Optimal Income Taxation under Monopolistic Competition*

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September 18, 2021

Abstract

This paper is concerned with cross-dependencies between endogenous market structure and tax policy. We extend the Mirrlees (1971) model of income taxation with a monopolistic competition framework with general additively separable consumer preferences. We show that price and variety distortions resulting from the market structure imply that income tax policy needs to be complemented with commodity or firm taxation to achieve the constrained social optimum. We calibrate the model and find that, when choosing optimal tax policy, the failure to account for the market structure results in a welfare loss of 1.77 percent. Motivated by practical cases, we study a policy regime that is solely based on income taxation. Under this policy regime, departures from the social optimum can be compensated by lower and less regressive income taxes than those obtained under the regime with all forms of taxation. We also examine the role of consumer preferences for policy outcomes and show that it is substantially amplified by an endogenous market structure.

JEL classification: D43, H21, L13
Keywords: tax policy, monopolistic competition, variety effect, consumer preferences, endogenous labor.

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1 Introduction

In the traditional approach to income tax policy design, the policy maker's redistributive and budgetary objectives are considered in isolation from the wider economy, which is taken as exogenously given. This approach has drawn criticism, most notably, from Atkinson (2012) who found the taxation literature to fail to take into account cross-dependencies between market structure and tax policy.[1] Income taxation may not only affect income distribution but also aggregate demand and, hence, product prices with implications for welfare. Furthermore, income taxation may also create a variety effect on welfare through the channel of market entry and exit. In this paper, we make a step forward in analyzing taxation policy by taking into account its effects on market outcomes in a general equilibrium model of monopolistic competition with general additively separable consumer preferences. The question addressed in this paper is also related to and motivated by the dual problem of achieving budgetary objectives and of rejuvenating economic activities that most governments faced in the aftermath of the Covid-19 pandemic.

In our paper, we endogenize the product space and prices in the Mirrlees (1971) model of optimal income taxation by extending it with the monopolistic competition framework of Dixit and Stiglitz (1977).[2] We study the public authority's problem of tax policy design to maximize the socially weighted welfare of a population of workers. A worker's utility is determined by her consumption of products and supply of labor. Workers differ in their intrinsic productivity, with less productive workers receiving a larger social weight. In the market equilibrium, the number of products and their prices are endogenously determined by the aggregate amount of labor exerted in the economy, the distribution of disposable income, consumer preferences for varieties, firms' profit-maximizing behavior, and free entry. We solve for the optimal tax policy while accounting for its effects on the market outcome.

In our analysis, we distinguish between two policy regimes. In the first regime, the government has at its disposal a full set of tax instruments consisting of income, commodity, and firm taxes. In the second regime, the government designs tax policy with only income taxes at its disposal. The first regime can be motivated by the example of Western European countries, where all forms of taxation play a sizable role in tax policy. The second regime can be motivated by the US example, where income taxation is the main instrument of tax policy. We compare the two regimes analytically and quantitatively, contributing to understanding why countries may select different tax policy paths. Note that instead of the dichotomy of regimes, we could only consider the regime with all forms of taxation with the regime of income taxation

[1]Recently, there has been a growing number of papers that study externalities of income taxation in general and partial equilibrium, which we discuss in Related Literature below.

[2]The monopolistic competition framework introduced by Dixit and Stiglitz (1977) is widely employed in many fields of economics, see Thisse and Ushchev (2018) for a literature review. The endogeneity of the product space also distinguishes our framework from Diamond and Mirrlees (1971).

replaced by the constraint that producer subsidies are not feasible. This alternative approach would yield conclusions similar to those obtained in the present paper.[3]

With general consumer preferences and endogenous labor supply, the monopolistic market structure implies market distortions associated with the variety effect due to inefficient market entry and with the price effect due to firms' noncompetitive price markups, which together result in inefficient labor supply. We demonstrate that income taxation and one additional tax instrument imposed on the product supply side can achieve the constrained social optimum characterized by public firm ownership. Specifically, the variety distortion is resolved by either commodity or firm taxes (or subsidies) aimed at correcting for inefficient market entry, whereas adjustments to income taxes resolve the price distortion related to noncompetitive markups. With only income taxes available, tax policy cannot resolve all market inefficiencies and, thus, achieve the constrained social optimum in the general case. For instance, in the event of market over-entry, the optimal income tax rates are increased in proportion to the effect of additional consumption on consumers' strength of preference for varieties but in reverse of tax reductions made to correct for non-competitive markups.

Using an Expo-Power utility function, which includes constant elasticity of substitution (CES) and constant absolute risk aversion (CARA) utility functions as special cases, we calibrate the model to explore quantitatively the welfare losses from the failure to account for the market structure in policy design and to compare the performance of different tax policy regimes. Our benchmark is the self-confirming policy equilibrium (SCPE) introduced by Rothschild and Scheuer (2013). This policy equilibrium is the solution to the standard Mirrlees (1971) problem with a market structure taken as given but in conformance with the market equilibrium conditions resultant from the SCPE allocation. We also use the SCPE benchmark to calibrate the parameters of the model.

We find that the failure to account for the market structure results in a welfare loss of 1.77 percent when all tax instruments are available and in 1.22 percent when only income taxation is available. The difference in the welfare outcomes between the two regimes can be attributed to market over-entry and higher markups which cannot be resolved by the means of income taxes only. We can also interpret this difference as a welfare loss if producer subsidies are not feasible, as in our quantitative analysis subsidies are found to be optimal. At the same time, tax policy based on income taxation can have advantages outweighing its under-performance in welfare comparison. In particular, we find that the optimal tax policy with commodity and income taxation requires a much bigger size of government and higher income tax rates at low incomes needed to pay for entry stimulating producer subsidies. In contrast, with income taxation as the only instrument, the size of the government as a share of total output needs to

[3] The constraint that producer subsidies are not feasible can be motivated by the presence of fraud risks, amply demonstrated, for example, by the UK Government's Covid-19 business support schemes (UK Parliament, 2021).

be smaller by about 10 percentage points and income tax rates are progressively reduced. From a different perspective, we do not obtain a "trickle down" effect where taxes are lowered for the rich to improve market outcomes for all. When preference for varieties becomes stronger with more consumption, lowering taxes for the rich can result in market over-entry accompanied by universally higher price markups, thus, hurting overall welfare. Further quantitative analysis shows that differences in economic outcomes between the policy regimes match the respective empirical differences between the US and European countries. In particular, we find that the optimal policy based on income taxation results in more market entry, lower income taxes, more labor supply, higher markups, smaller government, and more inequality compared to the optimal policy based on all tax instruments.

In our last quantitative exercise, we explore the role of consumer preferences for tax policy design by re-calibrating the model for CES and CARA utility functions. Consumer preferences can have a direct effect on tax policy design through behavioral response and an indirect effect through the market outcome. The SCPE benchmark with an exogenous market structure captures the direct effect and we observe that relative to the Expo-Power preferences the income tax schedule becomes more progressive for CARA preferences and less progressive for CES preferences. With an endogenous market structure, these differences are substantially amplified and, as a result, so are inaccuracies resulting from misspecified preferences, which further stresses the importance of market structure and consumer preferences on policy outcomes.

The remainder of this paper is organized as follows. After a literature review, we present the model in Section 2 and solve it for different policy regimes in Section 3. We conduct quantitative analysis in Section 4. The proofs of the theoretical results are provided in the Appendix.

