v = \eta/(1-\eta) < 1$, where there exists a one-to-one relationship between the market power and the degree of returns to specialization.

where τ_t^k and τ_t^l are the taxes on capital income and labor, respectively, T_t^c is a lump-sum tax/transfer and Π_t denotes aggregate profits. However, we know that in equilibrium $\Pi_t = 0$. The utility function $U(\cdot)$ is strictly concave, C^2, and satisfies the usual Inada conditions. We assume that B is a large positive constant that prevents Ponzi schemes. The solution to the consumer problem yields the standard first-order conditions

$$U_{c_t} = \beta U_{c_{t+1}} \left[1 + r_{t+1}(1 - \tau_{t+1}^k)\right], \tag{16}$$

$$-\frac{U_{L_t}}{U_{c_t}} = w_t(1 - \tau_t^l), \tag{17}$$

together with a transversality condition for the savings. The equilibrium in the capital market is given by

$$s_{t+1} = K_{t+1} + D_{t+1}, \tag{18}$$

where D_{t+1} denotes one-period government debt. Besides, the equilibrium in the output market yields

$$c_t + K_{t+1} - K_t + G_t = z_t^v F(K_t, L_t) - \phi z_t, \tag{19}$$

where G_t denotes the period government expenditure and the equilibrium number of firms is given by Eq.(13). Combining the consumer budget constraint with the aggregate resource constraint, the free-entry condition and Eq.(18), we can derive the government budget constraint. Next, we define the notion of market equilibrium of the described economy.

Definition 1 (Market equilibrium): *Given a tax policy $\psi = \left\{\tau_t^\pi, \tau_t^l, \tau_{t+1}^k, T_t^c, D_t\right\}_{t=0}^\infty$, government expenditure $\{G_t\}_{t=0}^\infty$, and the initial conditions K_0 and D_0, a market equilibrium is a set of plans $\{c_t, L_t, K_{t+1}, z_t\}_{t=0}^\infty$ satisfying 1) the household problem, 2) the firm problem in both sectors, and 3) the market clearing conditions.*

The following conditions are satisfied in the market equilibrium:

$$-\frac{U_{L_t}}{U_{c_t}} = z_t^v (1-\eta) F_L(K_t, L_t)(1 - \tau_t^l), \tag{20}$$

$$\frac{U_{c_t}}{\beta U_{c_{t+1}}} = 1 + z_{t+1}^v (1-\eta) F_K(K_{t+1}, L_{t+1})(1 - \tau_{t+1}^k), \tag{21}$$

together with the free entry condition (13) and the resource constraint (19). In this economy the optimal fiscal policy is a sequence of taxes and government debt $\widehat{\psi} = \{\widehat{\tau}_t^\pi, \widehat{\tau}_t^l, \widehat{\tau}_{t+1}^k, \widehat{T}_t^c, \widehat{D}_t\}_{t=0}^\infty$ associated with a market equilibrium that yields the highest level of utility to the representative consumer. In the presence of lump-sum taxes and transfers it is well-known that the government can achieve Pareto efficient allocations. The scope of this paper is to study the optimal fiscal policy when these transfers are not available. However, the analysis of the first-best policy is useful to illustrate the trade-offs that the government faces when is restricted to use distortionary taxes, and show the different inefficiencies introduced by the monopolistic competition sector.

3. Social optimum and first-best policy

Next, we show that the outcomes in the decentralized economy are not Pareto efficient. We can asses Pareto optimality by comparing the market allocation and the social optimum. The social planner can control the number of firms in the intermediate goods sector. Thus, the planner faces a trade-off between the fixed costs that society pays for the introduction of a new firm and the productivity gains associated to the introduction of a new variety.

The social planner takes as given the sequence of public expenditure $\{G_t\}_{t=0}^{\infty}$ and the initial level of the capital stock K_0. For a symmetric allocation across intermediate goods, the social planner solves

$$V(K_0) = \max_{y} \sum_{t=0}^{\infty} \beta^t U(c_t, L_t) \tag{14}$$

$$s.to \quad c_t + K_{t+1} - K_t + G_t = z_t^v F(K_t, L_t) - \phi z_t, \qquad \forall t, \tag{19}$$

and the usual non-negativity constraints $c_t \geq 0$ and $L_t \in [0,1]$, where $y = \{c_t, L_t, K_{t+1}, z_t\}_{t=0}^{\infty}$. The associated first-order conditions yield

$$-\frac{U_{L_t}}{U_{c_t}} = z_t^v F_L(K_t, L_t), \tag{22}$$

$$\frac{U_{c_t}}{\beta U_{c_{t+1}}} = 1 + z_{t+1}^v F_K(K_{t+1}, L_{t+1}), \tag{23}$$

$$U_{c_t}\left[v z_t^{v-1} F(K_t, L_t) - \phi\right] = 0, \tag{24}$$

together with a transversality condition for the capital and the economy resource constraint. Eq.(24) notes that the increase in the total factor productivity due to an increase in z_t, $v z_t^{v-1} F(K_t, L_t)$, which represents the marginal social benefit of a new firm, must be equal to the entry cost ϕ, which represents the marginal social cost of the new entry. Rearranging this equation we obtain an explicit expression for the efficient number of firms,

$$z_t = \left[\frac{vF(K_t, L_t)}{\phi}\right]^{\frac{1}{1-v}}, \quad v > 0. \tag{25}$$

Note that when $v = 0$ we have a corner solution, where the entry of a new firm does not increase the productivity of the final goods sector but duplicates the fixed costs. Therefore, the optimal government policy is to allow only one (normalized) firm in the market, $z = 1$.

