Essays on Corporate Taxation in the Open Economy

By

Siraj Gustavo Bawa Barrantes

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Approved:

Professor Mario Crucini, Ph.D

Professor Eric Bond, Ph.D

Professor Joel Rodrigue, Ph.D

Professor Craig Lewis, Ph.D

Para mi familia

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Optimal Corporate Taxes in the Open Economy without Pareto

1.1 Introduction

The trade literature with heterogeneous firms has in its great majority assumed Pareto distributions of productivities.[1] Recent studies have started a debate on how this “standard" assumption affects the outcomes of the models in question, with particular attention to the most widely used model of this type: the Melitz model. For example, Head et al. (2014) finds that using a lognormal distribution, instead of Pareto, allows them to fit their model significantly better using sales data from French and Spanish firms. Additionally, Bee and Schiavo (2015) provide a thorough comparison between the gains of trade obtained under both distributions to highlight that the standard assumption might be overstating the gains of trade in a significant way. I follow in these steps, but on a parallel path, by investigating the implications to optimal corporate taxation in a Melitz model when one departs from the standard assumption of Pareto productivity distribution in favor of a lognormal distribution. I also provide evidence that the latter distribution is consistently a better fit for productivities in over 100 countries that are part of the World Bank Entrepreneurial Survey.

This paper studies a multi-sector trade model à la Melitz in which I include governments that must provide a fixed amount of public goods, which they finance through the taxation of firms' profits. The tax framework used is modeled after the corporate taxation systems observed in most countries, which usually contain a single statutory corporate profit tax rate (τ), which is imposed on all firms producing in the country; and a set of sector-specific depreciation allowance rates for capital (δ_s), which in the case of my model is assessed in the fixed cost of production. What is special about this corporate tax framework is that the

[1] The justification for this assumption has roots in empirical evidence from Axtell (2001), Del Gatto et al. (2006). However, the real advantage of using the Pareto distribution lyes in the analytical tractability that it provides to the models.

effective tax rate is not only different from the statutory tax rate but it can vary significantly across sectors.[2]

The question of what are the optimal corporate tax rates is answered substantially differently depending on which productivity distribution is assumed. For example, the optimal statutory tax rate under lognormal is always lower than the rate derived under Pareto assumption. This property is complementary to the finding that depreciation allowance rates (δ), under the assumption of Pareto distributions, do not explicitly include sector specific fixed costs of production and/or entry cost. On the other hand, the optimal policy for the government in the lognormal model is to exploit these asymmetries in cost across the sectors by using a targeted approach through δ instead of τ which has an economy wide scope.

The difference in the optimal formulas for fiscal instruments is traced to a channel of transmission that is shut down when Pareto distributions are assumed. The channel is based on the ratio between the average firm and the marginal firm, which is fixed under Pareto but variable under lognormal distributions. This modification in the market landscape is obviated if we assume Pareto distributions, which eliminates one channel through which governments can influence the equilibrium outcomes through the fiscal instruments.

There are non-trivial welfare losses associated with using the simpler policy functions derived under the Pareto assumption in a country which has lognormal distributions. In the closed economy the welfare losses are enhanced with the degree of asymmetry across the sectors, with one of our numerical examples showing a 3 % loss of welfare relative to using the “correct" policy functions. When the open economy is considered, not only does the degree of asymmetry across sectors in one country plays role but a more important driver is the heterogeneity between countries. In this setting the same scenarios considered in the closed economy yield welfare losses 5 to 10 times as high. The significant welfare losses warrant the use of the more complicated policy functions (obtained under lognormal) when such corresponds to the appropriate distributional assumption of the country being studied.

[2] Effective tax rates are usually defined as the ratio of taxes paid over net profits. For a recent study in the variability of this measure across sector see Barrios et al. (2014)

Adding the proposed tax framework to a Melitz model also provides a basis to reconcile two contradictory findings about the relationship between corporate taxes and export dynamics. Using French firm level data Bernini and Treibich (2013) find that small and medium sized firms are less likely to export their products when they face higher corporate tax rates. On the other hand, Federici and Parisi (2014) use longitudinal data from Italian firms and find the opposite relation. My model is able to produce both relationships and it shows that the export cutoffs are not solely functions of domestic taxes but also depend on taxes from the target country.

The tax collected by the government is used to purchase an exogenous amount of a public good q_0^G, which is produced under perfect competition. Thus, my model uses the Ramsey approach in which governments choose tax rates to maximize the welfare of their citizens while raising enough tax revenue to cover an exogenous level of expenditure. This simple framework can be used to replace the decentralization scheme proposed by Nocco et al. (2014) – to achieve the efficient outcome in a multi-sector Melitz type model – which is based on subsidies and lump sum transfers.[3] If the amount q_0^G is set to the optimal amount found by Nocco et al., then my model provides a framework to compute the optimal tax rates that could be implemented in current tax codes to achieve such outcome.

1.2 Closed Model

This section presents an extended Melitz (2003) with asymmetric sectors and the addition of a set of fiscal instruments: a statutory corporate tax rate and depreciation allowance rates

[3] Recent papers have shown that market outcomes are inefficient when the economy is composed of a perfect competitive sector and a monopolistic competitive one. In particular, Dhingra and Morrow (2012) show that resources are mis-allocated between such sectors in a Melitz type model with Variable Elasticity of Substitution preferences (see Zhelobodko et al. (2012) for VES preferences exposition) leading to inefficient outcomes that could be improved. Additionally, Nocco et al. (2014) propose a decentralization scheme to achieve the efficient outcome via subsidies and lump sum taxes on consumers and firms. While this scheme provides us with useful insights into the mechanics at play it is hard to imagine its applicability in the real world given the amount of information that the central authority would need but most importantly, the tax codes of most countries would have to be scratched entirely. This seems like an impossible task from a practical perspective and thus I decide to frame the corporate taxes in my model in a way that is closely related to what we observe in most countries.

specific to each sector.[4] The model is first developed in a closed environment as it facilitates the discussion of the relations between the fiscal instruments and the equilibrium outcomes, specially: sector productivity and the number of firms producing in each sector. Special focus is put on the consequences that assuming Pareto distributions exert on the response of these variables to changes in the fiscal instruments. The following paragraphs define the model and its equilibrium.

Households

The country is home to L households who inelastically supply one unit of labor to fulfill demand from firms. The household receives a wage “w" per unit of labor and spends her income on a continuum of differentiated goods $q(\omega)$. Households also derive utility from consuming a public good q_0^G which is provided by the government. The functional form of utility is quasilinear thus the household maximization problem is:

$$\max_{Q_s} \quad q_0^G + \prod_{s=1}^{S} Q_s^{\alpha_s}$$

where Q_s is the aggregate consumption of sector “s" goods.

Let Ω_s represent the collection of available goods in sector “s"; the consumer problem can be broken into S separated maximization problems given by:

$$Q_s = \max_{q(\omega)} \left[\int_{\omega \in \Omega_s} q(\omega)^{\rho_s} \right]^{1/\rho_s} \tag{1.2.1}$$

such that

$$\int_{\omega \in \Omega_s} p_s(\omega) q(\omega) \leq Y_s$$

[4] Bauer et al. (2014) provides a similar taxation framework but their model considers only one sector with heterogeneous firms with no fixed production and/or entry costs.

where $Y_s = \alpha_s Y$ due to the Cobb-Douglas preferences over sectors. Equation (1.2.1) is a standard C.E.S utility with elasticity of substitution $\sigma_s = 1/(1-\rho_s)$. As shown in Dixit and Stiglitz (1977), the price index $P_s = \left[\int_{\omega\in\Omega_s} p_s(\omega)^{1-\sigma_s}\right]^{1/1-\sigma_s}$ is used to express quantities demanded as:

$$q_s(\omega) = \frac{Y_s p_i(\omega)^{-\sigma_s}}{P_s^{1-\sigma_s}} = Q_s \left[\frac{p_s(\omega)}{P_s}\right]^{-\sigma_s} \tag{1.2.2}$$

Firms

Firms operate in one of the S sectors of the economy which are characterize by monopolistic competition and costly entry. After paying the sector-specific entry cost of $F_{e,s}$, a firm randomly draws its productivity (φ) from the distribution $Z_s(\varphi)$. A firm in sector "s" with productivity φ requires $l = q/\varphi + f_s$ units of labor to produce q units of output. The fixed cost of production f_s is the same for all firms in the same sector.

The government sets a statutory corporate profit tax rate (τ), that is common for firms regardless of sector; and a set of sector-specific depreciation allowance rates (δ_s), which allows firms to deduct $\delta_s f_s$ from their taxable income. The value of these "fiscal rates" is known by firms before they make any decision inclusive of entry into a market.

With the above notation, the formulas for taxes paid (t_s), after tax profits (π_s) and, the profit maximizing price for a firm with productivity φ in sector s are:

$$t_s(\varphi) = \tau\left(p_s q_s - w\frac{q_s}{\varphi} - \delta_s w f_s\right) \tag{1.2.3}$$

$$\pi_s(\varphi) = (1-\tau)\left(p_s q_s - w\frac{q_s}{\varphi} - u_s w f_s\right) \tag{1.2.4}$$

$$u_s = \frac{1-\delta_s\tau}{1-\tau} \tag{1.2.5}$$

$$p_s(\varphi) = \left(\frac{\sigma_s}{\sigma_s - 1}\right)\frac{w}{\varphi}\,. \tag{1.2.6}$$

The variable u_s is the user cost of capital, in the spirit of Hall and Jorgensen (1967), when fixed costs of production f_s are interpreted as capital that firms spend in order to produce.[5] This capital (in a broad sense) could be any variable costs such as licenses, training, machinery costs, etc. However, the type of model that I use doesn't distinguish between labor and capital (in the neoclassical way), which makes the interpretation of δ_s less straightforward than a depreciation allowance on capital. Here, δ_s is a policy instrument to shift the effective tax rate for firms in sector "s". Holding τ fixed, increasing δ_s implies that the taxable income for firms in sector "s" is reduced and consequently their effective tax rates decrease; decreases in δ_s have the opposite effect.

1.2.1 Equilibrium

As is well known, in this type of model, the aggregate variables are functions of the average productivity of firms' that find it profitable to produce, $\tilde{\varphi}_s$:

$$\tilde{\varphi}_s(\varphi_s^*) = \left[\frac{1}{1-Z_s(\varphi_s^*)}\int_{\varphi_s^*}^{\infty} \varphi^{\sigma_s-1} z(\varphi_s)\, d\varphi\right]^{1/\sigma_s-1} \tag{1.2.7}$$

where φ_s^* is the productivity of the marginal firm in sector "s" i.e, the firm that makes zero after tax profit. Let M_s represent equilibrium number of firms producing in sector "s" then aggregation across firms in sector "s" yields the following sector-level economic variable

[5] An implicit assumption in the above equations is a physical depreciation rate of capital of 100 %. However, if the real depreciation rate of capital for sector "s" is d_s, the model solution is exactly the same if we modify the user cost of capital to:

$$u_s = \frac{d_s - \delta_s\tau}{1-\tau}$$

Furthermore, the solutions for the optimal tax problem remain valid by scaling the depreciation allowance rate and the fixed cost of production by the appropriate physical depreciation rate of capital.

$$\begin{aligned}\hat{\delta}_s &= \frac{\delta_s}{d_s}\\ \hat{f}_s &= d_s f_s\end{aligned}$$

$$P_s = M_s^{1/1-\sigma_s} p_s(\tilde{\varphi}_s)$$
$$Q_s = M_s^{1/\rho_s} q_s(\tilde{\varphi}_s)$$
$$R_s = M_s r_s(\tilde{\varphi}_s)$$
$$\Pi_s = M_s \pi_s(\tilde{\varphi}_s)$$
$$T_s = M_s t_s(\tilde{\varphi}_s)$$

where $z_s(\tilde{\varphi}_s)$ is the average value of z_s whereas Z_s is the sector aggregate value.

Given $(\tau, \{\delta_s\}_{s=1}^S, q_0^G)$, an equilibrium is defined by a collection of sets $\{\Omega_s\}_{s=1}^S$, a vector of productivity cut-offs $\{\varphi_s^*\}_{s=1}^S$, a vector of number of firms $\{M_s\}_{s=1}^S$ and, the consumption and price vectors q_s and p_s (each of size $|\Omega_s|$). These vectors solve the utility maximization problem (1.2.1) and the profit maximization problem of each firm. The equations that solve **q** and **p** have already been provided in the household and firms subsections.