Related Literature. There is a growing body of literature that deals with general and partial equilibrium effects of tax policy. The assumption of price taking behavior is invalidated if workers' occupational choice, including rent seeking activities, is endogenous as in Stiglitz (1982), Rothschild and Scheuer (2013, 2016), Ales et al. (2015), Lockwood et al. (2017), and Sachs et al. (2020). The externalities of adverse selection and moral hazard in labor markets and their effects on tax policy are studied by Golosov and Tsyvinski (2007), Chetty and Saez (2010), and Stantcheva (2014, 2017). Tax policy can create pecuniary externalities with implications for real wages due to its effects on aggregate demand and equilibrium prices (da Costa and Maestri, 2019; Kushnir and Zubrickas, 2019; Eeckhout et al., 2021; Kaplow, 2021). The distinctive feature of the present paper is its consideration of the variety effect under general additively separable consumer preferences that may offset the price effect of pecuniary externalities in tax policy design.

The role of additional varieties for consumer welfare has been the object of study in different strands of literature (Dixit and Stiglitz, 1977; Krugman, 1979; Romer, 1994; Broda and Weinstein, 2006; Arkolakis et al., 2008; Bilbiie et al., 2012). Welfare gains from product expansion can be decomposed into a direct variety effect and an indirect price effect arising from increased competition. Recent empirical studies find the welfare gain of each effect to be of equal size (Feenstra and Weinstein, 2017; Quan and Williams, 2018; also see Hausman and Leondard, 2002 and Brynjolfsson et al., 2003). This empirical finding suggests a role for the variety effect as important as that for the price effect in policy design. Besides the present paper, the variety effect is incorporated in policy design by Bilbiie et al. (2012, 2019), Bilbiie et al. (2014), Lewis and Winkler (2015), Colciago (2016), Etro (2018). Our paper differs from these papers in its study of optimal income tax policy in the Mirrleesian setting with heterogeneous population, imperfect information, and endogenous labor supply.

Our analysis also complements the commodity taxation literature. In the absence of firm profits, Atkinson and Stiglitz (1976) show that commodity taxation is unnecessary when optimal income taxes are employed under the assumption of weak separability of utility between labor and consumption goods (also see Mirrlees, 1976). Naito (1999) qualifies this result by showing its dependence on the assumption of constant marginal costs of production. For an encompassing treatment of income and commodity taxation, see Scheuer and Werning (2016). We further qualify the result of Atkinson and Stiglitz (1976) by showing that commodity taxes are zero only in the event of efficient market entry as in the case of CES preferences. Otherwise, commodity taxes are imposed to correct for inefficient market entry even when firm profits are zero and marginal costs of production are constant. The latter finding can be related to the production efficiency theorem of Diamond and Mirrlees (1971), when applied to the extensive margin of the product space. Finally, Myles (1987, 1989) demonstrate a role for corrective commodity taxation against noncompetitive markups, whereas our findings suggest that commodity taxation can be better suited for correcting inefficient entry and income taxes for correcting noncompetitive markups.

2 Model

We construct a model of one-sector monopolistic competition with homogeneous firms and heterogeneous consumers/workers who endogenously decide how many units of labor to supply. There is a unit continuum of workers indexed by productivity type n and distributed according to cumulative distribution $F(n)$ that has density function $f(n) > 0$ with support $[\underline{n}, \bar{n}]$. Worker n's earnings are given by $n\ell(n)$, where $\ell(n)$ is the amount of labor supplied by the worker. Disposable income is given by $y(n) = n\ell(n) - T(n\ell(n))$, where $T(n\ell(n))$ is a labor income tax function. The labor cost is captured by an increasing and convex function $c(\ell)$. There is a continuum of size N of differentiated varieties produced by homogeneous firms, with the consumer price of variety i denoted by p_i.

Worker n chooses consumption $q_i(n)$ of each variety i and labor $\ell(n)$ that maximize

$$U(n) = \max \int_0^N u(q_i(n))\, di - c(\ell(n)), \tag{1}$$

where u is a twice differentiable concave function, subject to the budget constraint

$$\int_0^N p_i q_i(n) di = y(n). \tag{2}$$

Denoting the Lagrange multiplier by $\kappa(n)$, we find the individual demand $q_i(n)$ from the first-order condition $u'(q_i(n)) = \kappa(n)p_i$ or $q_i(n) = (u')^{-1}(\kappa(n)p_i)$. The aggregate demand for variety i is equal to

$$Q_i \equiv \int q_i(n) dF(n) = \int (u')^{-1}(\kappa(n)p_i) dF(n).$$

Taking into account that the Lagrange multiplier $\kappa(n)$ represents the marginal utility of disposable income, the optimal labor supply is determined by $\kappa(n)n(1 - T'(n\ell(n))) = c'(\ell(n))$. In the symmetric case with $p_i = p$ and $q_i(n) = q(n) = y(n)/(Np)$, the optimal labor supply and consumption satisfy

$$\frac{u'(q(n))}{p} n(1 - T'(n\ell(n))) = c'(\ell(n)). \tag{3}$$

In the analysis below, we use the measure of the strength of preferences for varieties. Specifically, we follow Zhelobodko et al. (2012) to define a generalized *relative love for variety* as

$$\eta \equiv -\frac{Q}{\int \frac{u'(q(n))}{u''(q(n))} dF(n)}.$$

As argued by Zhelobodko et al. (2012) for the case of homogeneous population, when preferences feature an increasing (decreasing) relative love for variety in consumption q, consumers perceive varieties as less (more) differentiated when they consume more. This property follows from that the relative love for variety is inversely related to the elasticity of substitution between any given pair of varieties. We also denote uncompensated and compensated labor supply elasticity by ζ^u and ζ^c, respectively. To derive the labor supply elasticities, one needs to rewrite the individual budget constraint in the form $pNq = w\ell + R$, where $w = n(1 - T')$ is a net wage and R is virtual (non-labor) income. Then, the first-order condition (3) implicitly determines labor supply $\ell = \ell(w, R)$ for a given market structure. The uncompensated labor supply elasticity is determined by $\zeta^u = (d\ell/dw)(w/\ell)$ and the compensated labor supply elasticity is found from the Slutsky equation $\zeta^c = \zeta^u - \tau$, where $\tau = wd\ell/dR$ is the income effect. In the Appendix, we provide the exact formulas for labor supply elasticities.

Each variety i is produced by a single firm with the marginal and fixed cost of production equal to k and K, respectively. Letting s denote a unit tax/subsidy and S a lump sum entry tax/subsidy imposed on firm i, the firm's maximization problem can be expressed as

$$\max_{p_i} \Pi(p_i, Q_i) = (p_i - s - k)Q_i - S - K.$$

The first-order condition of profit maximization is given by

$$\eta = \frac{p - s - k}{p}, \tag{4}$$

which requires the price markup be equal to consumers' relative love for variety. Lastly, we assume free entry into the market, which implies non-negative profits or

$$(p - s - k)Q \geq K + S. \tag{5}$$

In sum, given the tax policy (T, s, S), the market outcome of the model is characterized by equations (2) and (3) for consumption and labor supply, (4) for price, and (5) for the number of varieties.

3 Government

We define social welfare W as a weighted sum of workers' utilities

$$W = \int \psi(n)U(n)dF(n), \tag{6}$$

where $\psi(n) > 0$ is a weight attached to a worker with productivity n with $\int \psi(n)dF(n) = 1$. The objective of the public authority is to design a tax policy that maximizes the social welfare subject to the market conditions (4), (5), and the tax revenue at least as large as the exogenous public expenditure of G. In addition, we impose that workers' productivity is their private information and, thus, cannot be conditioned upon. We will distinguish two main cases. In Subsection 3.1, we consider the case when the public authority has all three tax instruments (T, s, S) at its disposal, whereas in Subsection 3.2, we consider the case when only income taxation T is available for the public authority. For policy design, we use the benchmark of constrained social optimum where firm ownership is public but workers' productivity is their private information (the exact definition of constrained social optimum is provided in the Appendix).