Next, we use the social planner solution to asses the efficiency of the market allocation. First, we analyze the price-marginal cost distortion or mark-up distortion. An inspection of Eq.(20) and Eq.(22) reveals that the monopoly power in the intermediate goods sector reduces the wage below the marginal productivity of labor. Hence, there is a distortion in the household labor/consumption decision. At the same time, capital is paid below its marginal productivity, as the comparison of Eq.(21) and Eq.(23) shows, and therefore there is a distortion in the intertemporal household decision. Under monopolistic competition, the mark-up distortion does not depend on the number of firms in the market. Hence, even though we are in the case where z has been set at the social planner level, capital and labor are not paid according to its marginal productivity. Thus, the government can attain a Pareto efficient allocation by choosing

$$\tau_t^k = \tau_t^l = -\eta/(1-\eta), \qquad \forall t. \tag{26}$$

The subsidies, which depend only on the mark-up magnitude, ensure that the private return and the social return coincide and then, as in Judd (1997), the distortion on capital accumulation generated by the monopoly power is effectively eliminated.

There exists a second distortion: the market equilibrium can generate an inefficient level of firms, since when a firm has to decide if entering into the market, it only considers if the monopoly profits are higher than the fixed cost, and it ignores the productivity gains generated by the introduction of a new intermediate good. Hence, the private benefits from entry (monopoly profits) can be different than the social benefits (productivity increase). In contrast with the social planner's choice in Eq.(25), the market allocation for z in Eq.(13) is divided by η instead of v. The introduction of a new firm in the market is determined by two opposite effects: a complementary effect and a business-stealing effect. The complementary effect arises from the fact that a new firm in the market raises the demand by increasing the productivity in the final goods sector. Then, since profits increase relative to the fixed cost, entry becomes more profitable. The complementary effect tends to generate an inefficiently low number of firms, since firms do not take into account the positive effect on the total productivity when they enter into the market. The business-stealing effect is due to the fact that the existing firms in the market have to share the demand with the new firm although this new firm produces a differentiated product and it does not compete directly with the incumbent firms. Therefore, individual profits decline with the number of firms. The business-stealing effect tends to produce an excessive entry of firms, since new firms enter into the market attracted by high profits but they do not take into account the negative effect on the incumbent firms. Then, if the government does not control the entry, the market could generate a number of firms too low (high) relative to the social optimum when monopoly profits are too low (high). Therefore, by comparing Eq.(13) and Eq.(25), the Pareto efficient allocation implies setting[9]

$$\tau_t^\pi = (\eta - v)/\eta, \qquad \forall t. \tag{27}$$

The profits tax can be positive, negative or zero, depending on the relationship between the mark-up and the returns to specialization. When these returns are strong enough, then entry is insufficient and it is better to subsidize profits since the increase in the productivity of the economy due to a new firm offsets the fixed cost. When the returns to specialization are low enough, there is excessive entry and a positive profits tax results. When both the mark-up and the returns to specialization coincide, free market entry is optimal. Note that the profits tax does not depend on the other taxes, which means that the tax distortions do not matter when the R&D has to be set.

One of the main problems with the analysis of the previous cases is that it relies on the existence of lump-sum taxation. In reality governments are far from having access to this class of instruments, so that they must rely on distortionary taxes. As a result, governments have to prioritize the distortions when choosing the optimal fiscal policy.

4. Optimal taxation and second-best policy

In this section we state and solve the government problem. Then, we characterize the optimal fiscal policy. Since the optimal fiscal policy depends on the set of instruments available to the government, we consider three different cases. In the first, the government disposes of a complete set of fiscal instruments and, therefore, it can directly control entry through the profits tax. In the second case, the government has to apply the same marginal tax to both the capital income and the monopoly profits. In this case the government can indirectly control the entry through a corporate tax. And in the third case, we assume that the number of firms cannot be affected by authority.

[9] The government can also implement the optimal level of varieties by introducing a lump-sum tax/subsidy for the firm (measured in units of the final good) $P_t T_t^x$. In this case, the optimal tax is

$$T_t^x = \phi\left(\frac{\eta}{v} - 1\right), \qquad v > 0,$$

and $\tau_t^\pi = 0 \ \forall t$. The sign of this instrument also depends on the relation between η and v. Note that when $v = 0$, then $T_t^x = \eta F(K, L) - \phi$.