The productivity cutoff φ_s^* is found by equating two conditions on average *after tax* profits. The first condition is derived from the marginal firm which makes zero after tax profit:

$$\bar{\pi}_s = (1-\delta_s\tau) w f_s \left\{ \left[\frac{\tilde{\varphi}_s(\varphi_s^*)}{\varphi_s^*} \right]^{\sigma_s - 1} - 1 \right\}. \tag{ZPC}$$

Since the number of potential entrants into the market is unbounded, the average expected value of a firm equates the cost of entry $F_{e,s}$. The expected value of a firm is the *max* $\{0; \pi_s(\varphi_s)/\psi\}$, where ψ is the probability that a firm goes out of business at the end of the period. Thus, the free entry condition is:

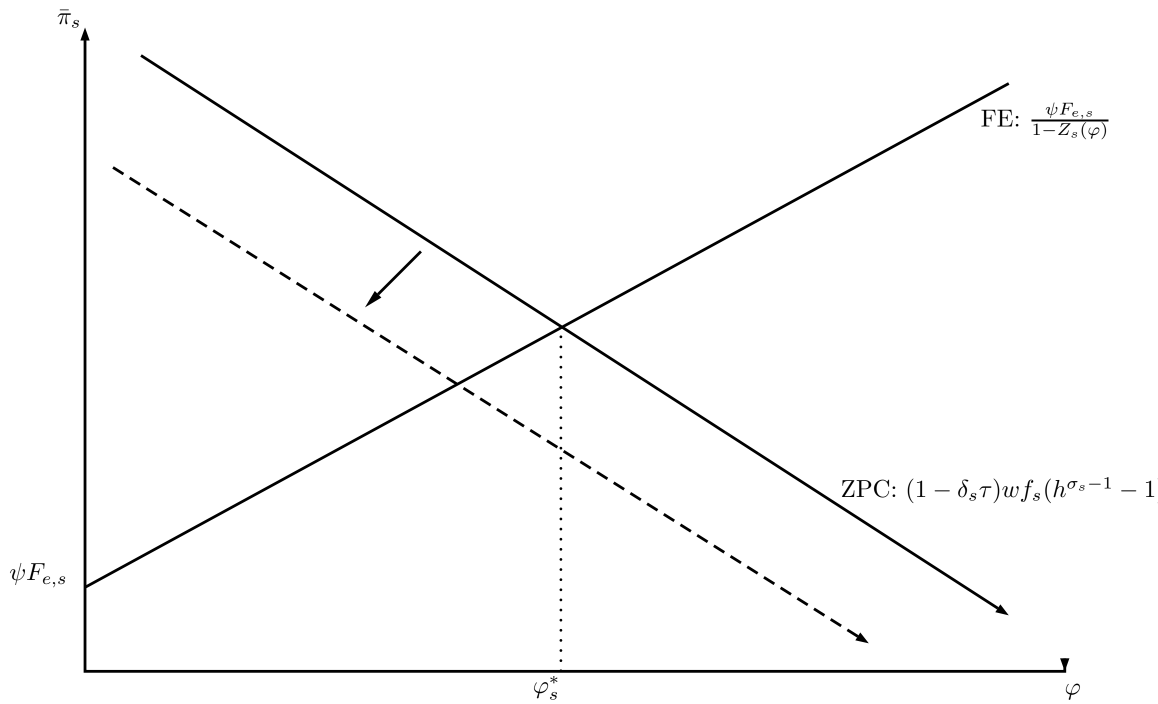
$$\bar{\pi}_s = \frac{\psi}{1 - Z(\varphi_s^*)} w F_{e,s} \ . \tag{FEC}$$

In equilibrium, the (ZPC) and (FEC) conditions hold in every sector determining the equilibrium cutoff productivities. Figure 1.1 shows the graphical representation of the equilibrium φ_s^*.[6]

The economy-wide labor supply L is allocated to firms in the monopolistic competition sectors and, a "firm" that produces the public good for the government and sells it at marginal

[6] An equilibrium in which all sectors are producing only exists if $\delta_s\tau \leq 1$ for all sectors.

Figure 1.1: Equilibrium productivity cutoff using the FEC and ZPC curves



cost. A firm with productivity φ has labor costs equal to $r(\varphi)-\pi(\varphi)-t(\varphi)$.

Aggregating the expression across all firms in sector “s" results in total labor used for production in such sector

$$wL_{p,s} = R_s - \Pi_s - T_s \qquad \forall s \in S\,. \tag{1.2.8}$$

In equilibrium the number of successful new entrants equates the number of exiting firms, thus: $(1-Z_s(\varphi_s^*))M_{e,s} = \psi M_s$. Using this inequality and the FEC condition we find that labor costs spent in entry ($wL_{e,s}$) is equal to sector aggregate profit Π_s. Thus, total labor cost for sector “s" is:

$$wL_s \;=\; wL_{p,s} + wL_{e,s} = R_s - T_s \tag{1.2.9}$$

Summing the above across sectors gives the total labor expenditure by firms in the monopolistic competition sectors.

Finally,the firm that produces public goods uses one unit of labor to produce one unit of q_0^G. Adding the labor used for the production of private consumption goods (eq. 1.2.8) plus that of the public good results in total labor income:

$$wL = \sum_{s=1}^{S} R_s - \sum_{s=1}^{S} T_s + wq_0^G \tag{1.2.10}$$

By clearing the labor market we have obtained an identity for aggregate revenue which is used to solve for the number of firms in equilibrium. To achieve this, use the aggregation identities for R_s and, $R_s = \alpha_s R$ which follows from the Cobb-Douglas preferences. Thus,

$$M_s = \frac{\alpha_s \left(wL + \sum_{i=1}^{S} T_i - p_0^G q_0^G\right)}{\sigma_s u_s f_s h_s^{\sigma-1}} \qquad \forall s \in S \tag{1.2.11}$$

where $p_0^G = w$ is the price of q_0^G. For the closed economy I will use the public good as the nummeraire which implies $w = 1$.

1.2.2 Fiscal Instruments and their effects on Equilibrium

In the following paragraphs I describe the relation between equilibrium variables and the “tax instruments": statutory tax rate (τ) and depreciation allowance rates (δ_s). The main results are a set of propositions that show the differences between the equilibrium responses under Pareto and lognormal distributional assumptions for firms' productivities, and trace such difference to a transmission channel that is erased when assuming a Pareto distribution.

Before proceeding, I define the following variables to facilitate notation and discussion:

$$h_s = \frac{\tilde{\varphi}_s(\varphi_s^*)}{\varphi_s^*} \qquad \xi_{x,y} = \frac{\partial X}{\partial Y}\frac{Y}{X}$$

where h_s is a measure of firm dispersion and $\xi_{x,y}^s$ is the elasticity of variable x with respect to variable y.[7]

[7] $h^{\sigma-1}$ is the ratio given by the revenue of the average firm with respect to the marginal firm. An h_s closer to one implies less heterogeneity in sector s in terms of productivities being $h_s = 1$ the model with

I start by describing the negative relationship between the depreciation allowance rate and the equilibrium cutoff productivity for the relevant sector. To illustrate, consider an increase in $\delta_{s'}$ which translates into a reduction in the user cost $u_{s'}$ and therefore decreasing the after-tax fixed costs of production $(u_{s'} f_{s'})$. These changes imply that the revenue required to make a zero after tax profit has decreased; consequently, the productivity cutoff for sector s' falls. In terms of the equilibrium conditions, the increase in $\delta_{s'}$ shifts the ZPC curve downward for sector s' since τ is greater than zero as long as there is a positive supply of the public good. In Figure 1.1, this shift is represented by the dash line which results in a smaller value of $\varphi^*_{s'}$.

Next, I explain the ambiguous relationship between τ and the productivity cutoffs which depends on the sign of the depreciation allowance rate for the sector. An important consequence is that changing τ affects all sectors simultaneously, but the direction of change of φ^* can be different across sectors. Instead of explaining each direction of the relationship, I find that is more useful to use the table below to show the sign of the changes after an increase in τ

$$\tau \uparrow \begin{cases} \varphi^*_s \downarrow & \text{if } \delta_s > 0 \\ \varphi^*_s \uparrow & \text{if } \delta_s < 0 \\ \varphi^*_s = & \text{if } \delta_s = 0 \end{cases}$$

the above relationships are a consequence of the $(1 - \delta\tau)$ factor in the ZPC equation. To understand this relationship, we must remember that a firm increases their operating profit by $\tau\delta w f_s$. When $\delta > 0$, an increase in τ increases operating profit which reduces the threshold productivity for the marginal firm; the case in which $\delta < 0$ has the exact opposite implication as the operating profits decrease for any level of productivity.

Now that the links between the tax instruments and the cutoff productivities have been determined I show that the change in average productivity has a special property under the Pareto assumption. Of course an increase in φ^*_s is positive for $\tilde{\varphi}_s$ regardless of distribution, but the relation is stronger under Pareto:

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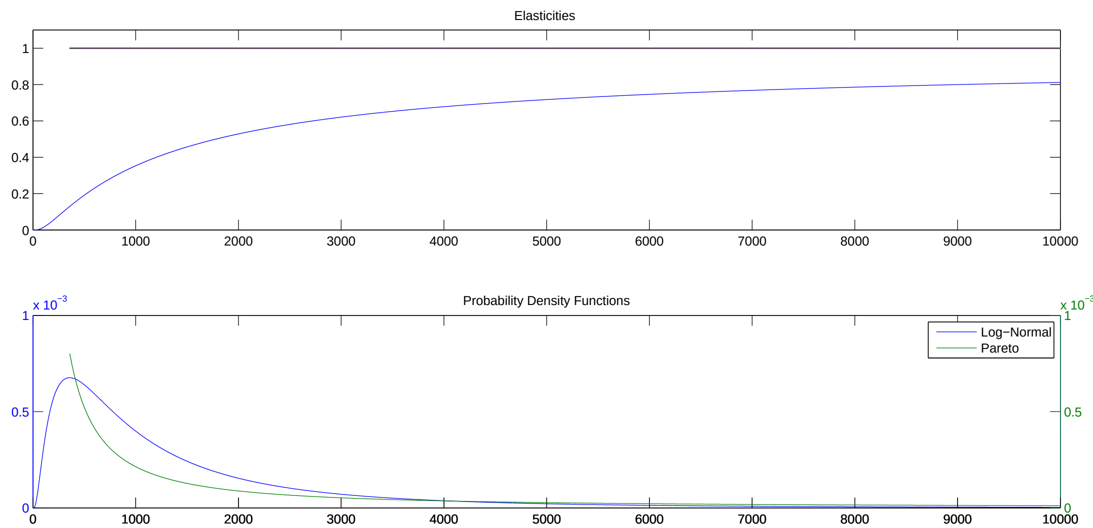
one representative firm in sector s or homogeneous firms

Figure 1.2: Log-normal distributions with parameters $m = 6.88$ and $v = 1$. Pareto distribution parameters selected to match the mode and mean of the lognormal distribution



Proposition 1.2.1. *For any random distribution $Z(\varphi)$ the value of $\xi_{\tilde{\varphi},\varphi^*}$ is strictly positive. If $Z \sim \log\mathcal{N}$ then $\xi_{\tilde{\varphi},\varphi^*} < 1$. If the random distribution is Pareto this elasticity is constant along the support of φ and $\xi_{\tilde{\varphi},\varphi^*} \equiv 1$*

Proof. Appendix 1.C.1 □

The property in proposition 1.2.1 is key since changes in τ, δ lead to alterations in h when the distribution is lognormal, while a Pareto distribution implies a constant value of h. Simply put, the assumption of a Pareto distribution of productivity precludes a sector recomposition that results in a wider/narrower disparity between the marginal and average firm. Furthermore, the constant versus variable h has consequences for the determination of the equilibrium as this variable appears in the ZPC equation.

The value $\xi_{\tilde{\varphi},\varphi^*}$ is determinant to the response in the number of firms to changes in the tax rates. To illustrate, the elasticities of the number of firms with respect to the statutory tax rate and the depreciation allowance rate are:

$$\xi_{M_s,\delta_{s'}} = \frac{\sum_{i=1}^{S} \frac{\partial T_i}{\partial \delta_{s'}} \delta_{s'}}{wL + \sum_{i=1}^{S} T_i - p^g q_0^G} - \left[\frac{-\tau\delta_s}{(1-\delta_s \tau)} + (\sigma_s - 1)\left(\xi_{\varphi_s^*,\delta_{s'}} \left[\xi_{\tilde{\varphi}_s,\varphi_s^*} - 1 \right] \right) \right] \quad \text{if s=s'}$$

$$\xi^s_{M_s,\tau} = \frac{\sum_{i=1}^{S} \frac{\partial T_i}{\partial \tau} \tau}{wL + \sum_{i=1}^{S} T_i - p^g q_0^G} - \left[\frac{(1-\delta_s)\tau}{(1-\tau)(1-\delta_s \tau)} + (\sigma_s - 1)\left(\xi_{\varphi^*,\tau} \left[\xi_{\tilde{\varphi}_s,\varphi_s^*} - 1 \right] \right) \right]$$

Using proposition 1.2.1, we can clearly see that the Pareto distributions annihilate the last term inside the square bracket of the above elasticities. This erased term captures the change in the dispersion of the firms, which is a measure of the new competition landscape for the sector.

Building upon the previous results I provide ordinal statements regarding ξ_M under the two distributional assumptions of productivity.