To illustrate the role of monopolistic market structure for tax policy, it is useful to contrast the case of no government intervention ($(T, s, S) = \mathbf{0}$) with the first best. In the social optimum with symmetric information and public firm ownership, the optimal allocation of consumption and labor supply can be shown to have

$$\frac{u'(q(n))n}{k} = c'(\ell(n)), \tag{7}$$

whereas without government intervention it has from (3)

$$\frac{u'(q(n))n}{p} = c'(\ell(n)). \tag{8}$$

As price p is larger than marginal cost k, for given consumption $q(n)$ we have the undersupply of labor in the decentralized market, which implies less market entry and, thus, fewer varieties. On the other hand, for given labor supply $\ell(n)$, under standard assumptions about $u(q)$ there is less consumption of individual varieties and excessive market entry in the decentralized market (see Dixit and Stiglitz, 1977, and Dhingra and Morrow, 2019). As a redistributive tax policy can affect labor supply, the optimal tax policy needs to account for cross-dependencies between labor supply and market structure and resultant inefficiencies.

3.1 Optimal Tax Policy

In this subsection, we let the public authority have at its disposal the full set of instruments: income tax $T(n\ell(n))$, commodity unit tax s (or subsidy when $s < 0$), and entry tax S (or subsidy when $S < 0$). As the public authority observes only workers' labor income, by the Revelation Principle the optimal income tax policy must satisfy the incentive compatibility constraint for each productivity type. In our framework, this condition can be written as follows

$$U(n) = Nu\left(\frac{n\ell(n) - T(n\ell(n))}{Np}\right) - c(\ell(n)) \geq Nu\left(\frac{n'\ell(n') - T(n'\ell(n'))}{Np}\right) - c\left(\frac{n'\ell(n')}{n}\right) \tag{9}$$

for any n and n'. In words, a worker with productivity n does not seek the labor income of a worker with productivity n'. This in turn implies that the tax function satisfies

$$\frac{1 - T'(n\ell(n))}{p} nu'\left(\frac{n\ell(n) - T(n\ell(n))}{Np}\right) = c'(\ell(n)), \tag{10}$$

which is equivalent to the labor supply condition in (3). Using the envelope theorem, we have that

$$U'(n) = \frac{\ell(n)}{p} u'\left(\frac{n\ell(n) - T(n\ell(n))}{Np}\right)(1 - T'(n\ell(n)))$$

or, using (10), that

$$U'(n) = \frac{\ell(n)}{n} c'(\ell(n)). \tag{11}$$

In subsequent analysis, we will use the latter expression for the incentive compatibility condition.

As it is standard in the taxation literature, rather than solving for the optimal income tax policy $T(n\ell(n))$, we will solve for the optimal consumption and labor supply allocation, from which the optimal taxes can then be derived. For analytical convenience, we present the public authority's problem maximized over utility $U(n)$, labor $\ell(n)$, number of varieties N, price p with the consumption of each variety $q(n)$ then found from

$$q(n) = u^{-1}\left(\frac{U(n) + c(\ell(n))}{N}\right) \equiv r\left(U(n), \ell(n), N\right). \tag{12}$$

Taking into account the market equilibrium conditions and the incentive compatibility condition, the public authority solves the following optimization problem:

$$\max_{U(n),\ell(n),p,N,s,S} \int \psi(n)U(n)dF(n) \tag{13}$$

$$s.t. \begin{cases} U'(n) - \frac{\ell(n)}{n}c'(\ell(n)) = 0, & (\mu(n),\ \text{ICC}) \\ \int \{n\ell(n) - N(p-s)\, r(U(n), \ell(n), N)\}\, dF(n) + NS \geq G, & (\lambda,\ \text{resource constraint}) \\ (p-k-s)\int r(U(n), \ell(n), N)dF(n) - K - S \geq 0, & (\alpha,\ \text{free entry}) \\ \eta - \frac{p-k-s}{p} = 0. & (\beta,\ \text{optimal price}) \end{cases}$$

In characterizing the optimal tax policy, it is useful to introduce, following Dhingra and Morrow (2019), a generalized *social markup* defined as

$$\delta = 1 - \frac{\int q(n)dF(n)}{\int \frac{u(q(n))}{u'(q(n))}dF(n)}. \tag{14}$$

It captures workers' net utility from consumption of an additional variety. Keeping everything else constant, an increase in the number of varieties N affects each worker's utility from consumption in two ways. First, there is a new variety effect that increases each worker's welfare by $u(q)$. Second, an increase in N implies a smaller amount q of each variety consumed, which reduces welfare by $q(n)u'(q(n))$. The concavity of $u(q)$ together with $u(0) = 0$ imply that we have $u(q(n))/u'(q(n)) > q(n)$ or $\delta > 0$ or, in words, a dominant first effect and, accordingly, utility increasing in the number of varieties given the income and price levels.

The following proposition holds.

Proposition 1. *(i) The optimal tax policy consisting of income tax T and commodity unit tax s or entry tax S implements the constrained social optimum. (ii) The marginal income tax*

$t = T'$ is determined by

$$\frac{t}{1-t} = \frac{1+\zeta^u}{\zeta^c} \frac{\kappa(n)}{nf(n)} \int_n^{\overline{n}} \left(\frac{1 - \kappa(n')\psi(n')/\lambda - \frac{p-k}{p}}{\kappa(n')} \right) f(n')dn' - \frac{p-k}{p}, \qquad (15)$$

where the marginal utility of disposable income $\kappa(n) = u'(q(n))/p$. If $(p-k)/p \lesseqgtr \delta$, then $S \lesseqgtr 0$ with $s = 0$ or $s \lesseqgtr 0$ with $S = 0$.

Proof. In the Appendix. □

The public authority can achieve the constrained social optimum with two instruments: income taxation and a commodity tax or an entry tax. An instrument related to the production supply side helps to correct the distortion associated with inefficient market entry. In particular, if absent any stimulus the price markup is smaller than the generalized social markup, $(p - k)/p < \delta$, or, put differently, if an additional variety is socially efficient, then the public authority facilitates entry either through entry or commodity subsidy, and *vice versa*. In the optimum, as demonstrated in the proof, the benefit from encouraging further entry, given by the multiplier α of the free entry condition, needs to be equal to the resultant welfare costs, given by the shadow price of public funds λ multiplied by the number of firms N. The optimality condition $\alpha = \lambda N$ will be relevant for our subsequent analysis and, in general, is reminiscent of the production efficiency principle of Diamond and Mirrlees (1971) when applied to the efficient number of varieties. We note that in the case of constant elasticity of substitution preferences, the social markup is equal to the price markup, implying zero entry or commodity taxes. The latter in turn means that income taxation is sufficient for achieving the socially optimal allocation.

The market inefficiency related to the presence of noncompetitive markups is corrected by the means of income taxation (15). Absent price markups ($p = k$), the tax formula in (15) reduces to the classical Mirrlees (1971) formula obtained under an exogenous market structure and determined by (i) workers' behavioral response to taxation captured by labor supply elasticities (ζ^u, ζ^c) and income effects ($\kappa(n)$), (ii) the shape of productivity distribution (F), and (iii) social concerns (ψ). With positive markups ($p > k$), the income tax rates are reduced to encourage more labor supply and, in turn, more production by firms.