In order to solve the government problem we use the primal approach of optimal taxation proposed by Atkinson and Stiglitz (1980). This approach is based on characterizing the set of allocations that the government can implement for a given fiscal policy $\psi = \{\tau_t^\pi, \tau_t^l, \tau_{t+1}^k, D_t\}_{t=0}^\infty$. The market equilibrium or the set of implementable allocations is described by the period resource constraints, the equilibrium entry condition and the so-called implementability constraints. The implementability constraints are the households' present value budget constraint, after substituting in the first-order conditions of the consumers' and the firms' problems. These constraints capture that changes in the tax policy have an effect on agents' decisions and prices. Thus, the government problem is to maximize its objective function over the set of implementable allocations. This is called the Ramsey allocation problem. From the optimal allocations we can decentralize the market economy finding the prices and the optimal fiscal policy.

Next, we define the set of implementable allocations and establish the equivalence to the definition of market equilibrium given in section 2. The derivation of the set of implementable allocations is described in the Appendix.

Definition 2 (Set of implementable allocations): *The set of implementable allocations is characterized by Eq.(13), Eq.(19) and the implementability constraint*

$$\sum_{t=0}^{\infty} \beta^t (c_t U_{c_t} + L_t U_{L_t}) = U_{c_0} \left[1 + z_0^v (1-\eta) F_K (K_0, L_0) (1 - \tau_0^k)\right] (K_0 + D_0). \tag{28}$$

The set of implementable allocations depends on the policy variables $\{\tau_t^\pi\}_{t=0}^\infty$ and the allocation $y = \{c_t, K_{t+1}, L_t, z_t\}_{t=0}^\infty$.

Proposition 1: *An allocation in the market equilibrium $y = \{c_t, K_{t+1}, L_t, z_t\}_{t=0}^\infty$ satisfies the set of implementable allocations. Moreover, if an allocation $y = \{c_t, K_{t+1}, L_t, z_t\}_{t=0}^\infty$ is implementable, then we can construct a fiscal policy $\psi = \left\{\tau_{t+1}^k, \tau_t^l, \tau_t^\pi, D_{t+1}\right\}_{t=0}^\infty$ and prices $\{r_t, w_t\}_{t=0}^\infty$, such that the allocation together with prices and the policy ψ constitute a market equilibrium.*

Proof: See the Appendix.

It is well-known that the government has an incentive to heavily tax the initial wealth of the consumer. This policy amounts to a nondistortionary lump-sum tax and, as a result, the Lagrange multiplier of the implementability constraint would be zero. Given that we already have characterized the first-best policy, we assume that the initial capital income tax τ_0^k is given.

4.1. Profits tax

In the present formulation we assume that the government uses a tax on variable profits to control the number of firms in the intermediate goods sector. As a result the choice of τ_t^π can determine directly the number of firms z_t and, then, the government will set a subsidy in case of an insufficient entry or a positive tax in case of an excessive entry. Using this fact we can reduce the number of choice variables in the government problem by substituting the zero profit condition, Eq.(13), into the aggregate resource constraint, Eq.(19), to obtain

$$c_t + K_{t+1} - K_t + G_t = F(K_t, L_t)^{\frac{1}{1-v}} \left[1 - \eta(1 - \tau_t^\pi)\right] \left(\frac{\eta(1 - \tau_t^\pi)}{\phi}\right)^{\frac{v}{1-v}}. \tag{29}$$

Given that the tax on variable profits, τ_t^π, only appears in the aggregate resource constraint, the optimal tax can be solved independently of the other allocations. The associated first-order condition is

$$\eta(1-\tau_t^\pi)^{\frac{v}{1-v}} - [1-\eta(1-\tau_t^\pi)]\,(\frac{v}{1-v})(1-\tau_t^\pi)^{\frac{v}{1-v}-1} = 0, \tag{30}$$

and rearranging terms we obtain the optimal tax [10]

$$\widehat{\tau}_t^\pi = (\eta - v)/\eta, \qquad v > 0. \tag{31}$$

Note that when $v=0$, then $\widehat{\tau}_t^\pi = 1-\phi/\eta F(K_t, L_t)$.

Substituting the optimal tax on variable profits into the free-entry condition in the market equilibrium, we obtain that the government can implement the Pareto efficient number of firms with a tax/subsidy in the intermediate goods production. As long as $v<\eta$ it is optimal to tax the variable profits in the intermediate goods sector, $\widehat{\tau}^\pi > 0$. When $v>\eta$ the efficient decentralization implies a subsidy. When there exists a one-to-one relationship between the market power and the degree of specialization, i.e. $v=\eta/(1-\eta)$, the efficient tax on variable profits is $\widehat{\tau}^\pi = -\eta/(1-\eta) < 0$.