Proposition 1.2.2. *Assume that the government runs a balanced budget. Let ξ^P be the elasticities implied from assuming a Pareto distribution and ξ^{log} be the elasticities obtained under a lognormal distribution of productivity.*

- *Let $s \neq s'$, then $\xi^{log}_{M_s,\delta_{s'}} = \xi^{P}_{M_s,\delta_{s'}} = 0$*
- *Let $s = s'$ then $\xi^{log}_{M_s,\delta_{s'}} < \xi^{P}_{M_s,\delta_{s'}}$. Furthermore if $\delta > (\leq) 0$ then $\xi^{P}_{M_s,\delta_{s'}} > (\leq) 0$*

Proof. See Appendix 1.C.2 □

The above proposition says that $\xi^{log}_{M_{s'},\delta_{s'}}$ is always lower than its Pareto counterpart, but its sign is not always determined. When $\delta_{s'} \leq 0$ the magnitude of change in the number of firms under lognormal distribution is greater; however, it is not possible to sign $\xi^{log}_{M_{s'},\delta_{\prime}}$ when $\delta_{s'} > 0$. The last case is intriguing since it opens the possibility that the direction of change for $M_{s'}$, following changes to $\delta_{s'}$, will have different signs for each distributional assumption of productivities.

Turning to the statutory corporate tax rate:

Proposition 1.2.3. *Assume $\sum_{i=1}^{S} T_i = p^g q_0^G$. Let ξ^P be the elasticities implied from assuming a Pareto distribution and ξ^{log} be the elasticities obtained under a lognormal distribution of productivity.*

- *If $\delta_s \leq 1$ then $\xi_{M_s,\tau}^{log} < \xi_{M_s,\tau}^{P} \leq 0$.*
- *If $\delta_s > 1$ then $\xi_{M_s,\tau}^{log} < \xi_{M_s,\tau}^{P}$ Furthermore, $\xi_{M_s,\tau}^{P}$ is positive but $\xi_{M_s,\tau}^{log}$ can't be signed.*

Proof. See Appendix 1.C.3 □

Interpretation and consequences of proposition 1.2.3 are similar to those of proposition 1.2.2 so they are skipped.

1.3 Optimal Fiscal Policy in the Closed Economy

This section describes and solves the optimal corporate tax rate under a fiscal framework designed to capture the important features of the corporate tax codes observed in the real world.

The government problem is to choose the optimal effective corporate tax rates that raise tax revenue sufficient to finance government expenditure $p^g q_0^G$, while maximizing national welfare. Let $E(\tau, \{\delta_s\}_1^S)$ be the set of optimal consumption and price vectors for given τ and $\{\delta_s\}_1^S$. The government problem is:

$$\max_{\tau, \{\delta_s\}_1^S} \quad L q_0^G + L \prod_{s=1}^{S} Q_s^{\alpha_s} \tag{1.3.1}$$

such that

$$\sum_{s=1}^{S} T_s \geq p^g q_0^G \tag{1.3.2}$$

$$(q^*, p^*) \in E(\tau, \{\delta_s\}_1^S) \tag{1.3.3}$$

$$0 < \tau \leq 1 \qquad \delta_s < 1/\tau \qquad \forall s \in S$$

Note that the fiscal authority must raise tax revenue using two instruments: a statutory corporate tax rate and depreciation allowance rates. In one hand, changing τ affects the equilibrium productivity in all sectors, and consequently the price indexes which determine welfare. On the other hand, it can affect a specific sector by modifying the relevant depreciation allowance rate, thereby enhancing or mitigating the effects of τ in the sector equilibrium productivity and number producing firms. Thus, the government can use cross sector heterogeneity to impose "differentiated" effective tax rates between the sectors.

The F.O.C of the government problem for δ_s and τ, respectively, can be written in terms of elasticities as follows:

$$\sum_{i=1}^{S} \alpha_i \left(\frac{1}{1-\sigma_i} \xi_{M_i,\delta_{s'}} - \mathscr{I}_{i=s'} \left(\xi_{\tilde{\varphi}_i,\varphi_i^*} \xi_{\varphi^*,\delta_{s'}} \right) \right) \leq \delta_{s'} \tilde{\lambda} \sum_{i=1}^{S} \frac{\partial T_i}{\partial \delta_{s'}} \quad \forall s' \in S \quad (1.3.4)$$

$$\sum_{i=1}^{S} \alpha_i \left(\frac{1}{1-\sigma_i} \xi_{M_i,\tau} - \xi_{\tilde{\varphi}_i,\varphi_i^*} \xi_{\varphi^*,\tau} \right) = \tau \tilde{\lambda} \sum_{i=1}^{S} \frac{\partial Ti}{\partial \tau} \quad (1.3.5)$$

$$\lambda \left(q_0^G - \sum_{i=1}^{S} T_i \right) = 0 \quad (1.3.6)$$

$$\tilde{\lambda} = \frac{\mathbb{P}\lambda + 1}{Y} \quad (1.3.7)$$

Here λ is the Lagrange multiplier associated with the government budget constraint, $\mathscr{I}$ is the indicator function and, $\mathbb{P}$ is the wide economy price index.[8] The second equation holds with equality since it is assumed that $q_0^G > 0$ and tax revenue can't be positive unless $\tau > 0$.

Expressing the FOCs iun this way shows the centrality of the distributional assumptions about productivity for the optimal tax problem as evident in the appearance of the elasticities of section 1.2.2 in the above FOCs.

Proposition 1.3.1. *Assuming that the government budget constraint is binding, the Lagrange*

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$$\mathbb{P} = \Pi_{i=1}^{S} \left(\frac{\mathbb{P}_s}{\alpha_s} \right)^{\alpha_s}$$

multiplier (λ) is given by:

$$\tilde{\lambda} = \frac{\sum_{i=1}^{S} \dfrac{\alpha_i}{\sigma_i - 1}}{wL\sum_{i=1}^{S} \dfrac{\alpha_i}{\sigma_i} - p^g q_0^G}$$

Proof. See Appendix 1.C.4 □

After establishing the conditions for a binding constraint and the multiplier value associated with it, I proceed to show the optimal tax/depreciation rates for the two different distributional assumptions of productivities.[9]

1.3.1 Optimal tax policy under Pareto

Assume productivities follow a Pareto distribution with CDF $Z_s(x) = 1 - \left(\frac{\varphi_{min,s}}{x}\right)^{k_s}$. The optimal statutory tax rate and depreciation allowance rates are:

$$\xi_{\varphi_i^*,\delta_i} = \xi_{\varphi_i^*,\tau} = \frac{-\tau\delta_i}{k_i(1-\delta_i\tau)} \tag{1.3.8}$$

$$1-\tau = \left[\sum_{i=1}^{S}\frac{\alpha_i}{k_i}\right]\left[\tilde{\lambda} wL \sum_{i=1}^{S}\frac{\alpha_i\rho_i}{k_i}\right]^{-1} \tag{1.3.9}$$

$$1-\delta_{s'}\tau = \left(\sum_{i=1}^{S}\frac{\alpha_i}{k_i}\bigg/\sum_{i=1}^{S}\frac{\alpha_i\rho_i}{k_i}\right)\rho_{s'} \tag{1.3.10}$$

Proposition 1.3.2. *The differences between sector depreciation rates are proportional to the elasticities of substitutions between their sectors. Furthermore, the ratio of usercosts is solely a function of such elasticities:* $\frac{u_{s'}}{u_s} = \frac{\rho_{s'}}{\rho_s}$.

The above proposition simply says that in an economy with Pareto distributions, firms in sectors with higher elasticities of substitutions get smaller depreciation allowance rates relative to sectors with lower elasticities of substitution. Going a step further, the elasticity of substitution within each sector is the sole driver for the targeted depreciation allowance rates.

Understanding the mechanics behind this result is useful since there are similar forces acting in the case of lognormal distributions. Consider two different sectors s', s with the

[9] Derivation of the optimal rates and the solution strategies are found in Appendix 1.A.1.

same shape parameter k but different elasticities of substitution and without loss of generality assume that $\sigma_{s'} > \sigma_s$. The key variable that drives the equilibrium results is $h^{\sigma-1}$, which appears in the ZPC condition and the formulas for M_s (equation 1.2.11). By proposition 1.2.1 we know that $h^{\sigma-1}$ is constant, regardless of the equilibrium value of φ^*; moreover, this variable is increasing in σ since in equilibrium $h_s^{\sigma_s-1} = \dfrac{k_s}{k_s-(\sigma_s-1)}$.

First, the result that h is constant under Pareto implies that changes in the tax instruments only modify the ZPC equation via the factor $(1-\delta\tau)$. Since this factor is multiplied by $(h^{\sigma-1}-1)$, changes in the tax instruments will have a greater effect in the productivity cutoff in sector s' relative to s. In subsection 1.2.2 we saw that decreasing δ_s increases the productivity cutoff φ_s^*; therefore, the government gives the smaller depreciation allowance rate to sector s' since it gains the most in terms of equilibrium productivities. The increase in productivities translates to higher welfare as the price index decreases.

Second, there is a trade off from having a high σ as it's negatively related to the number of equilibrium firms, which itself lowers the price indexes.[10] The denominator in equation 1.2.11 shows that the government could improve the number of firms by decreasing the user-cost, i.e increasing the depreciation allowance rate. The government does this for sector s as it has a higher impact on M relative to sector s'. Hence, the government aims to decrease the price index for sector s by increasing M_s.

The next proposition contains a surprising and strong result regarding the relation of depreciation allowance rates across all sectors.

Proposition 1.3.3. *Let the economy consist of S sectors with equal expenditure shares i.e,* $\alpha_i = \bar{\alpha} = 1/S$. *When productivities are Pareto distributed with homogeneous shape parameter* $\bar{k}$, *then* $\sum_{i=1}^{S} \delta_i^P = 0$.

Proof. See Appendix □

The above result says that regardless of the degree of heterogeneity in the fixed costs across the sectors, if market shares and Pareto shape parameters are the same, then the de-

[10] This is a common feature of monopolistic competition models with CES preferences.

preciation allowance rates will add up to zero. Notice that there isn't a condition on the distribution parameter φ_{min} only on the shape parameter k since h is only a function of the latter.

The next proposition describes how the optimal statutory tax rate reacts to changes in the shape parameter k. The direction of the change in τ is dependent on whether the increase in k occurred in an sector with a higher or lower elasticity of substitution relative to all other sectors. Consider the case in which the change happens in the sector with the highest σ, then the increase in k implies an increase in h and based on the discussion of proposition 1.3.2, the result is a significant increase in equilibrium productivity. Since more productive firms earn higher profits, the government can thereby reduce the statutory tax rate while satisfying its budget constraint, which in turn generates additional productivity gains across all sectors.

Proposition 1.3.4. *Let $i' \neq i \in S$. Then,*

- $\frac{\partial \tau}{\partial k_{i'}} < 0$ *if* $\sum_{i \neq i'} \frac{\alpha_i}{k_i}(\rho_i - \rho_{i'}) < 0$. *This condition is automatically fulfill if $\rho_{i'}$ is the maximum of all ρ's.*
- $\frac{\partial \tau}{\partial k_{i'}} > 0$ *if* $\sum_{i \neq i'} \frac{\alpha_i}{k_i}(\rho_i - \rho_{i'}) > 0$. *This condition is automatically fulfill if $\rho_{i'}$ is the minimum of all ρ's.*

1.3.2 Optimal tax policy under lognormal

Now, assume productivities follow a distribution $Z_i \sim log\ \mathcal{N}(m_i, v_i)$. In this economy, the average productivity in equilibrium can be expressed as:

$$\begin{aligned}\tilde{\varphi}_i^{\sigma-1} &= \exp\left(m_i(\sigma_i - 1) + \frac{((\sigma_i-1)v_i)^2}{2}\right)\frac{\Phi((\sigma_i-1)v_i - d_i)}{\Phi(-d_i)} \\ &= A_i g_i(\varphi_i^*)\end{aligned}$$

where Φ is the CDF of the standard normal distribution and $d_i = \frac{log(\varphi_i^*) - m_i}{v_i}$. The marginal productivity cutoff has to be solved numerically using:

$$\frac{A_i g_i(\varphi_i^*)}{(\varphi_i^*)^{\sigma-1}} = \frac{\psi F_{e,i}}{(1-\delta_i\tau)\Phi(-d_i)f_i} + 1$$

While the optimal tax rates for this economy don't have closed form solutions, it is possible to make some analytical comparisons of these optimal tax rates with those obtained under the Pareto distribution. First, consider the elasticity of productivity cutoff with respect to τ, δ:

$$\xi_{\varphi_i^*,\delta_i} = \xi_{\varphi_i^*,\tau} = \frac{\psi F_{e,i}}{X_i(1-\sigma_i)}\left(\frac{\tau\delta_i}{1-\tau\delta_i}\right) \tag{1.3.11}$$

$$X_i = \psi F_{e,i} + (1-\delta_i\tau)\Phi(-d_i)f_i \tag{1.3.12}$$

Unlike the case of Pareto distributions, these elasticities are dependent on the fixed cost of production and entry. Moreover, the elasticities are functions of the current level of φ^*, since h is variable in the lognormal case.