3.2 Optimal Income Tax Policy

In this subsection, we study the case when the public authority resorts only to income taxation with commodity and entry taxes correspondingly set to zero. In this case, the public authority's maximization problem reads as

$$\max_{U(n),\ell(n),p,N} \int \psi(n)U(n)dF(n) \tag{16}$$

$$s.t. \begin{cases} U'(n) - \frac{\ell(n)}{n}c'(\ell(n)) = 0 & (\mu(n),\ \text{ICC}) \\ \int \left[n\ell(n) - Np\, r(U(n),\ell(n),N)\right] dF(n) \geq G & (\lambda,\ \text{resource constraint}) \\ (p-k)\int r(U(n),\ell(n),N)dF(n) - K \geq 0 & (\alpha,\ \text{free entry}) \\ \eta - \frac{p-k}{p} = 0. & (\beta,\ \text{optimal price}) \end{cases}$$

We can formulate the following proposition about the optimal tax policy solely based on income taxation.

Proposition 2. *Under the policy regime with income taxation only, the optimal marginal income tax rate solves*

$$\frac{t}{1-t} = \frac{1+\zeta^u}{\zeta^c}\frac{\kappa(n)}{nf(n)}\int_n^{\bar{n}} \left(\frac{1-\kappa(n')\psi(n')/\lambda - E(n')}{\kappa(n')}\right) f(n')dn' - E(n), \tag{17}$$

where

$$E(n) = \frac{\alpha}{\lambda N}\frac{p-k}{p} + \frac{\beta}{\lambda p N}\frac{\partial \eta}{\partial q(n)} \tag{18}$$

and $sign(\beta) = sign(\alpha - \lambda N)$.

Proof. In the Appendix. □

The optimal income tax formula (17) takes a form similar to that in Proposition 1. The difference is that in Proposition 2 the additional tax term $E(n)$ aims to account for both market inefficiencies arising from the presence of markups and inefficient entry. The sign of $E(n)$ depends on the signs of the Lagrange multipliers: λ, α, and β; and the properties of relative love for varieties captured by the size and sign of $\partial\eta/\partial q(n)$. By the Kuhn-Tucker conditions, we have multipliers $\lambda \geq 0$ and $\alpha \geq 0$, whereas the sign of β has to be analytically determined (because it is associated with the equality constraint). In words, we note that λ represents the marginal utility of the public authority's spending, G, given by $-\lambda$. Since higher spending reduces workers' utility, multiplier λ is positive. In a similar way, $-\alpha$ stands for the marginal utility of the fixed entry costs K, which is negative, implying positive α. Hence, as before, we obtain that income tax rates are lowered to correct for the price effect of noncompetitive markups, which is captured by the first term of $E(n)$ in (18).

The role of the second term of $E(n)$ is to account for the variety effect related to free market entry. In the event of market over-entry (with $\alpha < \lambda N$ and, therefore, $\beta < 0$), which is typical for monopolistic competition models with pro-competitive entry effects, and absent other instruments, the public authority stimulates market exit by manipulating price markups through the demand side. Recalling that in the equilibrium the price markup equals relative love for varieties η, we obtain a further decrease in tax rates if the partial derivative of η with respect to $q(n)$ is negative, and an increase in tax rates if the derivative is positive. This mechanism works in reverse for market under-entry ($\alpha > \lambda N$ and, thus, $\beta > 0$). We also note that unlike the first term the second term of $E(n)$ is variable as

$$\frac{\partial \eta}{\partial q(n)} = -\frac{1 + \left(\frac{u'(q(n))}{u''(q(n))}\right)' \eta}{\int \frac{u'(q(n))}{u''(q(n))} dF(n)}.$$

Thus, it can have a variable effect on tax rates across income groups, with the degree of variation determined by $(u'(q)/u''(q))'$. For instance, if the latter is positive, then $\partial\eta/\partial q(n)$ is also positive, implying lower (higher) tax rates for positive (negative) β. In the case of constant elasticity of substitution (CES) or constant absolute risk aversion (CARA) preferences, the derivative $(u'(q)/u''(q))'$ is zero, implying a constant $E(n)$ across income groups.

4 Calibration

Our theoretical analysis shows that with only income taxation the public authority cannot generally achieve the constrained social optimum. In this section, we attempt to quantify the welfare loss due to the policy design restriction. We also analyze the effect of the endogenous market structure on income tax rates.

4.1 Benchmark

We calibrate the model considering the self-confirming policy equilibrium (SCPE) introduced by Rothschild and Scheuer (2013) as the benchmark. The SCPE is the solution to the standard Mirrleesian problem of optimal income taxation with the market structure, captured by the number of firms N and the market price p, taken as exogenously given. At the same time, the market price and the number of firms need to confirm with the equilibrium conditions for market price and zero profits. Put differently, those conditions are a part of the system of equations that determines the SCPE but their associated Lagrange multipliers are set at 0. In particular, the government solves

$$\max_{U(n),\ell(n)} \int \psi(n)U(n)dF(n) \tag{19}$$

$$s.t. \begin{cases} U'(n) - \frac{\ell(n)}{n}c'(\ell(n)) = 0 \\ \int \left[n\ell(n) - Np\,r\left(U(n), \ell(n), N\right)\right] dF(n) \geq G \end{cases}$$

taken N and p as given, while the latter variables solve

$$(p-k)\int r(U(n), \ell(n), N)dF(n) - K = 0,$$

$$\eta - \frac{p-k}{p} = 0.$$

We choose the parameters in such a way that some moments associated with the above equilibrium fit those in the data (see details below). We also note that in the SCPE, as in the standard Mirrleesian framework, the optimal commodity tax is zero. The calibrated parameters are then used in the numerical simulations of optimal taxation with the endogenous market structure under the scenarios when (i) only income taxes are available and (ii) income and commodity taxes are available.

4.2 Parameters

We model consumer preferences using the two-parameter Expo-Power utility function

$$u(q) = \frac{(1 - e^{-\gamma q^{1-\rho}})}{\gamma}, \tag{20}$$

where $\gamma \geq 0$ and $1 > \rho \geq 0$ are parameters to calibrate (Saha, 1993). Note that this utility specification captures two widely used specifications: the case of $\gamma \to 0$ corresponds to the CES utility function, and the case of $\rho \to 0$ to the CARA utility function. We calibrate the values of γ and ρ using the conditions for the price elasticity of aggregate demand ε defined by

$$\varepsilon \equiv -\frac{dQ}{dp}\frac{p}{Q} = -\frac{\int u'(q(n))/u''(q(n))dF(n)}{\int q(n)dF(n)}$$

and for pass-through elasticity ε_{pk} defined by

$$\varepsilon_{pk} \equiv \frac{d\log p}{d\log k} = 1 + \frac{d\log}{d\log k}\left(\frac{\varepsilon}{\varepsilon - 1}\right).$$

We set the price elasticity at $\varepsilon = 4$ in order to match the time average for markups equal to 1.33 (see de Loecker et al., 2020). The estimates of the pass-through elasticity vary in the range between 0.3 and 0.8 and we set $\varepsilon_{pk} = 0.6$ at the rounded midpoint of this range (see Kichko and Picard, 2020), which is also the value estimated by Campa and Goldberg (2005) and Amiti et al. (2019).