The optimal policy implies that if the government can tax/subsidize the variable profits in the intermediate goods sector, this instrument can be used to implement the efficient number of varieties $\widehat{z}_t = [vF(K_t, L_t)/\phi]^{\frac{1}{1-v}}$. When there is no profits tax, the market equilibrium number of firms is $z_t = [\eta F(K_t, L_t)/\phi]^{\frac{1}{1-v}}$, which shows that the government optimally sets the number of firms having into account only the productivity gains associated to the introduction of a new variety. Therefore, as long as this instrument is available we can ignore the choice of z_t in the government problem.

Definition 3 (Ramsey allocation problem): *Given a sequence of government expenditure $\{G_t\}_{t=0}^\infty$, a sequence of firms $\{\widehat{z}_t\}_{t=0}^\infty$, and the initial conditions $\{\tau_0^k, K_0, D_0\}$, the allocations associated to the optimal fiscal policy ψ are derived by solving*

$$V(K_0, D_0, \tau_0^k) = \max_{\{c_t, K_{t+1}, L_t\}_{t=0}^\infty} \sum_{t=0}^\infty \beta^t U(c_t, L_t) \tag{14}$$

$$s.to \qquad \sum_{t=0}^\infty \beta^t (c_t U_{c_t} + L_t U_{L_t}) = U_{c_0}(K_0 + D_0)\left[1 + z_0^v(1-\eta)F_K(K_0, L_0)(1-\tau_0^k)\right], \tag{28}$$

$$c_t + K_{t+1} - K_t + G_t = \widehat{z}_t^v F(K_t, L_t) - \phi \widehat{z}_t, \qquad \forall t, \tag{19}$$

where $c_t \geq 0$ and $L_t \in [0,1]$.

Let λ and α_t be the Lagrange multiplier of the implementability constraint and the resource constraint, respectively. The first-order conditions of the government problem with respect to $\{c_t, L_t, K_{t+1}\}$ are [11]

$$\beta^t\left[U_{c_t} + \lambda\left(U_{c_t} + c_t U_{c_t c_t} + L_t U_{L_t c_t}\right)\right] - \alpha_t = 0, \tag{32}$$

$$\beta^t\left[U_{L_t} + \lambda\left(U_{L_t} + L_t U_{L_t L_t} + c_t U_{c_t L_t}\right)\right] + \alpha_t \widehat{z}_t^v F_L(K_t, L_t) = 0, \tag{33}$$

[10] From now on a hat denotes optimality.

[11] Throughout the paper we assume that the solution of the Ramsey allocation problem exists and converges to an unique steady-state. Neither of these assumptions are innocuous. The sufficient conditions for an optimum involve third derivatives of the utility function. Therefore, the solution might not represent a maximum, or the system might not have a solution because it does not exist a feasible policy that satisfies the intertemporal government budget constraint. However, if the solution to the government problem exists and is interior, it satisfies the above first-order conditions. Hence, the optimal tax analysis applies only to these cases.

$$-\alpha_t + \alpha_{t+1}[1 + \widehat{z}^v_{t+1} F_K (K_{t+1}, L_{t+1})] = 0, \tag{34}$$

together with a transversality condition for the capital, the period resource constraint and the implementability constraint. Note that $\lambda(c_t U_{c_t m_t} + L_t U_{L_t m_t})$ for $m_t = c_t, L_t$, measures the effect of the distortionary taxes on the utility function. In particular, it can be interpreted as the amount that the households would be willing to pay in order to replace one unit of distortionary tax revenue by one unit of lump-sum revenue, all measured in terms of the consumption good at time zero. If the implementability constraint does not bind, then $\lambda = 0$ and the government problem collapses into the social planner problem. The resulting allocation can be decentralized as a market equilibrium if the government has access to lump-sum taxation.

It is straightforward to find the optimal tax on capital income in the long-run. From the first-order conditions of the government problem, Eq.(32) and Eq.(34), evaluated in steady-state, we find

$$\frac{1}{\beta} = 1 + z^v F_K(K, L). \tag{35}$$

By comparing this condition with that of the market equilibrium, Eq.(21), evaluated in steady-state, we find the optimal capital income tax for $v \geq 0$, $\widehat{\tau}^k = -\eta / (1 - \eta)$. The next Proposition summarizes these results.

Proposition 2: *When a tax on variable profits is available to the government, then,*
1) the sign of the optimal capital income tax in steady-state is negative regardless of the returns to specialization.
2) the optimal profits tax is constant and its sign depends on the relationship between the mark-up and the returns to specialization.

The optimal capital income tax in steady-state is negative regardless of the relative magnitude of the returns to specialization with respect to the mark-up. The government faces a trade-off between the business-stealing effect and the complementary effect, i.e. the fixed costs that society pays for the introduction of a new firm and the productivity gains associated to the introduction of this new variety. Since the government can control the entry of firms without distorting any individual or firm decision, the degree of returns to specialization does not have any impact on the capital income tax. By implementing the optimal capital income tax, the government recovers the efficient capital-labor ratio.[12] Note that the optimal profits tax coincides with the social planner profits tax. This implies that when the government decides to subsidize/tax R&D, it ignores the social cost of the labor tax (the capital-labor ratio is not distorted and the magnitude of the subsidy/tax does not depend on the labor tax distortion). Similarly to Diamond and Mirrlees (1971), the government searches for aggregate production efficiency. The fiscal system should allow the economy to be in the production frontier and then individual decisions among the possible combinations in the frontier are distorted.