The key difference between the optimal tax policies of government in the lognormal environment is given in the following proposition:

Proposition 1.3.5. *The optimal statutory corporate tax rate under Pareto productivities is greater than or equal to its counterpart found under lognormal distributions. The inequality is strict if there is at least one sector that is asymmetric to the rest.*

Proof. Appendix 1.C.4 □

The result of this proposition highlights that the government in the lognormal scenario has another transmission channel of their policies via alterations of h, which is muted in the Pareto case. These additional channels allows the government to take full advantage of sector asymmetries by using δ more heavily than τ as the latter affects all sectors simultaneously.

1.3.3 Optimal fiscal tools as functions of selected parameters

I continue by exploring the difference in responses of optimal depreciation and tax rates to changes in the elasticity of substitution, country size, government spending and fixed costs. To ease the exposition the economy is restricted to two almost identical sectors whose only difference lie in their elasticity of substitution σ_i. The parameters for the model are found in table 1.1, values are standard except for the productivity parameters which are explain in the footnote.[11]

The take away from all these response functions is twofold. First, the productivity distribution assumption is not important when sectors are identical but becomes critical when the economy is composed of asymmetric sectors. Moreover, the divergence between the optimal rates implied by each distributional assumption increases with the degree of asymmetry between sectors, especially when the asymmetry involves the elasticity of substitution. Second, if an sector experiences changes in fixed cost (production or entry) then each distributional assumption will result in completely different responses for the depreciation allowances and the corporate tax rates.

Although a full symmetric case is not used as a baseline, the response functions in Figure 1.4 contain a point ($\sigma_2 = 2.5$) for which both sectors are completely symmetric. This special case generates depreciation rates equal to zero for both sectors regardless of distributional assumption. Intuitively, when both sectors are completely symmetrical they can be aggregated into one sector with the same properties. In this case, the government can't improve upon the

[11] The lognormal distribution parameters (m_i, v_i) are similar to the average of the LAC region while the Pareto distribution parameters $(k_i, \varphi_{min,i})$ are found by matching the mean and variance of both distributions. We do not use the empirical values for k_i as they are in the neighborhood of 1 implying values of σ significantly lower than those used in the literature. By matching the variances we impose that the Pareto distribution variance is finite, which implies that k is strictly greater than 2. Solving for the Pareto distribution parameters leads to a quadratic polynomial for k; choosing the non-negative root gives the following formulas:

$$\begin{aligned} k_i &= 1 + \sqrt{\frac{\exp(v_i^2)}{\exp(v_i^2) - 1}} \\ \varphi_{min,i} &= \exp(m_i + \frac{v^2}{2}) \frac{k_i}{k_i - 1} \end{aligned}$$

free market (“first best") outcome by shifting resources across the sectors. The “first best" is the productivity equilibrium found in Melitz (2003), which is attained in my model by setting δ or τ to zero. Since $q_0^G > 0$, the corporate tax rate is strictly positive which implies depreciation rates are optimally zero.

The requirements to obtain optimal depreciation allowances equal to zero depend on the distribution of productivity

Proposition 1.3.6. *Let $q_0^G > 0$ and $\lambda > 0$. The conditions for $\delta_i = 0 \quad \forall i$ are:*

1. *Pareto distribution: The shape parameter and elasticity of substitution must be equal across sectors ($k_i = \bar{k} \quad \forall i \in S$, $\sigma_i = \sigma \quad \forall i \in S$).*

2. *Log-normal distribution: The sectors in the economy must be symmetric in all respects.*

Proof. See Appendix 1.C.4. □

The condition placed on the Pareto model is significantly weaker from that of lognormal model. Part of the condition imposes homogeneous shape parameters across sectors but not necessarily on the productivity cutoff parameter. Once again, this is a result of h being fully determined by σ, k and fixed to a constant value under Pareto. As mentioned previously, the optimal rates in the Pareto setting don't depend on the fixed cost of production, hence there is no need to impose symmetry on them. In contrast, the optimal rates in the lognormal environment are affected by such costs and thus a stringent condition is needed to obtain all depreciation allowances set optimally to zero.

I now describe the sensitivity of optimal tax instruments rates and equilibrium responses as the elasticity of substitution in sector 2 varies between 2 and 3.5 (the substitution elasticity for sector 1 is fixed at 2.5). In Figure 1.4, the solid lines are values under the lognormal assumption and the dash lines represent values from assuming a Pareto distribution.

Optimal depreciation rates produced under lognormal productivities exhibit a larger degree of responsiveness to changes in σ_2 when compared to their Pareto counterparts; the divergence between such rates increases as the distance between σ_1 and σ_2 grows larger.

This divergence occurs even though the Pareto and lognormal productivity distributions have the same unconditional mean and variance. Thus, the divergence is mainly a result of the extra channel of effect (through $\xi_{\tilde{\varphi},\varphi^*}$) that the lognormal setting posses.

In contrast to the optimal depreciation allowance rates, the response functions for τ are more responsive when Pareto distributions are assumed and, as stated in proposition 1.3.5, $\tau^{log} < \tau^P$. The take away of this analysis is that a policymaker in an environment with Pareto distributed productivity will optimally distribute the burden of taxation more evenly across the sectors than the lognormal case. Importantly, the relative small differences in observed tax and depreciation allowance rates have significant implications for the number of firms in each sector and the efficiency of the marginal firm.

A common property of the optimal depreciation rates across both productivity distribution is that the sector with the smallest elasticity of substitution is given the lesser of the depreciation allowances. In proposition 1.3.2 I explained the mechanics for this property for the Pareto case. The same applies for the lognormal environment with the addition that the term $h^{\sigma-1}$ is variable for this setting, hence depreciation rates change more drastically in the lognormal environment.

Next, figure 1.5 shows the response functions for changes in government spending, country size, entry cost and fixed costs of production. As government expenditure increases, the budget constraint becomes tighter, which limits the ability of governments to exploit the variability of productivity distributions; hence, we observe a convergence in the values of δ and τ of the two distributional assumptions. When L increases, the corporate tax rate decreases as firms in both sectors earn higher revenues. Since changes in q_0^G, L affect both sectors equally via $\tilde{\lambda}$ and the income available to spend, response functions of τ, δ are approximately the same under both productivity distribution assumptions.

The last two rows show the responses to changes in fixed cost of production and entry in sector 2. The optimal δs response functions in a Pareto environment are invariant to changes in fixed costs while the optimal δs under lognormal present some response; the optimal response of τ exhibits the same property.

1.3.4 Inefficient outcomes from assuming a Pareto distribution

To finalize this section, I study the welfare implications of a government mis-specifying the productivity distribution when deciding the optimal depreciation and corporate tax rates. Based on recent theoretical and empirical research, as well as evidence in section 1.6.2, I posit that countries contain firms that draw their productivities from a lognormal distribution and conduct the following experiment. First, I compute the optimal δ and τ using the formulas implied by the Pareto setting. I call these the “null" optimal rates and use them used to compute the equilibrium for the economy.[12] Next, the process is repeated but using the “alternative" formulas for the optimal rates, i.e the formulas under the lognormal assumption. I then compare the outcomes of the model as well as the ratio of welfare of the “null" model and the “alternative" model. Welfare under both models is comparable since household income can receive lump sum taxes when the government budget constraint doesn't hold with inequality and amount of public good q_0^G is the same for the “alternative" and “null" model. Experiments are conducted under 5 different scenarios and the results of these are reported in Table 1.1, where the “null" model outcomes are displayed on the top lines while “alternative" model values are directly underneath.[13]

The almost symmetric scenario shows that using the simpler Pareto formulas for the optimal δs and τ carries a 0.14% loss in welfare relative to using the “alternative" formulas. The “alternative" and “null" models have equilibrium outcomes that are almost identical, except for the depreciation allowances which are non-symmetric across sectors for the lognormal case.

[12] These rates are not the solution to the government problem and therefore the budget constraint may not hold with equality, i.e $\Sigma T_i \neq p^g q_0^G$. Hence, the number of firms for this equilibrium is found as the solution to the system of equations:

$$M_s = \frac{\alpha_s(wL + \Sigma_{i=1}^S T_i - p^g q_0^G)}{\bar{r}_s} \qquad s = 1,2$$

[13] We continue to find the Pareto distribution parameters by matching the mean and variance

The next two scenarios have sector asymmetries in the fixed cost of production or entry costs. For these scenarios the penalties in welfare are larger than that of the almost symmetric case; albeit, the equilibrium variables for both models are almost equal to each other. The optimal δ, τ under Pareto are the same as those of the almost symmetric scenario, but these rates differ from the baseline scenario in the lognormal case. The adaption of fiscal rates to changes in fixed cost drives the improvement in welfare benefits from using the "alternative" rates.

The next scenario increases the difference between the elasticities of goods substitution between the sectors. This scenario generates the most significant losses in welfare from using the "null" rates in the economy whose firms have lognormal distributed productivity. The loss in welfare is over 2%, which is significantly higher than any of the other losses in the previous scenarios. Moreover, the equilibrium outcomes of the two models are considerably different particularly for the number of firms and optimal tax rates. The policies obtained from a lognormal rely on targeting specific sectors at different rates instead of heavily readjusting τ, as is the case with the Pareto assumption. These results, coupled with the evidence in the variability of σ across sectors, illustrates the importance of computing the optimal depreciation and tax rates using the proper distributional assumption. The analytically convenient assumption that productivities follow Pareto distribution is not innocuous for welfare in the context of corporate tax policy.

1.4 Open Economy

This section extends the model into the open economy to study the linkage between export status and corporate taxation. I find that my model provides a basis for explaining conflicting empirical results regarding this linkage. In my model, modifications to the statutory corporate tax rate alone generates an ambiguous change in the probability of becoming an exporter, with the sign of the change being determined by the value of the depreciation allowance rate. Expanding on this point, in the next section I show that in a symmetric country setting, the probability of exporting is invariant to changes in tax rates when Pareto distribution are assumed. This property fails to hold in the lognormal case, reinforcing the argument that Pareto distributions eliminate important channels of economic change induced by modifications in effective corporate tax rates.

Additionally, including corporate taxes can solve an important issue of the multi-sector Melitz model regarding unilateral liberalization of some sectors.[14] The evidence (see Trefler 2004) tells us that following unilateral liberalization there is a stronger rise in productivity in the liberalized sectors, relative to those that are not liberalized. In theory, Demidova and Rodriguez-Clare (2013) find that a one sector Melitz model generates such implication; however, Segerstrom and Sugita (2014) find that such implication doesn't hold when a multi-sector Melitz model is considered. In fact, they find that such model generates the reverse implication under very general conditions. My model can reconcile the theory and empirical evidence by accounting for changes in corporate tax rates faced by specific sectors, which offsets/enhance the productivity gains from a unilateral tariff reduction.

The next paragraphs contain only the key elements and results of the model when countries open to trade and under the assumption that utilities are identical across countries. A general model derivation with N countries and asymmetric parameters of the utility (α, σ) is provided in Appendix 1.B.

1.4.1 Setup, Aggregation and Equilibrium

I assume that household preferences in both nations have the same functional form and parameters as in section 2, with the exception of sector markets shares α, and no labor migration across borders is allowed. Since consumers can now buy products from another countries I use x_{jis} to represent a variable from country j with final market in country i, for sector s.

The timing of decisions by the firm is the same as in the closed economy, but firms serving the domestic market can choose to serve the foreign country via exports. Thus, after

[14] Unilateral liberalization refers to a a single country reducing their trade barriers/cost to imports

a firm (from sector s) in country j draws its productivity from the distribution $Z_s^j(\varphi)$ they decide whether to serve country i via exports or remain solely a domestic supplier. Shipping goods across countries involves an iceberg trade cost $\theta_{jis} \geq 1$; and exporting firms pay a fixed investment cost of f_{jis} every period which is subject to the depreciation allowance rate δ_{js}. Hence, the after tax profit formula for a representative firm in country j is:

$$\pi_{js}(\varphi) = (1-\tau_j)\left(\frac{r_{jjs}(\varphi)}{\sigma_s} - u_{js}w_j f_{jj} + \mathscr{I}_{export}\left(\frac{r_{jis}(\varphi)}{\sigma_s} - u_{js}w_j f_{jis}\right)\right) \quad (1.4.1)$$

$$r_{jis}(\varphi) = \left(\frac{p_{jis}(\varphi)}{\mathbb{P}_{is}}\right)^{(1-\sigma_s)} Y_{is} \quad (1.4.2)$$

Define φ^*_{jj}, φ^*_{ji} as the cutoff productivity levels for the marginal firm that decides to serve the domestic market and the productivity level of the marginal firm that chooses to, in addition, export to country i. Using $\tilde{\varphi}(\ )$ (equation 1.2.7) define the average productivity of all firms producing in j ($\tilde{\varphi}_{jj}$) and the average productivity of firms that export their goods to i ($\tilde{\varphi}_{ji}$):

$$\tilde{\varphi}_{jj} = \tilde{\varphi}^j(\varphi^*_{jj}) \qquad \tilde{\varphi}_{ji} = \tilde{\varphi}^j(\varphi^*_{ji})$$

The number of producing firms in sector "s" based in country j is M_{js} with a subset $M_{jis} = \kappa^x_{jis} M_{js}$ serving country i via exports; where κ_{ji} is the conditional probability of becoming an exporter.[15] Hence, the total amount of products available to consumers in country j is $M^j_{tot,s} = M_{js} + M_{ijs}$.