Productivity n and its distribution F are proxied by hourly wages and its empirical distribution is taken from Mankiw et al. (2009). We set $\underline{n} = 0$ with its mass at 5 percent of the population to account for economically inactive people. The labor cost function is given by $c(\ell) = \ell^3/3$, which corresponds to the Frisch labor supply elasticity of 0.5 (Chetty et al., 2013). The marginal cost of production k is set to be equal to the reciprocal of the average hourly wage $1/\int ndF(n)$ similarly to Behrens et al. (2020).

We calibrate the fixed cost of production K to match the estimated welfare effects of introducing a new variety. There are a direct variety effect due to the expansion of variety selection and an indirect price effect due to the price change caused by a higher level of competition. In particular, recall that the utility from individual consumption can be written in the case of homogeneous firms as $Nu\left(y(n)/Np\right)$. Based on that, we define the variety effect (keeping the disposable income fixed) as

$$\int \frac{\partial}{\partial N}\left[Nu\left(\frac{y(n)}{Np}\right)\right] dF(n) = \int \left[u(q(n)) - q(n)u'(q(n))\right] dF(n), \tag{21}$$

while the price effect is given by

$$\int N \frac{\partial u\left(\frac{y(n)}{Np}\right)}{\partial p}\frac{dp}{dN} dF(n) = -\int q(n)u'(q(n))\frac{dp}{dN}\frac{N}{p} dF(n), \tag{22}$$

where dp/dN is the implicit derivative of the profit maximizing price with respect to the number of firms N. In our calibration, we draw on Feenstra and Weinstein (2017) and Quan and Williams (2018) who show that the price and variety effects are of a similar size. As a result, we set K such that the value of the variety effect is the same as that of the price effect in the SCPE.

Finally, we assume that the government intervenes out of considerations for redistribution only and, therefore, we set its exogenous expenditures at $G = 0$. We follow Rothschild and Scheuer (2013) in modeling the social welfare weights by $\psi(n) = \iota(1 - F(n))^{\iota - 1}$ with $\iota = 1.3$.

4.3 Results and Discussion

The calibration of the benchmark SCPE case yields the following parameters values: $\gamma = 0.655$ and $\rho = 0.091$ for the utility function and $K = 0.005$ for the fixed costs of production. The first observation is that calibrated consumer preferences do not exhibit constant elasticity of substitution as parameter γ is different from zero. In Figure 1, for different regimes we plot the optimal marginal income tax rates against gross earnings z, where the earnings of the

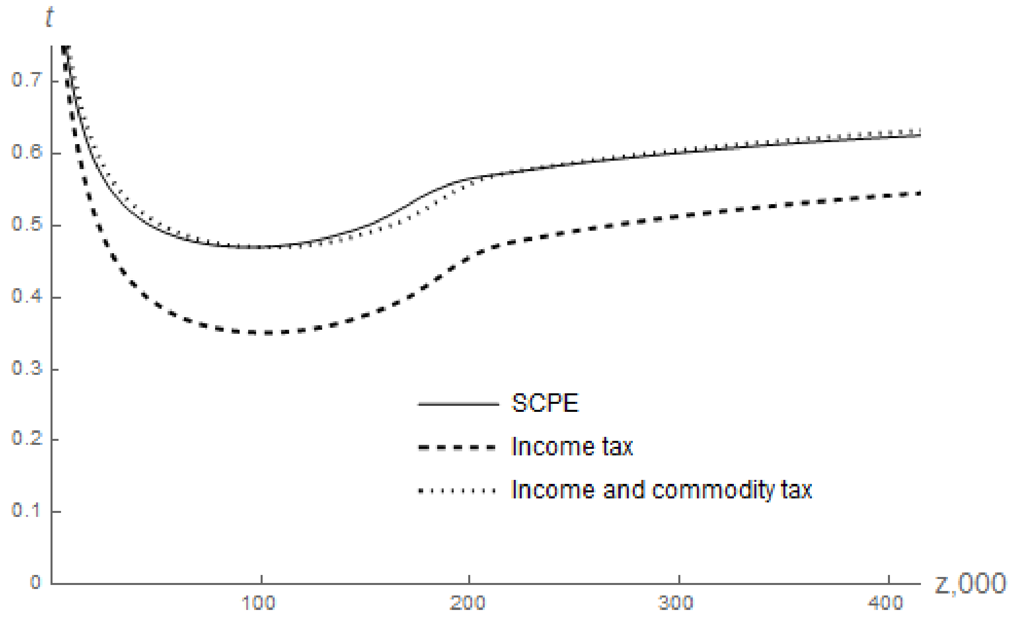

Figure 1: Income tax rates and policy regimes

Note: The income tax rate schedules for Income and commodity tax policy (dotted line) and Income tax policy (dashed line) are found from Propositions 1 and 2, respectively. The SCPE tax schedule is found from the solution to problem (19).

median consumer are normalized to be equal to the empirical median earnings in the US. In the SCPE, the marginal income tax schedule (solid line) takes a shape familiar to those reported in the related literature (Saez, 2001; Mankiw et al., 2009). The high tax rates at low incomes correspond to the phase-out of transfer payments, whereas the kink at high incomes with the flattening of tax rates is due to the Pareto tail of the productivity distribution.

Next, we observe that the optimal policy regime with income and commodity taxation results in the marginal income tax schedule (dotted line) that is very similar to the SCPE outcome. We recall from Proposition 1 that market inefficiencies related to the price effect of noncompetitive markups need to be corrected by lower marginal tax rates. The price effect is, however, countered by the variety effect that requires additional tax revenue for the optimal unit subsidies of $s = -0.012$ disbursed to firms to encourage market entry (see the Expo-Power preferences section of Table 1 for numerical outcomes of the policy regimes). Notwithstanding the similarity in the tax schedules, under the optimal tax policy the overall effect of market cross-dependencies on tax rates is to the relative disadvantage of consumers with lower incomes, as they face higher tax rates by up to several percentage points. At the same time, we note that the optimal policy achieves its objective of lower price markups and, in turn, higher average consumption $\overline{q}$ of individual varieties. The resultant welfare improvement over the SCPE outcome is about 1.77 percent, which, as already suggested by changes in tax rates, is not evenly distributed, as we obtain an increase in the coefficient of variation of utility (see column CV in Table 1).

Under the optimal policy regime with income taxation only (dashed line), we see a steep

Policy regime	W	$(p-s)/k$	s	N	$\overline{q}$	L	T/L	CV
Expo-Power preferences								
SCPE	3650.7	1.333	0	20890	0.216	295.3	0.57	0.42
Income & commodity tax	3715.2	1.287	-0.012	20217	0.251	320.3	0.58	0.47
Income tax	3695.0	1.338	0	23018	0.213	322.3	0.479	0.49
CES preferences								
SCPE	5330.7	1.333	0	16871	0.31	337.4	0.56	0.53
Income & commodity tax	5454.6	1.333	0	19148	0.31	383.0	0.43	0.68
Income tax	5454.6	1.333	0	19148	0.31	383.0	0.43	0.68
CARA preferences								
SCPE	2727.7	1.333	0	35059	0.12	265.4	0.58	0.39
Income & commodity tax	2775.4	1.281	-0.016	32714	0.14	282.1	0.63	0.42
Income tax	2754.4	1.333	0	37856	0.12	286.6	0.50	0.44

Table 1: Numerical outcomes of policy regimes

Note: W welfare; $(p-s)/k$ producer price markup; s commodity tax/subsidy; N number of firms; $\overline{q}$ average consumption; L total labor earnings; T/L ratio of total tax revenue to total labor earnings; CV coefficient of variation of utility (standard deviation divided by average utility).