Except for the endogenous entry of firms $\widehat{z}^v_t$, the first-order conditions for the government problem in the economy with imperfectly competitive markets yield the same conditions as an economy

[12] If we assume that the tax on variable profits is not available to the government, but the number of firms in the intermediate goods sector can be directly controled by setting a tax τ^x_t on intermediate production x, then the steady-state optimal policy implies

$$\widehat{\tau}^x = \frac{\eta - v}{\eta}, \qquad v > 0,$$

$$\widehat{\tau}^k = [(1-\eta)\, v - \eta] \,/\, (1-\eta)\, v, \qquad v > 0,$$

and when $v = 0$ then $\widehat{\tau}^x = 1 - \phi/\eta F(K, L)$ and $\widehat{\tau}^k = 1 - \eta F(K, L)/(1-\eta)\,\phi$. In fact, the government uses the tax on output to efficiently set the number of varieties and after uses the capital income tax to efficiently set the capital level by correcting the distortion due to the tax on output, so that $(1 - \widehat{\tau}^k)(1 - \widehat{\tau}^x) = 1/(1-\eta)$.

with perfect competition. As a result we can extend some of the results of the uniform commodity tax literature (see Atkinson and Stiglitz, 1980). An inspection of the first-order conditions gives some insight about the requirements that the utility function needs to satisfy in order to have constant taxes from $t > 1$.

Corollary 1: *For the class of utility functions that are additively separable (across time and goods) and homothetic with respect to consumption and hours worked, the optimal policy from $t > 1$ prescribes constant taxes.*

Proof of Corollary 1: See the Appendix.

An example of utility function that satisfies this property is

$$U(c_t, L_t) = \frac{c_t^{1-\sigma}}{1-\sigma} - \frac{L_t^{1+\varphi}}{1+\varphi}. \tag{36}$$

4.2. Corporate tax

In the next case, we assume that the government cannot distinguish between capital income and profits. Therefore, both taxes have to be the same in all periods, $\tau_t^k = \tau_t^\pi \ \forall t$. We call them corporate tax, τ_t^c. Guo and Lansing (1999) consider the optimal corporate tax when the number of firms is fixed and where the corporate tax is used by the government as an indirect way to tax the economic rents or monopoly profits. In our case, since profits determine the number of firms in the market and thus the productivity of the economy, the government uses the corporate tax to indirectly set the measure of firms z_t. In contrast with Judd (1997), we find that the optimal corporate tax depends on several variables, as the returns to specialization, the mark-up and the fixed costs, but more importantly on the curvature degree of the production function.

The restriction on the set of instruments that the government can use takes the form of additional constraints on the Ramsey allocation problem. In this case, by substituting the tax from Eq.(21) into the zero profit condition, we obtain the following new constraint for an allocation to be implementable,

$$\left(\frac{U_{c_{t-1}}}{\beta U_{c_t}} - 1\right)\left(\frac{\eta}{\phi(1-\eta)}\right) F\left(K_t, L_t\right) = z_t F_K\left(K_t, L_t\right). \tag{37}$$

From the government perspective, the tax distortion due either by the returns on savings or by the introduction of a new firm has to be the same. In the Appendix it is shown that, from the government optimal conditions, the following condition is satisfied in steady-state:

$$\frac{1}{\beta} - 1 = z^v F_K\left[v + 1 - v\varepsilon - \frac{(1-\varepsilon)(1-\tau^c)\eta}{\phi}\right], \tag{38}$$

where $\varepsilon = \varepsilon_{F_K,K}/\varepsilon_{F,K} = \left(F_{KK}K/F_K\right)/\left(F_K K/F\right) < 0$ is the inverse ratio between the elasticities of the production function and of the marginal productivity of capital with respect to the capital, and represents the curvature degree of the production function. Combining this equation with Eq.(21) evaluated in steady-state, we find the optimal corporate tax, $\widehat{\tau}^c = \left[\eta\left(1-\varepsilon-\phi\right) - \phi v(1-\varepsilon)\right] / \left[\phi + \eta\left(1-\varepsilon-\phi\right)\right]$. The next Proposition summarizes this result.

Proposition 3: *When the government cannot differentiate between capital income and profits, then the sign of the optimal corporate tax in steady-state is positive [negative] whenever $v <$*

$\eta\left(1-\varepsilon-\phi\right)/\phi(1-\varepsilon)$ $[v>\eta\left(1-\varepsilon-\phi\right)/\phi(1-\varepsilon)]$.