With the above, the price index for sector s as well as the average productivity of firms *selling* in country j sector "s":

$$\tilde{\varphi}^j_{tot,s} = \left[\frac{1}{M^j_{tot,s}}\left(M_{js}\left(\tilde{\varphi}_{jj}\right)^{\sigma_s-1} + M_{ijs}\left(\hat{\theta}^{-1}_{ijs}\tilde{\varphi}_{ijs}\right)^{\sigma_s-1}\right)\right]^{\frac{1}{\sigma_s-1}} \quad (1.4.3)$$

$$\mathbb{P}_{js} = \left(M^j_{tot,s}\right)^{\frac{1}{1-\sigma_s}} p_{jjs}(\tilde{\varphi}^j_{tot,s}) \quad (1.4.4)$$

[15] $\kappa^x_{jis} = \dfrac{1-Z_{js}(\varphi^*_{jis})}{1-Z_{js}(\varphi^*_{jjs})}$

where $\hat{\theta}_{ijs} = \frac{w_i \theta_{ijs}}{w_j}$ measures a combination of shipping costs and wages (input costs in this model). The total average productivity ($\tilde{\varphi}_{tot,s}$) is the weighted average of mean productivities of all domestic firms and the firms shipping into the country.

The sector price index formulas are needed to solve for the equilibrium since the new zero profit condition (ZCP) contains domestic and export productivity cutoffs that have to be linked through the sector price index. To be more clear, the new ZCP condition is:

$$\bar{\pi}_{js} = (1 - \delta_{js}\tau_j)\left[w_j f_{jjs}\left(\left(\frac{\tilde{\varphi}_{jjs}}{\varphi^*_{jjs}} \right)^{\sigma_s - 1} - 1 \right) + \kappa^x_{jis} w_{js} f_{jis}\left(\left(\frac{\tilde{\varphi}_{jis}}{\varphi^*_{jis}} \right)^{\sigma_s - 1} - 1 \right) \right] \tag{1.4.5}$$

and to solve φ^*_{jis} it must be expressed as a function of φ^*_{jjs}:

$$\varphi^*_{jis} = \left[\frac{M^i_{tot,s}}{M^j_{tot,s}} \right]^{\frac{1}{\sigma_s - 1}} \frac{\tilde{\varphi}^i_{tot,s}}{\tilde{\varphi}^j_{tot,s}} \left[\frac{Y_{js}}{Y_{is}} \frac{f_{jis}}{f_{jjs}} \right]^{\frac{1}{\sigma_s - 1}} \hat{\theta}_{jis} \varphi^*_{jjs} \tag{1.4.6}$$

Notice that the above equation expresses the export productivity cutoff for country j as a function of other productivity cutoffs, including those of country i. Many papers at this point invoke a symmetry assumption across the countries making the above sufficient to pin down the equilibrium productivities. However, in my model even if countries were completely symmetric in all their parameters but one of their corporate tax rates, it would generate different domestic cutoffs which translate into heterogeneous equilibrium outcomes between the countries. Borrowing from Segerstrom and Sugita (2015), I use the relationship between the domestic and import productivity cutoffs:

$$\varphi^*_{jis} = \left(\frac{u_{js} w_j f_{jis}}{u_{is} w_i f_{ii}} \right)^{\frac{1}{\sigma_s - 1}} \hat{\theta}_{ji} \varphi^*_{ii} \tag{1.4.7}$$

to convert equation 1.4.6 into a function of φ^*_{jj} only.

Lastly, the number of firms is solved to complete the description of the equilibrium. This is simple as labor used for production is still given by $r(\varphi) - \pi(\varphi) - t(\varphi)$ and we can use the same procedure as in section 3 to obtain aggregate revenue $R = wL + \sum T - p^g q^G_0$. Therefore, the equilibrium is found by solving a $S\times 2\times 2$ simultaneous system of equations consisting of the following 2 equations for each sector, for each country:

$$ZCP_s = FE_s \tag{1.4.8}$$

$$M_{js} = \frac{\alpha_{js}(w_j L_j + \Sigma_{s'=1}^{S} T_{js'} - p_j^g q_0^G)}{\sigma_{js} u_{js} w_j \left(f_{jjs} h_{jjs}^{\sigma_s - 1} + \kappa_{jis}^x f_{jis} h_{jis}^{\sigma_s - 1} \right)} \tag{1.4.9}$$

where $h_{jj} = \tilde{\varphi}_{jj}/\varphi_{jj}^*, \quad h_{ji} = \tilde{\varphi}_{ji}/\varphi_{ji}^*$

1.4.2 Tax rates and the decision to export

This subsection provides a detailed account of the relationship between the export productivity cutoffs and corporate tax rates. I find that the conditional probability of exporting κ is negatively related to the depreciation rate (in the source country), but the relationship with the statutory corporate tax rate is ambiguous. The first part of the result is not surprising as increasing δ decreases the cost of f_{ji} which incentives more firms to enter the export markets, all else equal. However, the direction of change for modification in τ is ambiguous as it depends on the level of δ. These properties can possibly explain why Bernini and Treibich (2013) and Federici and Parisi (2014) find opposite signs for the correlation between the proportion of exporting firms and corporate tax rates.

The effects of changes in δ, τ on the probability of exporting (κ^x) are expressed in terms of the elasticities of φ^*. Let Z_{js} be the productivity distribution in country j sector s, then:

$$\Upsilon_{js}(x) = \frac{z_{js}(x)x}{1 - Z_{js}(x)} \tag{1.4.10}$$

$$\frac{\partial \kappa_{jis}^x}{\partial y} y = \kappa_{jis}^x \left(\Upsilon(\varphi_{jjs}^*) \xi_{\varphi_{jjs}^*, y} - \Upsilon(\varphi_{jis}^*) \xi_{\varphi_{jis}^*, y} \right) \qquad \text{for y} = \tau, \delta \tag{1.4.11}$$

the function $\Upsilon(x)$ has the following properties:

- If $Z_{js} \sim Pareto(k_{js}, \varphi_{min})$ then $\Upsilon(\varphi) = k_{js}$ for any φ in the support of Z_{js}.

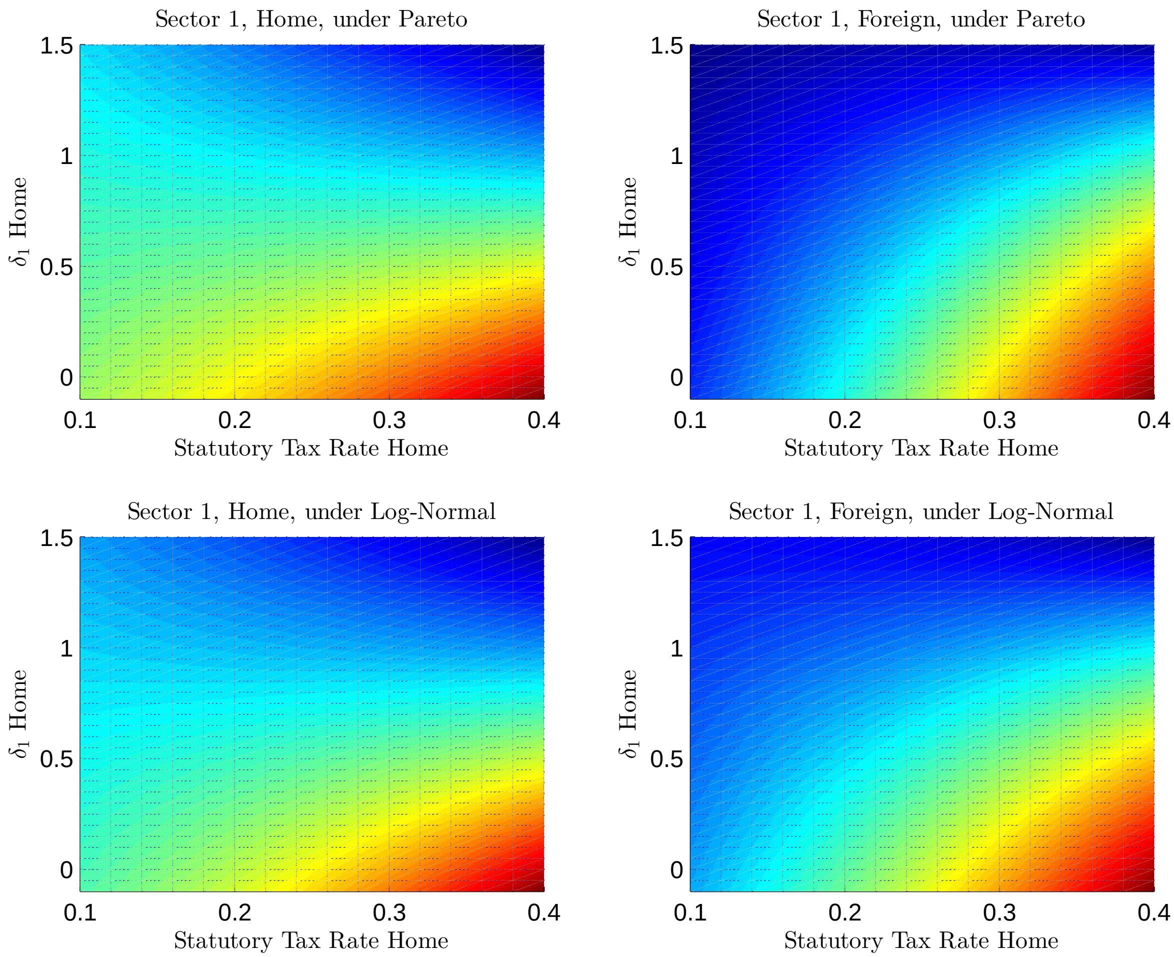
- If $Z_{js} \sim log\mathcal{N}(m_{js}, v_{js})$ then $\Upsilon(\varphi)$ is an increasing function.

The above shows once again that distributional assumptions about productivity are important for the comparative statics of the model. Under the Pareto assumption, the function Υ is constant implying that the change in κ is determine by the unweighted difference of the elasticities across firms that produce for the domestic and export market. In contrast, in the lognormal case the function Υ is increasing on its argument implying that a higher weight is given to the elasticity of the export cutoff over the domestic one.

A graphical representation is helpful to see the relation between tax rates and the probability of export. Figure 1.3 (below) presents a heat map for the probability of export κ_{ji1} as a function of τ_j and δ_{j1}. These values come from solving the equilibrium for countries whose parameters are equal to those of the almost symmetric scenario, with τ_j, δ_{j1} varying to generate the surface of the plot. The left graphs of the panel show that increasing the depreciation allowance rate (δ_{1j}) results in a decrease in the propensity to export by firms in country “j", but the relationship between the statutory tax rate (τ_j) and the probability of export is ambiguous. In the graphs we observe that increasing τ_j results in an increase in the probability of exporting but only when the value of δ_{j1} is below a certain threshold. On the other hand, if δ_{j1} is above such threshold, the probability of export decreases with the statutory corporate tax rate. The reason behind the ambiguous effect goes back to the movement of the ZPC condition in closed economy, which was positive for $\delta > 0$ but negative for $\delta < 0$. In the open economy the new ZPC condition also contains the term φ^*_{ji} which is determine by ratio of user costs across countries; thereby, the threshold value for δ at which the relation between τ and productivity cutoffs change is different than zero.

The relation shown in Figure 1.3 bridges two conflicting empirical findings regarding corporate tax effects on export dynamics. First, Bernini and Treibich (2013) find that corporate tax rates are negatively correlated with the probability that firms will engage in export activities. Their results are obtained by exploiting an exogenous variation in the statutory tax rate

Figure 1.3: Heat Map for the probability of exporting obtained by simultaneously varying the values of the depreciation allowance rate of sector 1 and the statutory tax rate at Home.



charged to small-medium firms in France, which was reduced from 33.33% to 15% for the years 2001 to 2003, and compare the export outcomes of such firms relative to large firms as their statutory tax rate was unchanged. As we have seen in Figure 1.3, my model predicts such relationship but only when the depreciation allowance rate is above a threshold. On the other hand, Federici and Parisi (2014) use data from Italian firms, for the years 2004 to 2006, to show that export propensity is positively associated with corporate taxation, which in their study is a measure of firms' specific effective tax rate. In my model, this would translate to a negative relationship between the sector depreciation allowance rate and the probability of exporting, which is what we observe in Figure 1.3.[16]

Adding corporate taxation to a multi-sector Melitz model can also solve the critique of Segerstrom and Sugita (2014) who find that such model is inconsistent with the data. In the data, sector productivity increases more strongly in liberalized sectors than in non-liberalized sectors; however, the multi-sector Melitz model generates the opposite relationship under fairly general conditions. Using equation 1.4.7, we can observe that the effects of a unilateral decrease in trade costs (θ) can be directly offset via corporate tax changes in either country. Hence, the critique of Segerstrom and Sugita (2014) regarding the implication of a multi-sector Melitz model can be attenuated.