reduction in income tax rates compared to the tax policy with both types of taxation. The largest reduction of about 12 percentage points occurs at tax rates for low incomes, with the level of reduction gradually diminishing for higher incomes. We can attribute this reduction in tax rates to price markup corrections. However, tax reductions and subsequent larger earnings can lead to market over-entry as we observe in our analysis. Formally, we have multiplier $\beta < 0$ or $\alpha < \lambda N$, which can also be inferred from a larger number of firms under the income tax policy regime as shown in Table 1. We recall from Proposition 2 that the purpose of the second part of the market correction term $-E(n)$ in the tax formula is to account for the variety effect arising from market entry in the absence of producer subsidies or taxes. Given market over-entry, income taxes are increased to reduce demand for varieties, thus, partially offsetting the tax reduction due to the price effect of noncompetitive markups. The size of tax increase is proportional to the effect of additional consumption on relative love for varieties η. As $\partial\eta/\partial q$ is positive and larger at higher incomes or, in other words, richer consumers have an increasingly stronger love for varieties, tax rates are corrected upwards more for higher incomes (see the solid line in Figure 2 for the plot of $-E(n)$ term under Expo-Power preferences). Thus, we obtain more progressivity in tax rates for reasons other than income redistribution. Put differently, the "trickle-down" effect from less progressive taxes can lead to inefficient entry with more varieties but, inevitably, also with higher price markups and welfare losses.

Comparing welfare outcomes, we find that the income taxation policy under-performs the optimal tax policy by 0.55 percent relative to the SCPE outcome. This under-performance can be attributed to market over-entry and higher markups which are impossible to resolve by the means of income taxes only. Yet, from a practical perspective it is not unequivocal which tax regime the government may prefer. Based on our quantitative analysis, the optimal tax policy

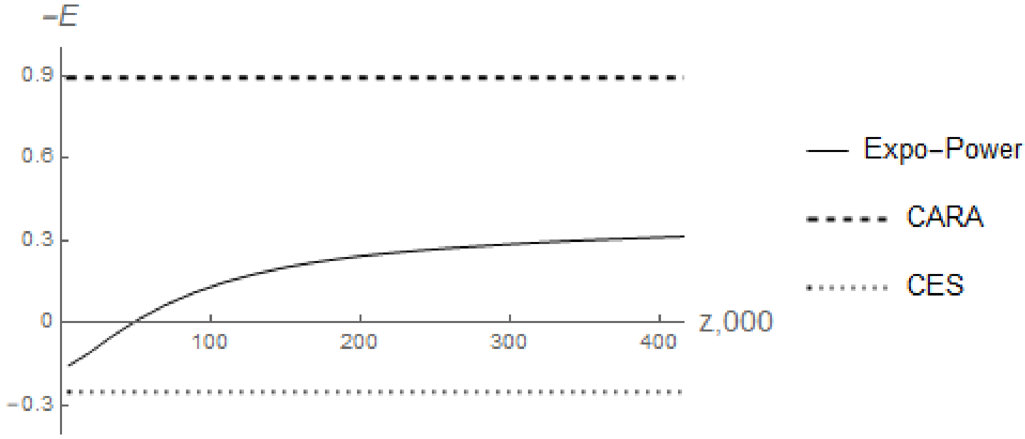

Figure 2: The role of market structure for income tax rates

Note: The figure plots market correction term $-E(n)$, defined in Proposition 2, against corresponding labor earnings $z(n)$.

comes with higher taxes for low incomes and with producer subsidies, which may be infeasible due to fraud risks or politically unpopular in practice. From a different perspective, we can interpret our findings as that if fraud risks inhibit the introduction of producers subsidies, then the associated welfare loss is 0.55 percent. At the same time, the income taxation policy comes with progressive marginal tax reductions and, as a result, a much smaller government (by nearly 10 percentage points, see column T/L in Table 1), which may be politically more appealing. Hence, the welfare gain of 0.55 percent may not be a universally sufficient advantage for the optimal tax policy, suggesting that both policy regimes are viable options in practice. Lastly, the observed differences in the quantitative outcomes between the two regimes match well the corresponding differences across countries where different regimes are practiced. In the US, where the main tax instrument is income taxation, there are higher markups, more entrepreneurs and income per capita, and more inequality, but smaller government compared to Western European countries where both income and commodity taxation are widely used.[4]

4.4 Role of Preferences

In this subsection, we examine the role of consumer preferences for policy outcomes. Besides Expo-Power preferences, we consider two commonly used types of preferences: constant elasticity of substitution (CES) and constant absolute risk aversion (CARA) preferences. As CES and CARA preferences are characterized with a one-parameter utility function, we accordingly need one moment condition less and, for this purpose, remove the condition on pass-through elasticity $\varepsilon_{pk} = 0.6$. Furthermore, CES preferences imply the constant ratio of the variety and price effects, respectively defined by (21) and (22), which therefore cannot then be used to calibrate fixed costs of production K. Therefore, for CES preferences we take $K = 0.005$

[4]See Aquilante et al. (2019) for empirical evidence on markups, GEM (2020) on entrepreneurship, and, e.g., the OECD on country statistics.

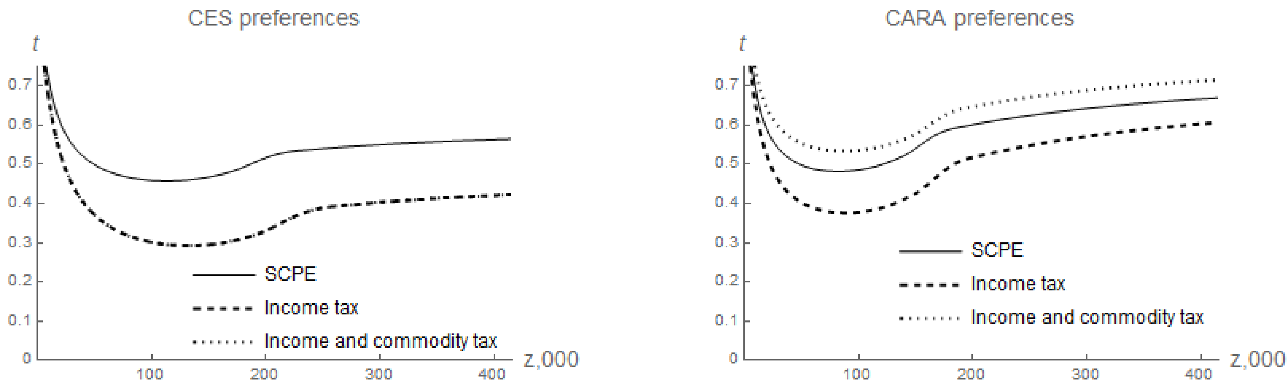

Figure 3: Income tax rates for CES and CARA preferences

Note: The income tax rate schedules for Income and commodity tax policy (dotted line) and Income tax policy (dashed line) are found from Propositions 1 and 2, respectively. The SCPE tax schedule is found from the solution to problem (19).

calibrated under Expo-Power preferences.

The left and right panels of Figure 3 plot the optimal marginal income tax schedules for CES and CARA preferences, respectively, under the different policy regimes previously studied. Table 1 reports numerical economic outcomes. As theoretically predicted, with CES preferences the policy outcomes coincide under the regimes with commodity and income taxation and with only income taxation. The correction of the inefficiency related to non-competitive price markups also ensures the efficiency of market entry, implying the sufficiency of income tax policy. Thus, under both regimes after the phase-out stage of transfer payments we obtain a uniform reduction in income tax rates compared to the SCPE benchmark. From a different perspective, the market correction term $-E(n)$ is constant and negative as shown in Figure 2 (dotted line).