When profits and capital income taxes cannot be different, the government faces a trade-off between eliminating distortions associated to the market power and determine the efficient level of entry. In general, we find that the optimal corporate tax can be positive, negative or zero. It depends on the relative magnitude of the returns to specialization with respect to the mark-up, the fixed cost and the curvature degree of the production function. If the fixed cost or the returns to specialization are big enough, the government lowers the corporate tax in order to promote the entry of new firms. The curvature degree of the production function shows the trade-off that the government faces between the fixed costs that society pays for the introduction of a new firm (business-stealing effect) and the productivity gains associated to the introduction of a new variety (complementary effect).

Note that $\widehat{\tau}^c$ is always lower than one. When there are no returns to specialization, $v=0$, then $\widehat{\tau}^c>0$ if $-\varepsilon>\phi-1$. Next, we illustrate the case of a Cobb-Douglas production function.

Corollary 2: *If the production function is $F\left(K,L\right)=K^uL^{1-u}$, where u is the production elasticity with respect to the capital, then $(1-\varepsilon)=1/u$ and therefore the steady-state corporate tax is positive $\widehat{\tau}^c>0$ if either $v<\eta\left(1-u\phi\right)/\phi$ or if $u<1/\phi$ and $v=0$.*

4.3. Government cannot control entry-decisions

An alternative formulation to the government problem, the third case, assumes that the number of firms or varieties cannot be affected by the fiscal authority. This is an extreme case, but it helps to understand the previous results. Since the government cannot tax profits, i.e. $\tau_t^\pi=0$ $\forall t$, the zero profit condition without taxes becomes a constraint for an allocation to be implementable,

$$\eta z_t^{v-1}F\left(K_t,L_t\right)=\phi, \tag{39}$$

and combining it with the aggregate resource constraint we have

$$c_t+K_{t+1}-K_t+G_t=(1-\eta)F\left(K_t,L_t\right)^{\frac{1}{1-v}}\left(\frac{\eta}{\phi}\right)^{\frac{v}{1-v}}. \tag{40}$$

In this formulation the government treats z_t as an exogenous variable. However, it knows that it can affect the measure of firms by changing the aggregate level of output, but it has to bear a cost in terms of utility by modifying the consumption and leisure paths.

Let λ and α_t be the Lagrange multiplier associated to the implementability constraint and the new resource constraint, respectively. Then, the associated first-order conditions with respect to $\{c_t,L_t,K_{t+1}\}$ are

$$\beta^t\left\{U_{c_t}+\lambda[U_{c_t}+c_tU_{c_tc_t}+L_tU_{L_tc_t}]\right\}-\alpha_t=0, \tag{41}$$

$$\beta^t\left\{U_{L_t}+\lambda[U_{L_t}+L_tU_{L_tL_t}+c_tU_{c_tL_t}]\right\}+\alpha_t\frac{(1-\eta)}{(1-v)}z_t^vF_L\left(K_t,L_t\right)=0, \tag{42}$$

$$-\alpha_t+\alpha_{t+1}[1+\frac{(1-\eta)}{(1-v)}z_{t+1}^vF_K\left(K_{t+1},L_{t+1}\right)]=0. \tag{43}$$

It is straightforward to find the optimal tax on capital income. From the first-order conditions of the government problem evaluated in steady-state we have

$$\frac{1}{\beta}=1+\frac{(1-\eta)}{(1-v)}z^vF_K(K,L), \tag{44}$$

and comparing this condition with Eq.(21) evaluated in steady-state, we obtain the optimal capital income tax $\widehat{\tau}^k = -v/(1-v)$. The next Proposition summarizes this result.

Proposition 4: *When the government cannot control entry-decisions, then the sign of the optimal capital income tax in steady-state is negative regardless of the magnitude of the mark-up. Nevertheless, when $v = 0$ the optimal capital income tax is zero.*

The optimal capital income tax does not depend on the magnitude of the mark-up, as in the case where the government can tax profits. Since the government cannot control firms' entry, it uses the capital income tax to correct partially the effects of the returns to specialization. Consequently, the magnitude of the mark-up does not have any impact on the capital income tax.

One particular case deserves special attention. In the absence of aggregate returns to specialization, $v = 0$, it is optimal not to subsidy/tax the investment decisions of the intermediate goods firms. For this case, the introduction of a new firm only has negative consequences: a business-stealing effect associated to the new entry, which translates into a social waste of resources by means of the fixed cost. As a result, the government tries to minimize the negative effects by only implementing one variety in equilibrium, $z = 1$, and hence the zero profit condition becomes $F(K_t, L_t) = \phi/\eta$. This condition is effectively an isoquant that determines the equilibrium level of output, and shows that the government cannot increase simultaneously capital and labor to achieve the efficient plant level without violating the entry condition. With a concave production function the government chooses not to subsidize capital, and place all the tax burden in labor income taxes. When z cannot be controlled, a capital subsidy/tax would lead to an inefficient capital-labor ratio. This result is rather surprising, because in equilibrium the optimal number or measure of firms is one, as in Judd (1997). However, the threat of endogenous entry makes the prescribed capital income tax to be zero instead of negative.