While the question of interest was on the relationship between exports and the corporate tax rates I also show that the model is consistent with other standard results. Using equation 1.4.6, we see that liberalization (reduction of θ) reduces the productivity cutoff to serve country i via exports. The same equation also provides a relationship between market competition and the export productivity required to "carve" a space in such market. For example, if there are many firms operating in country i and/or the productivity of such firms is high ($\tilde{\varphi}_{tot,i}$), then the required export productivity cutoff will be higher relative to other less competitive markets.

1.5 Optimal Corporate Tax Rates in the Open Economy

This section will provide the characterization of the optimal corporate tax rates in the open economy, for a general case; and its solutions, for the special case of symmetric countries.

Without loss of generality assume $j \neq i$. The following conditions are for country j but they are analogous for country i.

[16] Increasing δ_s allows firms in sector "s" to increase their reduction in taxable income and thereby reduce their tax liability. Thus, all else equal, the ratio of taxes paid to profits will decrease i.e their effective tax rate will decrease.

$$\max_{\tau_j,\{\delta_{js}\}_1^S} \quad L_j q_{j0}^G + L_j \prod_{s=1}^S Q_{js}^{\alpha_{js}} \tag{1.5.1}$$

$$\tag{1.5.2}$$

such that

$$\sum_{s=1}^S T_{js} \geq p_j^g q_0^G \tag{1.5.3}$$

$$(q^*, p^*) \in E(\tau_j, \{\delta_{js}\}_1^S) \tag{1.5.4}$$

$$0 < \tau_j \leq 1 \qquad \delta_{js} < 1/\tau_j \qquad \forall s \in S$$

Analysis is restricted for the case of a binding constraints leading to the following FOCs:

$$\left(\frac{\alpha_{js} a_{js}^{-1}}{\sigma_{js}-1}\right)\left(\frac{\xi_{M_{js},\delta_{js}}}{\tilde{\varphi}_{jj}^{1-\sigma}} + \frac{\partial \tilde{\varphi}_{jj}^{\sigma-1}}{\partial \delta_{js}}\delta_{js} + \frac{M_{is}}{M_{js}}\hat{\theta}_{ijs}^{1-\sigma}\left(\frac{\partial \kappa_{ijs}^x}{\partial \delta_{js}}\delta_{js}\tilde{\varphi}_{ijs}^{\sigma-1} + \kappa_{ijs}^x\left(\frac{\xi_{M_{is},\delta_{js}}}{\tilde{\varphi}_{ijs}^{1-\sigma_s}} + \frac{\partial \tilde{\varphi}_{ij}^{\sigma-1}}{\partial \delta_{js}}\delta_{js}\right)\right)\right)$$
$$= -\tilde{\lambda} M_{js}\left(\xi_{M_{js},\delta_{js}}\bar{t}_{js} + \frac{\partial \bar{t}_{js}}{\partial \delta_{js}}\delta_{js}\right) \qquad \forall s \in S$$

$$\sum_{s=1}^S \left(\frac{\alpha_{js} a_{js}^{-1}}{\sigma_{js}-1}\right)\left(\frac{\xi_{M_{js},\tau_j}}{\tilde{\varphi}_{jj}^{1-\sigma}} + \frac{\partial \tilde{\varphi}_{jj}^{\sigma-1}}{\partial \tau_j}\tau_j + \frac{M_{is}}{M_{js}}\hat{\theta}_{ijs}^{1-\sigma}\left(\frac{\partial \kappa_{ijs}^x}{\partial \tau_j}\tau_j\tilde{\varphi}_{ijs}^{\sigma-1} + \kappa_{ijs}^x\left(\frac{\xi_{M_{is},\tau_j}}{\tilde{\varphi}_{ijs}^{1-\sigma_s}} + \frac{\partial \tilde{\varphi}_{ij}^{\sigma-1}}{\partial \tau_j}\tau_j\right)\right)\right)$$
$$= -\tilde{\lambda}\sum_{s=1}^S M_{js}\left(\xi_{M_{js},\tau_j}\bar{t}_{js} + \frac{\partial \bar{t}_{js}}{\partial \tau_j}\tau_j\right)$$

with

$$a_{js} = \tilde{\varphi}_{jjs}^{\sigma_s-1} + \kappa_{ijs}^x \frac{M_{is}}{M_{js}}\left(\hat{\theta}_{ijs}^{-1}\tilde{\varphi}_{ijs}\right)^{\sigma_s-1}$$
$$\bar{t}_{js} = \tau_j\left(w_j f_{jj}(u_{js}h_{jjs}^{\sigma_s-1} - \delta_{js}) + w_j f_{ji}\kappa_{ji}^x(u_{js}h_{jis}^{\sigma_s-1} - \delta_{js})\right)$$

where $\bar{t}_{js}$ is the average tax revenue from sector s.

The FOCs tell us that the government faces a similar problem as in the closed economy section: the left hand side is the benefit/cost to the average productivity of firms and the right hand side is the benefit/cost to tax revenue. However, the left hand side now includes a term for the productivity of importers which is affected by tax policy in j as stated in equations 1.4.6 and 1.4.7. The right hand also includes an additional revenue factor from exporting products into i, which can be influenced by the fiscal instruments.

To illustrate the effects of Pareto distribution on the determination of the fiscal instrument rate, I once again present the elasticity of the number of firms with respect to the different tax rates are the following:

$$\xi_{M_{js},\delta_{js}} = -\left[\frac{-\tau_j\delta_{js}}{1-\tau_j\delta_{js}} + \frac{f_{jjs}\frac{\partial h_{jjs}^{\sigma_s-1}}{\partial\delta_{js}}\delta_{js} + f_{jis}\left(\frac{\partial h_{jis}^{\sigma_s-1}}{\partial\delta_{js}}\delta_{js}\kappa_{jis}^x + \frac{\partial\kappa_{jis}^x}{\partial\delta_{js}}h_{jis}^{\sigma_s-1}\delta_{js}\right)}{f_{jjs}h_{jjs}^{\sigma_s-1} + \kappa_{jis}^x f_{jis}h_{jis}^{\sigma_s-1}}\right]$$

$$\xi_{M_{js},\tau_j} = -\left[\frac{(1-\delta_{js})\tau_j}{(1-\tau_j\delta_{js})(1-\tau_j)} + \frac{f_{jjs}\frac{\partial h_{jjs}^{\sigma_s-1}}{\partial\tau_j}\tau_j + f_{jis}\left(\frac{\partial h_{jis}^{\sigma_s-1}}{\partial\tau_j}\tau_j\kappa_{jis}^x + \frac{\partial\kappa_{jis}^x}{\partial\tau_j}h_{jis}^{\sigma_s-1}\tau_j\right)}{f_{jjs}h_{jjs}^{\sigma_s-1} + \kappa_{jis}^x f_{jis}h_{jis}^{\sigma_s-1}}\right]$$

Just like in the closed economy, the response of the equilibrium number of firms with respect to τ, δ depend upon the distributional assumptions being made. This is clear from the terms $\partial h^{\sigma-1}/\partial x$ which are identical to zero when productivities are assumed to be distributed as Pareto. For the general distribution, the above elasticities contain an additional term that captures the changes in the export market. These alterations are a combination of effects on the productive term or the “intensive" margin; and the change in the ex-ante probability of entering the export market, the“extensive" margin.

1.5.1 Symmetric countries

The main result of this subsection shows that under the Pareto distribution assumption, optimal tax rates for the open economy are identical to those of the closed economy. This odd result is unique to the Pareto environment since it generates ex-ante probabilities of exporting that are invariant to changes in tax rates. In contrast, the optimal tax rates in the open economy under lognormal distribution are different since governments' power to affect M, φ^* via tax policy is diminish when the country opens to trade.

In this setting I impose the additional restriction that both countries are completely symmetric and both governments set their optimal fiscal policies together. In this case, we can think of countries having a "harmonization" scheme with respect to their statutory tax rates and depreciation allowance rates.[17] To avoid the nuisances of first-player advantages or incentives to deviate from the commonly agreed tax rates, I assume that there is a global planner that sets the tax rates.

The full symmetric assumption allows for a straightforward relationship between the export cutoff and the domestic productivity cutoff.

$$\varphi^*_{ji} = \left(\frac{f_{jis}}{f_{jjs}}\right)^{\frac{1}{\sigma_s - 1}} \theta_{jis}\varphi^*_{jj} \tag{1.5.5}$$

$$M^j_{tot,s} = M_{js}\left(1 + p^x_{jis}\right) \tag{1.5.6}$$

The particular relation of φ^*_{ji} with the domestic productivity cutoff has powerful implications for the optimal tax rates; in particular for the case of Pareto as highlighted in the following lemma:

Lemma 1.5.1. *Let $x_s = \tau, \delta_s$, under the symmetric assumption the following holds:*

$$\frac{\partial \kappa^x_{jis}}{\partial x}x = \kappa^x_{jis}\xi_{\varphi^*_{jj},x}\left(\Upsilon_{js}(\varphi^*_{jjs}) - \Upsilon_{js}(\varphi^*_{jis})\right) \qquad x = \tau, \delta_s \tag{1.5.7}$$

Furthermore,

- *If $Z \sim Pareto$ then $\frac{\partial \kappa^x_{jis}}{\partial x}x = 0$.*
- *If $Z \sim log\mathcal{N}$ then $\frac{\partial \kappa^x_{jis}}{\partial x}x > (<)\ 0$ if $\xi_{\varphi^*_{jjs},x_s} < 0\ (> 0)$. This derivative is only equal to zero when $\xi_{\varphi^*_{jjs},x_s} = 0$ or as $\varphi^*_{jj} \to \infty$*

[17] This "harmonization" scheme has been argued as optimal for the case of the Europe Union with Devereux as one of the main voices supporting this type of framework.

Lemma 1.5.1 says that under the country symmetry assumption and Pareto productivities there is no change in the *ex-ante* probability, of a successful firm , of entering the export market following changes to corporate tax rates. Thus, a symmetric country model with Pareto productivities can't explain the results found by either Bernini and Treibich (2013) or Federici and Parisi (2014).

In contrast, when lognormal productivities are assumed the modifications to tax rates have an effect on the export probabilities and hence on the number of exporters in equilibrium. The intuition for the direction of the change is simple. First, assume that τ, δ have a negative effect on the domestic productivity cutoff. Since φ^*_{jis} is a fixed multiple of the domestic cutoff, the probability of obtaining a productivity above it – conditional on successful entry to domestic market – increases since the right tail of the lognormal distribution is monotonically decreasing. A more intuitive explanation: under the symmetry assumption, the foreign market has become less competitive due to the reduction in average productivities and making it easier for domestic firms to serve the foreign market via exports.

The invariability of the number of exporters to modifications in the tax rate, under the Pareto assumption, has the following implication:

Proposition 1.5.2. *Assume productivities are Pareto distributed. The optimal tax rates for the open economy under the symmetry assumption are exactly equal to those obtained in the closed economy.*

Proof. See Appendix □

While proposition 1.5.2 states that the optimal formula for τ, δ have not changed in this setting, it doesn't imply that equilibrium outcomes haven't changed. The model still generates gains from trade spawn from the increased productivity of the firms following the opening to trade that enhances competition.

Nonetheless, the implication that optimal taxes remain the same in the opening economy is striking, and might be judge as an undesirable property generated by the Pareto distribution. The explanation behind this odd outcome is quite simple. It was shown that the Pareto distribution muted a channel of transmission by precluding the rearrangement of the sector via h, which in this open economy setting is extended to the export market via h_{ji}. Moreover, the Pareto distribution also erases a channel of effect through the invariability of the number of exporting firms in equilibrium. Hence, the closed and open economy optimal rates are the same since the export channels of transmission are also annihilated under the Pareto distribution assumption.

In contrast, export market channels play a significant role in the determination of the optimal tax rates in the lognormal scenario. The transition from autarky to trade cuts the power of the government to influence equilibrium outcomes as stated in the proposition below:

Proposition 1.5.3. *Let $\varepsilon^{C}_{\varphi^*_{jjs},x_{js}}$, $\varepsilon^{O}_{\varphi^*_{jjs},x_{js}}$ be the elasticity of the domestic cutoff productivity in the closed and open economy respectively. If firms draw productivity from a lognormal distribution then the following holds:*

$$|\varepsilon^{O}_{\varphi^*_{jjs},x_{js}}| < |\varepsilon^{C}_{\varphi^*_{jjs},x_{js}}| \qquad \forall s \in S \text{ and } x_{js} = \tau_j, \delta_{js}$$

Proof. See Appendix □

From the discussion of 1.3.2, we saw that governments make a trade off between raising productivity in some sectors while increasing the number of firms in others. In the open economy the degree by which governments can influence the equilibrium productivities diminishes relative to the closed economy setting. In one hand, this is “bad" for sectors with high σ as the government loses power to raise equilibrium productivity. On the other hand, sectors in which government policies were reducing equilibrium productivity are affected to a lesser degree, a“good" outcome.