With CARA preferences, the policy outcomes differ because the income tax instrument alone cannot rectify both market entry and non-competitive markup inefficiencies. As the social markup is different from the price markup (Proposition 1), income taxation needs to be complemented with commodity or firm taxation to achieve the social optimum. Comparing the policy outcomes obtained under Expo-Power and CARA preferences, we observe larger commodity subsidies under CARA preferences, 0.016 vs 0.012 (see Table 1), which imply a larger market inefficiency related to the variety effect. As a result, and unlike with Expo-Power preferences, we obtain increases in income tax rates above the SCPE benchmark. For the policy regime with only income taxes we observe a larger market correction term $-E(n)$ under CARA preferences (see the dashed line in Figure 2) and, accordingly, smaller reductions in tax rates compared to the SCPE benchmark. Further analysis of CARA preferences provided in Table 1 reveals that the qualitative difference in economic outcomes between the two policy regimes is similar to that obtained under Expo-Power preferences.

Lastly, in Figure 4 we compare income tax schedules among the preference types studied for a given policy regime. First, consumer preferences matter for policy design directly through

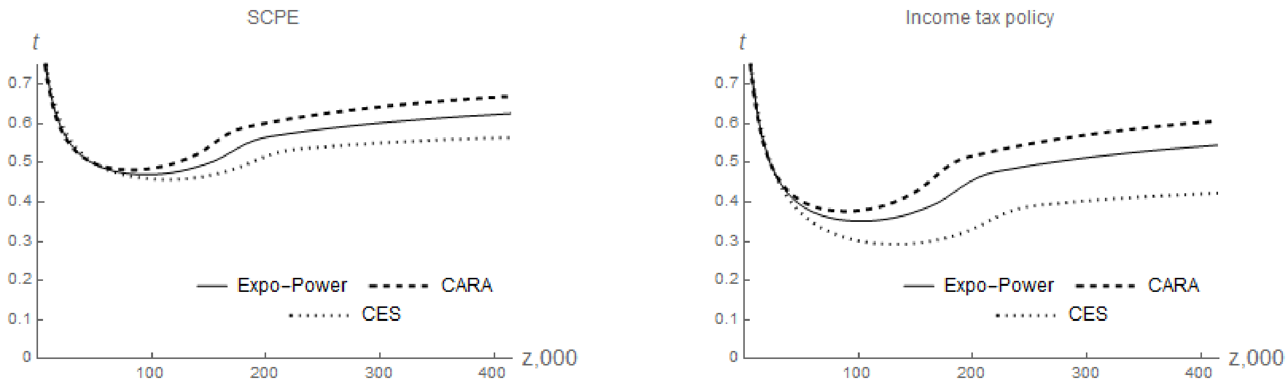

Figure 4: Income tax rates and preferences

Note: For each type of preference considered, the tax schedule for the SCPE benchmark (left panel) is found from the solution to problem (19) and for Income tax policy from Proposition 2.

workers' behavioral response, which is captured by the SCPE benchmark with an exogenous market structure (left panel). We observe that relative to the Expo-Power preferences the income tax schedule becomes more progressive for CARA preferences and less progressive for CES preferences. Second, with an endogenous market structure preferences can also matter indirectly through their influence on the market outcome. In the right panel of Figure 4, we plot the tax schedules under the policy regime with income taxation. We observe that compared to the SCPE benchmark the differences in tax schedules are qualitatively similar though substantially amplified. In other words, when the market structure is endogenous preferences play a more profound role for income tax policy than in the case of a fixed market structure.

5 Conclusion

In this paper, we study the role of the price and variety effects arising from an endogenous market structure in determining optimal tax policy design. We demonstrate that due to the variety effect income taxation needs to be complemented with commodity or firm taxes (or subsidies) to achieve the constrained social optimum. Quantitative analysis demonstrates that the price and variety effects almost offset each other in the optimal design of income tax rates. While the price effect of non-competitive markups exerts a downward pressure on income taxes to stimulate labor supply and more production, additional tax revenue needed for efficient market entry can reverse this pressure. We estimate that the failure to account for the price and variety effects results in a welfare loss of 1.77 percent. Following practical examples, we also study a policy regime that is solely based on income taxation. For such regime, the conflicting goals of correcting for the price and variety effects imply departures from the constrained social optimum, which we estimate at 0.55 percent. However, this policy regime results in lower and less regressive income taxes than those obtained under the regime with all forms of taxation and also in a substantially smaller government. Lastly, we examine the role of consumer preferences for policy outcomes and show that it is amplified by an endogenous market structure and, as a result, so are inaccuracies resulting from misspecified preferences.

Appendix

In this Appendix, we provide proofs for the propositions stated in the main body of the paper.

Proof of Proposition 1

First, we show that optimal tax policy leads to the constrained social optimum where workers' productivity is their private information but firm ownership is public. We define the constrained social optimum $(q(n), \ell(n), N)$ as the solution to the welfare maximization problem

$$\max_{q(n),\ell(n),N} \int \{Nu(q(n)) - c(\ell(n))\}\psi(n)dF(n)$$

subject to the incentive compatibility constraint

$$U(n) = Nu(q(n)) - c(\ell(n)) = \max_{n'} Nu(q(n')) - c(n'\ell(n')/n)$$

and the resource constraint

$$\int \{n\ell(n) - kNq(n)\}dF(n) - NK \geq G.$$

Using the envelope theorem, we can rewrite the incentive compatibility condition as

$$U'(n) = \frac{\ell(n)}{n}c'(\ell(n)). \tag{23}$$

Hence, the public authority's problem becomes

$$\max_{U(n),\ell(n),N} \int \psi(n)U(n)dF(n)$$

$$s.t. \begin{cases} U'(n) - \frac{\ell(n)}{n}c'(\ell(n)) = 0, & (\mu(n),\ \text{ICC}) \\ \int \{n\ell(n) - kNr(U(n), \ell(n), N)\}dF(n) - NK = G. & (\lambda,\ \text{resource constraint}) \end{cases}$$

It is straightforward to show that the constrained social optimum is characterized by the following first-order conditions

$$U(n): \left(\psi(n) - \frac{\lambda k}{u'(q(n))}\right) f(n) = \mu'(n), \tag{24}$$

$$\ell(n): \lambda\left(n - k\frac{c'(\ell(n))}{u'(q(n))}\right) f(n) = \mu(n)(c' + \ell(n)c'')/n, \tag{25}$$

$$N: \int \frac{u(q(n))}{u'(q(n))/k} f(n)dn - (kQ + K) = 0. \tag{26}$$

Now consider the public authority's problem stated in (13) with private firm ownership. If we denote

$$Z(n) = \lambda N(p - s) - \alpha(p - k - s) - \beta\partial\eta/\partial q(n),$$

the first-order conditions for the optimal income and firm taxation can be written as

$$U(n): \left(\psi(n) - \frac{Z(n)}{Nu'(q(n))}\right) f(n) - \mu'(n) = 0, \tag{27}$$

$$\ell(n): \left(\lambda n - \frac{Z(n)c'(\ell(n))}{Nu'(q(n))}\right) f(n) - \mu(n)(c' + \ell c'')/n = 0, \tag{28}$$

$$p: \int \left(-\lambda Nq(n) + \alpha q(n) - \beta\frac{k+s}{p^2}\right) f(n)dn = 0, \tag{29}$$