This finding is consistent with some theoretical findings in the industrial organization literature. When the government cannot control the entry decisions on a market and there are no returns to specialization, a tax or a subsidy leads to a socially inefficient number of firms since it increases the fixed costs; this is called inefficient economies of scale. This result proves to be more general because we are considering a dynamic general equilibrium analysis instead of a partial equilibrium. Finally, using the same arguments than in the Proof of Corollary 1, it is straightforward to extend the results of Proposition 4 to the transition path.

5. Conclusions

In recent papers, Judd (1997, 2002) has presented evidence in favor of a negative capital income tax. Using a representative-agent model with a fixed number of goods produced by monopolistic competitive firms, he finds that the optimal fiscal policy implies a negative capital income tax and a 100% tax rate on firms profits.

The main contribution of this paper is to show that, once we consider an endogenous number of firms or varieties, the optimal fiscal policy can lead to different results. In contrast with Judd (1997), we identify some additional sources and parameters that affect the sign of both the capital income tax and the profits tax, since the optimal fiscal policy affects the size of the intermediate goods sector. In particular, if we introduce both an index of market power and an index of returns to specialization, the government faces a trade-off between the fixed costs that the society pays for the introduction of a new firm and the productivity gains associated to this new variety. Both the optimal capital income tax and the optimal profits tax depend on the relationship between these two parameters and the fiscal instruments available to the government, because the government effectiveness to control the entry-exit of firms depends on them.

We consider three different cases. In the first case, the government disposes of a complete set of fiscal instruments and, therefore, it can directly control entry through the profits tax. We show that the optimal capital income tax is negative regardless of the relative magnitude of the returns to specialization with respect to the mark-up. However, the optimal profits tax depends on this relationship. In the second case, the government has to apply the same marginal tax to both the capital income and the monopoly profits. In this case, the government can indirectly control the firms' entry through a corporate tax. We find that the optimal corporate tax depends not only on the magnitude of the returns to specialization and the mark-up, but also on the fixed cost and the curvature degree of the production function. This curvature degree of the production function shows the trade-off that the government faces between the fixed costs that society pays for the introduction of a new firm and the productivity gains associated to this new variety. Finally, the third case assumes that the number of firms or varieties cannot be affected by authority. Under this restriction, we find that the optimal capital income tax does not depend on the magnitude of the mark-up but it does on the returns to specialization. The implied value is zero in the absence of returns to specialization or negative otherwise.

Appendix

Derivation of the set of implementable allocations: The implementability constraint can be derived as follows. Multiplying Eq.(17) by L_t we have

$$-L_t U_{L_t} = U_{c_t} w_t \left(1 - \tau_t^l\right) L_t. \tag{A.1}$$

Multiplying Eq.(15) by U_{c_t} and using Eq.(A.1) gives

$$c_t U_{c_t} + L_t U_{L_t} = s_t U_{c_t} \left[1 + r_t(1 - \tau_t^k)\right] - s_{t+1} U_{c_t}. \tag{A.2}$$

Multiplying Eq.(A.2) by β^t and adding up from $t = 0$ to $t = \infty$ yields

$$\sum_{t=0}^{\infty} \beta^t \left(c_t U_{c_t} + L_t U_{L_t}\right) = s_0 U_{c_0} \left[1 + r_0(1 - \tau_0^k)\right]$$

$$+ \sum_{t=0}^{\infty} \beta^t \left(\beta s_{t+1} U_{c_{t+1}} \left[1 + r_{t+1}(1 - \tau_{t+1}^k)\right] - s_{t+1} U_{c_t}\right). \tag{A.3}$$

Using Eq.(A.3), Eq.(8), Eq.(16) and Eq.(18) we obtain the implementability constraint.

Proof of Proposition 1: The first part of the proposition is always satisfied, since any market equilibrium allocation has to satisfy the resource constraint, the zero profit condition and the implementability constraint. Now we prove the second part of the proposition. Given an implementable allocation $\{c_t, K_{t+1}, L_t, z_t\}_{t=0}^{\infty}$, the market prices can be back out using Eq.(8), Eq.(9) and Eq.(11). The fiscal policy $\psi = \{\tau_{t+1}^k, \tau_t^l, \tau_t^\pi, D_{t+1}\}_{t=0}^{\infty}$ is recovered from Eq.(13), Eq.(16) and Eq.(17). The debt level is found from the market clearing condition in the capital markets, Eq.(18). Substituting U_{c_t} and U_{L_t} in the implementability constraint we obtain the consumer budget constraints. Finally, given the tax on capital income τ_{t+1}^k and the interest rate r_{t+1}, by arbitrage we find the return on government debt. If the resource constraint, the consumers budget constraints and the arbitrage condition are satisfied, then the government budget constraint is also satisfied.