The effects of proposition 1.5.3 are passed into the equilibrium number of firms and therefore into the aggregate variables. If governments – in an economy with lognormal distributed productivities – didn’t adapt their corporate tax rates when opening to trade, the policy recommendation under Pareto distributions, they will experience increases/decreases in their tax revenue thereby missing their target spending. Table 1.2 contains the results of an economy that opens to trade; assuming that governments keep using the optimal tax instrument rates of the closed economy. Consistent with Head et al. (2014) I find that gains from trade (GFT) under Pareto are significantly higher than those obtained by assuming lognormal distribution of productivities. Moreover, the tax revenue in the lognormal environment decreases for all scenarios which forces the government to tax households in order to meet their expenditure. This reduction in disposable income has a negative effect in the number of firms; therefore, this fiscal issue also plays a factor in the GFT differences.

To further illustrate the effects in tax revenue from moving into the open economy without changing the corporate tax rates, I present its response function in terms of several parameters in Figure 1.6. In these graphs the dash lines correspond to the Pareto distribution assumption while the solid lines are for the economy with lognormal distribution of productivities. In the first panel we see that the wedge between the public spending ($q_0^G = 0.5$) and tax revenue increases with the degree of asymmetry in the elasticity of substitution across sectors. Just as in the closed economy, when the sectors are completely symmetric there is no difference in the optimal tax rates between the Pareto and lognormal distribution assumptions. In term of the fixed cost of production we observe that the tax revenue increase with f_1 but decreases with f_2. This happens because the increase in fixed production cost reduces the number of firms and in the case of sector 1, which gets a positive depreciation allowance rate, it reduces the total amount of “subsidy" given to this sector. For sector 2 the explanation is analogous, but for this sector the depreciation allowance rate is negative.

Lastly, I provide some examples of the welfare loses that government can incur by using the incorrect policy recommendation for the corporate tax instrument rates. For the open economy case, the policy recommendation under Pareto is to keep taxes unchanged when switching from autarky to trade. Thus, the “null" model will use the optimal tax rates found in the closed economy, for the lognormal assumption, and compute the open economy equilibrium. These outcomes are compared to the “alternative" model in which the optimal tax rates have been updated to their new values. The welfare gains from using the correct taxes are found in the last row of Table 1.2. Governments can gain an additional 0.12% to 0.32% in welfare by adjusting their corporate tax rates and, once more, the gains from using the correct tax rates increase with the degree of asymmetry across the sectors.

1.6 Empirical Evidence for using lognormal distributions

To finalize this paper I present some basic empirical findings that suggest lognormal distributions are a better fit for the empirical distribution of productivities for developing countries. This adds to the evidence first found by Sun et al. (2011) for Chinese firms, and Head et al. (2014) for French and Spanish firms.

I test the fitness of the Pareto distribution using multiple estimation methods on two different measure of productivity. The first measure is direct estimation of productivities under the assumption that the productive technology of firms is Cobb-Douglass. Under this approach I follow Del Gatto et al. (2006) as this paper has been cited multiple times to justify the validity of the Pareto assumption for European firms. Thus, I replicate their studies using data for developing countries. Nonetheless, there are many issues involving the direct estimation of productivity which can be reduced if I were to use Olley-Pakes method; however, the data available isn't a proper panel which precludes me from using such method. Therefore, the second approach I use involves using direct sales data for the firms. In this case the assumption isn't on the firms' technology but on the characteristic of the sector which is assumed to be monopolistic competitive with firms pricing their products at a markup.

Regardless of which measure of firm productivity is used, the results strongly point in the direction of a lognormal distribution over a Pareto distribution for firm level productivity. Moreover, for most empirical distributions the estimated parameters for the Pareto distribution violate the equilibrium conditions for the Melitz model, rendering it inapplicable.

1.6.1 Data

The necessary firm level data comes from the Enterprise Surveys database, which is provided by the World Bank. The survey is given to firms with 5 or more full time employees in 136 countries and contains a rich set of variables that provide a detailed picture of the firms' performance as well as the environment in which they operate. To ensure that data is comparable across countries, we make use of the standardized surveys for the period 2006 to 2013. These surveys were designed to be representative of the economy of each country, including its sector composition, with sample sizes chosen to ensure robust statistical inferences.

I restrict the database to manufacturing firms that have completed the *manufacturing questionnaire*.[18] Observations are dropped if they are missing any of the following variables: total sales, net book value of machinery and equipment and, number of full time employees. Monetary variables in the survey are reported in local currency units (LCU) in nominal terms which are transformed into real values expressed in international 2010 dollars. The transformation is accomplished using GDP deflators and PPP exchanges obtained from the World Bank financial database. Labour input is measured by the number of full time *permanent* workers that the firm employed during the fiscal year. A permanent full time employee is a full time paid worker that has been in the firm for a year or more and/or full time workers that have been there for less than a year but have a renewal offer.[19]

The ISIC codes of the firms are used to classify them into 18 sectors. Table 1.3 shows the distribution of observations across these sectors and geographical regions. The Middle East

[18]There are 3 types of questionnaires in the survey: core, manufacturing and service. The last two questionnaires contain the same questions as the core plus a set of extra questions related to manufacturing or service sectors. The manufacturing questionnaire is the only one that asks for the net book value of current machinery and equipment, which is our fixed capital variable.

[19]A second measure that takes into account the *temporary* full time workers was also considered. The importance of including the temporary workers stems from the vast differences in labor markets of the countries in the sample. Regulations, unions, internship requirement, etc are quite different across countries/regions and thus the firms' composition of permanent and temporary full time workers will differ greatly depending on location. We calculate the modified labor measure by computing the median (across firms in a particular country)of the average months a temporary worker is employed; the median is then divided by 12 and the resulting number is multiplied by the number of temporary full time workers the firm employed. This last number is added to the full time permanent workers to generate the modified labor measure.

region (MNA) is substantially underrepresented compared to other regions and it's dropped due to an insufficient number of observations. The “Petroleum and Coal" sector is omitted for the same reason.

1.6.2 Testing the fitness of distributions: productivity as the residual of the production function

Assuming a Cobb-Douglas production, the productivity of a firm j in sector i is estimated by $\exp(c_i + \varepsilon_i)$:

$$log(sales_j) = c_i + a_i log(K_j) + b_i log(N_j) + \varepsilon_{j,i} \tag{1.6.1}$$

This regression is computed separately for each sector/region pair and summary statistics are presented in table 1.5. Eastern Europe and Central Asia region comes atop with an average (across sectors) of 222.62 while Africa stands last among all regions studied, with an alarming low 4.78. A minor surprise is Latin America ranking second, right above the Asia Pacific region.

Sectors inside each region are remarkably different reinforcing that such cross-sector heterogeneity should be explicitly consider in my corporate taxation model. “Electric machinery" and “professional and scientific equipment" are the two sectors that exhibit some of the best performance in all regions; however, no common worst performing sectors across regions were found. Nonetheless, the worst performing sector in ECA (wearing apparel) is 4 to 6 times better than the worst performer in the other regions, excluding Africa. If the paper product sector is not included then the top performer of ECA is less than twice as productive as the top performers of other regions, including Africa.

Pareto

Now that productivities have been estimated I test if their distribution can be properly fitted by a Pareto distribution. The functional form of the Pareto distribution implies that for a region r and sector s, the shape parameter k_s can be estimated by:

$$log(1-F(x_{s,r})) = cons - k_s log(x_{s,r}) + \varepsilon_{s,r,} \tag{1.6.2}$$

This estimation approach is used in Del Gatto et al. (2006) with the difference that I include fixed year effect in the OLS regression. Estimation results are found in Tables 1.6-1.10 under the OLS headings.

It will be shown below that estimates for k_s using OLS are unreliable but they are reported for the sake of comparison with the values for Western Europe in Del Gatto et al. (2006). Most of the estimated k_s are below one which could present a problem, since the shape parameter (k_s) has to be greater than the elasticity of substitution minus one, for the existence of an equilibrium in the Melitz model. Even though there is no consensus among economist about the exact value of the Armington elasticity of substitution, the range is usually between 1 to 4.6; though there are estimates as high as 12 and as low as 0.51.[20] The estimated k_s under OLS are consistent with the model if the elasticities are in the lower range of what is commonly assumed in trade models. Thus, the elasticities bounds imply by the estimated k_s are plausible but not likely.

An alternative estimator for k_s has to be employed since the OLS estimator is biased, which is clear once 1.6.2 is re-written into:

$$log(1-F(x_{s,r})) = k_{s,r} log(x_{min,s,r}) - k_s log(x_{s,r}) + \varepsilon_{s,r,}$$

the constant term in the previous regression is a function of the shape parameter and the lower bound of the support of $F(x)$. Due to the unreliability of the estimators of k_s using simple regression I use a maximimum likelihood estimator instead; where I assume $x_{min,s,r}$ is equal to the minimum productivity observed in sector s in region r. [21]

[20]The most recent estimation of Armington elasticities can be found in Feenstra et al. (2014)

[21] As a robustness check, the same estimation is carried assuming that $x_{min,s,r}$ is equal across all sectors in the same region, and its value is given by the smallest productivity observed in such region. Results of both

Estimation using MLE generates a very different picture from what was obtained under OLS. First, the estimated shape parameters are smaller for all cases, which highlights the bias of the OLS estimator. A detail description of results under this estimation is not provided since the estimated distributions are not good approximations of the empirical distributions. These goodness of fit conclusions are derived using the Kolmogorov-Smirnov test with the associated $p-values$ reported in the same tables.[22] Using a threshold of $p > 0.05$, there is no case but one in which the estimated Pareto distributions fit the data well. The "Professional and Scientific equipment" in the SAR region is the only case that passes the KS test; however, the number of observations is 19, which is below the $n = 50$ sample size requirement to ensure the asymptotic properties.[23]

I continue by testing if the Pareto distributions fit only a part of the empirical distributions for productivity. Income distribution was believed to follow a Pareto distribution until Clementi and Gallegati (2005) , Brzezinski (2014) showed that such was not the case when the considering distribution of *all* incomes. The latter paper goes further and applies methodology developed in Clauset et al. (2009) to show that the right tails of the distribution are nicely fitted by a Pareto distribution. Following this insight, I employ the same methods to test the Pareto distributions one last time. The estimation procedure is simple. First, MLE estimation is perform in all observations and the KS statistics is computed, then the smallest observation is dropped and the estimation is re-run. This process continues until one of these happens: the KS statistic is below the threshold to pass or the next iteration would generate a bias that is greater than 0.10.

Surprisingly, no dramatic improvement was found with regards to the goodness of fit criteria as only two more cases passed the p-value threshold. Nonetheless, these cases are now

estimations are almost the same. Furthermore, it can be shown that the MLE estimator for x_{min} is the minimum observed value from the sample.

[22] Kolmogorov-Smirnov tests the null hypothesis that the estimated distribution and the empirical distribution are statistically no different.

[23] This case was re-estimated using a finite sample bias correction, which produced estimators not significantly different from the one reported in table 1.10

a good fit without discarding a significant amount of the empirical data.[24] What is clear, is that the shape parameters under these estimations are consistenlty greater than those obtained by setting x_{min} equal to the lowest value observed in the full sample of the sector-region pair. The values for k_s are closer to those found in Del Gatto et al. (2006) and other studies conducted in developed countries. Furthermore, if the upper bound for $\hat{x}_{min}$ is removed then Pareto distributions are a decent approximation for the reduced data. This is a similar result to Head et al. (2014), which finds that only the right tails of productivity distributions can be approximated by a Pareto distribution.

Alternative Distribution: Log-Normal

I continue by testing if lognormal distributions perform better at describing the empirical data than the Pareto distributions. The pdf of the lognormal distribution is given by:

$$f(x) = \left(\frac{1}{x\sqrt{2\pi}v}\right) exp\left(-\frac{(ln(x)-m)^2}{2v^2}\right)$$

in which m, v are the scale and variance parameters. MLE is used to estimate the parameters and the results are reported in Tables 1.6-1.10.

The goodness of fit are a dramatic improvement over the Pareto distribution as attested by the Kolmogorov-Smirnov tests. Using the same $p-value$ threshold of 0.05, the estimated lognormal distributions are a good fit for 72 out of 85 possible cases. Africa is the region with the least sectors (9) that are satisfactory fitted while the rest of regions exhibit empirical productivity distributions that are well approximated for most, if not all, sectors.

The Kolmogorov-Smirnov tests strongly suggest that the data is well described by the lognormal distribution, but I perform an additional robustness check to confirm/reject these initial conclusions. Ross (2013) gives a thorough exposition of the advantages of using Monte Carlo simulations to obtain reliable $p-values$ that take into account the possibility that initial

[24] Paper product in EAP region discard 16% of observation while Electric Machinery in LAC discards only 7%

results were the product of chance. Synthetic data is generated for each sector/region pair by drawing values from the estimated distribution that best fitted it, where the number of draws is equal to the amount of observations used in the initial estimation. Then, the parameters to best fit the synthetic data are estimated and the Kolmogorov-Smirnov statistic computed. The whole procedure is repeated 10000 times (for each sector-region pair) to obtain a precision of $\varepsilon = 0.005$.[25] The $p-value$ based on the Monte Carlo simulation is the fraction of KS statistics larger than the value obtained for the empirical data. In this case, higher $p-values$ are "good" in the sense that they imply a lower probability that the results from the KS test was just an outcome of chance.