$$N: \int \left(-\lambda(p - s)q(n) + \lambda S - Z(n)\frac{-u(q(n))}{Nu'(q(n))}\right) f(n)dn = 0, \tag{30}$$

$$s: \int \left(\lambda Nq(n) - \alpha q(n) + \frac{\beta}{p}\right) f(n)dn = 0, \tag{31}$$

$$S: \lambda N - \alpha = 0. \tag{32}$$

We now consider two scenarios: 1) the optimal income taxation with the optimal entry subsidy, but without commodity taxation: $s = 0$; and 2) the optimal income taxation with the optimal commodity taxation, but without entry subsidy: $S = 0$. For the first scenario, equation (31) is not present, whereas equations (32) and (29) then imply $\alpha = \lambda N$ and $\beta = 0$ and, in turn, $Z(n) = \lambda Nk$. Taking this into account, we obtain

$$U(n): \left(\psi(n) - \frac{\lambda k}{u'(q(n))}\right) f(n) - \mu'(n) = 0, \tag{33}$$

$$\ell(n): \lambda\left(n - \frac{kc'(\ell(n))}{u'(q(n))}\right) f(n) - \mu(n)(c' + \ell c'')/n = 0, \tag{34}$$

$$N: \int \left(-(K + kq(n)) + \frac{ku(q(n))}{u'(q(n))}\right) f(n)dn = 0, \tag{35}$$

where the last equation follows from (30) and the zero profit condition $(p - k)Q - K - S = 0$. Hence, workers' utility, labor supply, and firms' production coincide with the ones in the constrained social optimum characterized by (24)–(26).

In the second scenario with $S = 0$, equation (32) is not present, whereas adding (31) and

(29) yields

$$\beta\frac{p-k-s}{p^2}=0.$$

The latter implies that $\beta=0$ ($p=k+s$ would violate the free entry condition) and, therefore, $\alpha=\lambda N$ and, in turn, $Z(n)=\lambda Nk$. Hence, the public authority can achieve worker's utility level, labor supply, and firms' production as in the constrained social optimum. This proves part (i) of the proposition.

The optimal income tax rates are found from equations (27) and (28) and as these equations are the same in each scenario considered, the presence of commodity or entry taxation has no impact on optimal tax rates. Recall that we have

$$1-t=\frac{pc'(\ell(n))}{nu'(q(n))}\Longleftrightarrow\frac{t}{1-t}=\frac{nu'(q(n))}{pc'(\ell(n))}-1.$$

From (34), we can derive that

$$\frac{nu'(q(n))}{c'(\ell(n))}=\frac{u'(q(n))\mu(n)(1+\ell c''(\ell(n))/c'(\ell(n)))}{\lambda nf(n)}+k.$$

we obtain

$$\frac{t}{1-t}=\frac{u'(q(n))\mu(n)(1+\ell c''(\ell(n))/c'(\ell(n)))}{\lambda pnf(n)}-\frac{p-k}{p}.$$

The integration of (33) from n to $\overline{n}$ and the transversality condition $\mu(\overline{n})=0$ yield

$$\mu(n)=\int_n^{\overline{n}}\left(\frac{\lambda k}{u'(q(n'))}-\psi(n')\right)f(n')dn'.$$

Using the marginal utility of income $\kappa(n)=u'(q(n))/p$, we derive

$$\mu(n)=\int_n^{\overline{n}}\left(\frac{\lambda k}{\kappa(n')p}-\psi(n')\right)f(n')dn'.$$

The uncompensated and compensated labor supply elasticities are found to be equal to

$$\zeta^u=-\frac{(u''/N)(c'/u')^2+c'/\ell}{(u''/N)(c'/u')^2-c''}\qquad\zeta^c=-\frac{c'/\ell}{(u''/N)(c'/u')^2-c''}$$

yielding $1+\ell(n)c''/c'=(1+\zeta^u)/\zeta^c$. Hence, we have

$$\frac{t}{1-t}=\frac{1+\zeta^u}{\zeta^c}\frac{\kappa(n)\int_n^{\overline{n}}\left(\frac{\lambda k}{\kappa(n')p}-\psi(n')\right)f(n')dn'}{\lambda nf(n)}-\frac{p-k}{p},$$

which is equivalent to the formula from the proposition.

Regarding the sign of the optimal entry tax S, from the zero profit condition we have

$$S=pQ-kQ-K$$

or, using equation (35) and the definition of social markup δ in (14),

$$\begin{aligned} S =& pQ - k\int \frac{u(q(n))}{u'(q(n))} f(n)dn \\ =& Q\left(p - \frac{k}{1-\delta}\right). \end{aligned}$$

Thus, we obtain $S \lesseqqgtr 0$ if $\frac{p-k}{p} \lesseqqgtr \delta$ as required. Similarly, from the zero profit condition, the optimal commodity tax s has

$$sQ = pQ - kQ - K.$$

Repeating the same steps as with the entry tax S, we obtain $s \lesseqqgtr 0$ if $\frac{p-k}{p} \lesseqqgtr \delta$.

Proof of Proposition 2

As before, we define

$$Z(n) = \lambda Np - \alpha(p-k) - \beta\partial\eta/\partial q(n).$$

Then, the first order conditions for the public authority's maximization problem are given by

$$U(n) : \left(\psi(n) - \frac{Z(n)}{Nu'(q(n))}\right) f(n) = \mu'(n), \tag{36}$$

$$\ell(n) : \left(\lambda n - \frac{c' Z(n)}{Nu'(q(n))}\right) f(n) = \frac{\mu(n)(c' + \ell(n)c'')}{n}, \tag{37}$$

$$p : \int \left(-\lambda Nq(n) + \alpha q(n) - \frac{k\beta}{p^2}\right) dF(n) = 0 \tag{38}$$

$$N : \int \left(-\lambda pq(n) + \frac{Z(n)u(q(n))}{Nu'(q(n))}\right) dF(n) = 0. \tag{39}$$

From (37), we have

$$\lambda\left(\frac{nu'(q(n))}{pc'(\ell(n))} - 1\right) + \frac{\alpha(p-k) + \beta\partial\eta/\partial q(n)}{pN} = \frac{u'(q(n))}{p}\frac{\mu(n)(1 + \ell(n)c''/c')}{f(n)n}.$$

Taking into account that

$$\frac{t}{1-t} = \frac{nu'(q(n))}{pc'(\ell(n))} - 1,$$

we have

$$\frac{t}{1-t} = \frac{u'(q(n))\mu(n)(1 + \ell(n)c''/c')}{\lambda pnf(n)} - \frac{\alpha(p-k) + \beta\partial\eta/\partial q(n)}{\lambda pN}.$$

From (36), we obtain that

$$\mu(n) = \int_n^{\bar{n}} \left(\lambda p\frac{1 - E(n')}{u'(q(n'))} - \psi(n')\right) f(n')dn',$$

where

$$E(n) = \frac{\alpha(p-k) + \beta \partial\eta/\partial q(n)}{\lambda p N}.$$

Hence, the marginal tax is given by

$$\frac{t}{1-t} = \frac{1+\zeta^u}{\zeta^c}\frac{\kappa(n)}{nf(n)}\int_n^{\bar{n}} \left(\frac{1-\kappa(n')\psi(n')/\lambda - E(n')}{\kappa(n')} \right) f(n')dn' - E(n).$$

Regarding the sign of multiplier β, from (38) we have

$$Q(-\lambda N + \alpha) = \frac{\beta k}{p^2}, \tag{40}$$

where Q is the aggregate demand for a variety. This implies $sign(\beta) = sign(\alpha - \lambda N)$.

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