Proof of Corollary 1: The class of utility functions that are additively separable (across time and goods) and homothetic with respect to consumption and hours worked satisfies

$$L_t U_{L_t L_t} + c_t U_{c_t L_t} = B U_{L_t}, \tag{A.4}$$

$$c_t U_{c_t c_t} + L_t U_{L_t c_t} = D U_{c_t}, \tag{A.5}$$

where B and D are different constants and separability between consumption and hours worked implies $U_{c_t L_t} = U_{L_t c_t} = 0$. In this case, the first-order conditions of the government problem can be written as

$$\frac{U_{c_t}}{\beta U_{c_{t+1}}} = 1 + \widehat{z}_{t+1}^v F_K\left(K_{t+1}, L_{t+1}\right), \tag{A.6}$$

and

$$-\frac{\left[1 + \lambda(1 + B)\right] U_{L_t}}{\left[1 + \lambda(1 + D)\right] U_{c_t}} = \widehat{z}_t^v F_L\left(K_t, L_t\right), \tag{A.7}$$

where λ is constant. Clearly, from the market equilibrium Eq.(21), we derive the optimal capital income tax

$$\widehat{\tau}_{t+1}^k = -\frac{\eta}{(1 - \eta)}. \tag{A.8}$$

From the consumption-labor decisions we can derive the optimal labor tax

$$1-\widehat{\tau}_t^l=\frac{[1+\lambda(1+D)]}{[1+\lambda(1+B)]}\frac{1}{(1-\eta)}. \tag{A.9}$$

For the example stated in Corollary 1 we have $D=-\sigma$ and $B=\varphi$, and clearly $D<B$. Note that λ, and therefore $\widehat{\tau}^l$, depends on the initial conditions K_0 and D_0. Both taxes are constant for $t>1$. At $t=1$, the first-order conditions contain additional terms.

Derivation of Eq.(38): Substituting Eq.(37) into the aggregate resource constraint, we obtain a new resource constraint,

$$c_t+K_{t+1}-K_t+G_t=$$
$$\left[\frac{\left(\frac{U_{c_{t-1}}}{\beta U_{c_t}}-1\right)\eta}{\phi(1-\eta)F_K(K_t,L_t)}\right]^v F(K_t,L_t)^{v+1}-\frac{\left(\frac{U_{c_{t-1}}}{\beta U_{c_t}}-1\right)\eta F(K_t,L_t)}{(1-\eta)F_K(K_t,L_t)}. \tag{A.10}$$

Let λ and α_t be the Lagrange multiplier of the implementability constraint and the new resource constraint, respectively. The first-order conditions of the government problem with respect to $\{c_t,L_t,K_{t+1}\}$, after substituting for Eq.(37), are

$$\beta^t\left[U_{c_t}+\lambda\left(U_{c_t}+c_tU_{c_tc_t}+L_tU_{L_tc_t}\right)\right]-\alpha_t\left(1+\left[\frac{U_{c_{t-1}}U_{c_tc_t}}{\beta U_{c_t}^2\left(\frac{U_{c_{t-1}}}{\beta U_{c_t}}-1\right)}\right]\left[vz_t^vF(K_t,L_t)-z_t\phi\right]\right)$$
$$+\alpha_{t+1}\left[\frac{U_{c_tc_t}}{\beta U_{c_{t+1}}\left(\frac{U_{c_t}}{\beta U_{c_{t+1}}}-1\right)}\right]\left[vz_{t+1}^vF(K_{t+1},L_{t+1})-z_{t+1}\phi\right]=0, \tag{A.11}$$

$$\beta^t\left[U_{L_t}+\lambda\left(U_{L_t}+L_tU_{L_tL_t}+c_tU_{c_tL_t}\right)\right]+\alpha_tz_t^v\left[(v+1)F_L(K_t,L_t)-v\frac{F(K_t,L_t)F_{KL}(K_t,L_t)}{F_K(K_t,L_t)}\right]$$
$$-\alpha_tz_t\left[\frac{F_L(K_t,L_t)}{F(K_t,L_t)}-\frac{F_{KL}(K_t,L_t)}{F_K(K_t,L_t)}\right]=0, \tag{A.12}$$

$$-\alpha_t+\alpha_{t+1}\left\{1+\left[z_{t+1}^vF_K(K_{t+1},L_{t+1})\right]\right.$$
$$\left.\left(v+1+\left[\frac{F(K_{t+1},L_{t+1})F_{KK}(K_{t+1},L_{t+1})}{F_K(K_{t+1},L_{t+1})F_K(K_{t+1},L_{t+1})}\right]\left[\frac{z_{t+1}^{1-v}}{F(K_{t+1},L_{t+1})}-v\right]-\frac{z_{t+1}^{1-v}}{F(K_{t+1},L_{t+1})}\right)\right\}=0. \tag{A.13}$$

Evaluating Eq.(A.12) in steady-state and dividing it by the same equation one period forward, we obtain that

$$\beta\alpha_t=\alpha_{t+1}. \tag{A.14}$$

Noting that $\varepsilon=\varepsilon_{F_K,K}/\varepsilon_{F,K}=(F_{KK}K/F_K)/(F_KK/F)<0$ and using Eq.(13) and Eq.(A.14), in steady-state Eq.(A.13) becomes Eq.(38).

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