Using a $p-value$ threshold of $p > 0.05$ ($p > 0.10$) only 44 (38) sector-region pairs pass the Monte-Carlo simulation confirmation. This number of successful fits is lower than the amount obtained by using the KS test criteria (72 cases) for which the estimated and empirical distribution were not statistically significantly different from each other. Nonetheless, the rejections/acceptance of fits based on the Monte Carlo simulations are in line with observations of the quantile-on-quantile plots.

1.6.3 Testing the fitness of distribution: sales data

The previous estimation using estimated values of firms' productivities is prone to many critics, specially regarding endogeneity issues between revenues and the amount of labor employed. Methods to solve this problem (such as Olley-Packes and its derivatives) require a proper panel data which is not available in these surveys.

Therefore, I perform an alternative analysis that uses revenues for firms to infer the productivity parameter consistent with the model presented in this paper. The Melitz model

[25] For computational considerations, the procedure is only carried for sector-region pairs that have passed the initial K.S test ($p > 0.05$).

implies that a firm with productivity φ has revenue:

$$
\begin{aligned}
r(\varphi) &= p(\varphi)^{1-\sigma}\frac{Income}{\mathbb{P}^{1-\sigma}} \\
p(\varphi) &= \frac{w}{\rho}\varphi^{-1}
\end{aligned}
$$

Thus, revenues under this model have the same distributional form as φ since the transformation $Y = \varphi^{\sigma-1}$ preserves the shape of the distribution of φ. Specifically:

- If φ came from a Pareto distribution with shape parameter k, then $\varphi^{\sigma-1} \sim Pareto(\tilde{k})$, where $\tilde{k} = \dfrac{k}{\sigma-1}$
- If $\varphi \sim log\mathscr{N}(m,v)$ then $\varphi^{\sigma-1} \sim log\mathscr{N}((\sigma-1)m,(\sigma-1)v)$

The analysis using firms' revenues has additional advantages: it expands the number of non-missing observations significantly, and it can be used to test if the estimated parameters for the Pareto distribution satisfy the equilibrium conditions of the model. Previously, observations missing input for capital equipment had to be deleted since it was a necessary input to estimate the residual from the production function; however, for the current estimation method this is not necessary and thus valid observations are increased by approximately 8000. The distribution of valid observations across the sector and regions is found in Table 1.4.[26]

Pareto or lognormal?

Before proceeding to the more rigorous testing, using the Kolmogorov-Smirnov statistics, it is useful to analyze the histograms for the distribution of the logarithm of revenues. The distribution of the log of sales is expected to be: exponential if sales were Pareto distributed;

[26] The analysis presented in the main body uses the full sample of firms. Nonetheless, concerns may arise since the sample has a mix of firms that sell only domestically with others that also engage in export. Therefore, separate analysis using: (i) firms whose revenues are fully realized from the domestic market, (ii) firms whose national sales account for 90 % or more of their revenue. The results are not significantly different from using the full sample. In fact, when the sample consist of firms that only sell on the domestic market the conclusion in favor of using lognormal distributions to approximate the empirical distribution of productivity is stronger.

and normal if the sales follow a lognormal distribution. Figures 1.7 to 1.11 contain the histograms for log sales and several of them favor the lognormal as the underlying distribution for sales. In particular, Latin America region and Eastern Europe have the most consistent patterns supporting the hypothesis of lognormal distributions.

Next, I conduct the same analysis as in section 1.6.2 and obtain similar findings for the fit of the Pareto distribution. Estimation results are found in Tables 1.11 to 1.15 with the first columns containing the estimated parameters for a Pareto distribution. Similarly to results using estimated productivities, the KS statistics for most sectors in each region are unfavorable to the hypothesis that revenues are Pareto distributed. Only 2 cases, out of a possible 85, pass the KS test with a threshold $p-value$ of 0.05. The modified MLE, in which the cut-off parameter is free to move, doesn't provide significant improvements except for "Electric Machinery" in LAC region which now passes the KS test by dropping only 7% of the lower observations.

Furthermore, the MLE results in values of $\tilde{k}$ that are below unity for all cases which is problematic. The condition for the existence of an equilibrium in the Melitz model is $k > \sigma - 1 \implies \tilde{k} > 1$, therefore the estimated parameters using the Pareto distribution are inconsistent with this model. The modified MLE estimation barely improves the problem as it results in estimates of $\tilde{k}$ that are above one in most case but not by a significant amount. In fact, for Africa the average $\tilde{k}$ still remains below one and the averages for the other regions are at most 1.66.

Finally, the estimated lognormal distributions perform remarkably well (and strongly outperform the Pareto distribution) in fitting the sales data, corroborating the first impressions from looking at the histograms of the logarithm of revenues. The lognormal distributions pass the Kolmogorov-Smirnov test for 70 sector-region pairs, out of a possible 85 cases, a dramatic improvement over the performance of the Pareto distribution. Once again, Monte Carlo simulations were performed (10 000 repetitions) to confirm the initial conclusions of the KS test. Using a p-value of 0.10 (0.05) the KS test is confirmed for 35 (42) cases, which is half of the cases that passed the KS test.

1.7 Conclusion

The question of the implication of assuming productivities that are Pareto distributed in a Melitz model has largely been neglected until recently when Head et al. (2014) showed their effects in equilibrium outcomes and how this assumption enhances the gains from trade relative to using a model with lognormal distributed productivities. However, the implications for policy of this de facto assumption have not been explored; specifically, the question of the difference between optimal corporate tax rates derived under the Pareto distribution and the lognormal distribution.

Using an enhanced Melitz model with heterogeneous sectors and corporate taxation under a framework that resembles those observed in the real world, I have demonstrated that using the Pareto distribution assumption mutes a transmission channel between the corporate tax rates and the equilibrium outcomes. Thus, I find not only quantitative differences between the optimal tax rates derived under the Pareto and lognormal distribution assumptions, but also qualitative implications for the optimal corporate tax rates. Optimal rates derived under both distributional assumptions share many properties, especially the attribute that firms in sectors with higher elasticities of substitution get smaller depreciation allowance rates on their fixed cost of productions. Quantitatively, the differences between the optimal rates derived under both distributions become more prominent with the degree of cross sector heterogeneity. There are also many qualitative differences with one of the most important regarding the explicit inclusion of fixed production and entry costs in the determination of the statutory corporate tax rate and the sector specific depreciation allowance rate. Under the Pareto distribution assumption the optimal rates are not functions of these fixed costs; hence, the optimal rates formulas derived under the lognormal assumption exploit sector heterogeneity along all dimensions. This issue is particularly important given that changes in fixed cost of sectors occur, and such changes can be quite significant as in the case of entry costs following regulations targeting the competitiveness of the sector. Another example is the evolution of fixed production costs that sectors experience through their life cycle, from infancy to maturity.

Additionally, incorporating the corporate tax framework into the Melitz model allows me to provide the theoretical basis to explain conflicting empirical results regarding the relationship between corporate taxes and export dynamics. My model shows that decreasing the statutory corporate tax rate can increase or decrease the probability of becoming an exporter, the sign of this relationship depends on the level of the depreciation allowance rate on fixed costs. Nonetheless, increasing the depreciation allowance rate decreases the probability of exporting for all levels of the statutory corporate tax rate since this increase reduces the equilibrium productivity cutoff of domestic firms which makes them less competitive relative to firms in the other country.

Table 1.1: Parameters and results for the different scenarios used to compute the inefficiencies from using the incorrect distribution for productivities. For outcomes with two values, the top comes from the "null" model while the value for the "alternative" model is directly underneath

Scenario	Almost Symmetric		Different Entry Cost		Different Cost of Production		More asymmetric Elasticities		Different Variance	
	Sector 1	Sector 2	Sector 1	Sector 2	Sector 1	Sector 2	Sector 1	Sector 2	Sector 1	Sector 2
Parameters										
Wage	1		1		1		1		1	
Labor Size	5		5		5		5		5	
q_0^G	0.5		0.5		0.5		0.5		0.5	
ψ	0.02		0.02		0.02		0.02		0.02	
Elasticity of Subs.	2.5	3	2.5	3	2.5	3	**1.5**	3	2.5	3
Share (α)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Fixed cost Production	0.1	0.1	0.1	0.1	0.1	**0.2**	0.1	0.1	0.1	0.1
Entry cost	0.5	0.5	0.5	**0.1**	0.5	0.5	0.5	0.5	0.5	0.5
m_i	2	2	2	2	2	2	2	2	2	**6**
v_i	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7
k_i	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	2.61
φ_{min}	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	317.69
Results										
Number Firms	4.72 4.76	2.19 2.16	4.73 4.76	2.55 2.53	4.72 4.76	1.18 1.17	12.56 12.82	1.57 1.48	4.72 4.76	1.61 1.59
Sector Price Index	3.69 3.68	5.20 5.21	3.69 3.67	3.82 3.82	3.69 3.67	5.97 5.97	0.18 0.17	5.73 5.75	3.70 3.68	0.06 0.06
Depreciation Rate (%)	28.32 29.70	-28.32 -35.50	28.32 28.17	-28.32 -36.11	28.32 29.02	-28.32 -35.62	90.57 94.56	-90.57 -120.54	30.11 32.45	-25.11 -31.51
Corporate Tax (%)	30.71 30.31		30.71 29.91		30.71 30.13		40.15 35.85		31.25 31.06	
$\sum T_{alternative}$	0.5049		0.5083		0.5065		0.5696		0.5044	
$\mathbb{W}_{null}/\mathbb{W}_{alternative}$	0.9986		0.9977		0.9982		0.9766		0.9987	

Table 1.2: Results for the open economy equilibrium with symmetric countries using the Pareto distribution recommend policy: the "optimal" corporate tax rates are the same as in the closed economy. The welfare gain from changing the corporate tax rates to their optimal value is given by $\mathbb{W}_{alternative}/\mathbb{W}_{null}$

Scenario	Almost Symmetric		Different Entry Cost		More asymmetric Elasticities		Different Variance	
	Pareto	Log-Normal	Pareto	Log-Normal	Pareto	Log-Normal	Pareto	Log-Normal
Sector 1								
$\%\Delta\varphi_{jj}$	16.436	9.567	16.436	9.550	8.349	10.283	16.436	9.599
$\tilde{\varphi}$	20.267	17.162	20.267	17.181	9.297	11.265	20.216	17.127
M	2.453	3.245	2.453	3.245	10.248	9.314	2.453	3.243
φ_{ex}	16.283	15.883	16.283	15.906	10.392	11.683	16.243	15.840
$\tilde{\varphi}_{ex}$	25.175	20.374	25.175	20.398	14.726	15.533	25.112	20.329
M_{ex}	1.245	1.498	1.245	1.496	2.433	3.339	1.245	1.500
GFT($\%\Delta\tilde{\varphi}_{tot}$)	21.607	9.801	21.607	9.794	16.824	12.671	21.607	9.815
% decrease in Prices	16.436	9.555	16.436	9.531	8.349	9.674	16.436	9.579
Sector 2								
$\%\Delta\varphi_{jj}$	18.703	8.510	18.704	6.379	18.704	7.987	24.595	12.585
$\tilde{\varphi}$	42.955	21.059	71.879	26.645	46.187	22.148	217.370	38.734
M	0.534	1.467	0.534	1.766	0.367	1.006	0.105	1.043
φ_{ex}	26.716	18.931	44.704	25.240	28.726	20.173	71.630	31.110
$\tilde{\varphi}_{ex}$	50.825	24.115	85.048	30.792	54.649	25.422	257.196	44.296
M_{ex}	0.315	0.718	0.315	0.729	0.217	0.475	0.068	0.598
GFT($\%\Delta\tilde{\varphi}_{tot}$)	22.155	8.003	22.155	6.934	22.155	7.789	28.415	11.193
% decrease in Prices	18.703	8.503	18.704	6.368	18.704	7.868	24.595	12.573
Country								
Tax Collected	0.500	0.499	0.500	0.499	0.500	0.486	0.500	0.499
Welfare	77.430	64.804	99.428	74.543	305.773	275.690	125.039	82.248
Gains from Trade	16.901	8.632	17.048	7.624	13.284	8.383	19.956	10.665
% ($\mathbb{W}_{alt}/\mathbb{W}_{null}-1$)		0.12		0.163		0.327		0.154

Table 1.3: Distribution of observations across sectors and regions

	Region						
	AFR	EAP	ECA	LAC	MNA	SAR	Total
Food beverages and tobacco	1,532	402	1,130	2,195	211	549	6,019
Textiles	185	326	287	872	7	484	2,161
Wearing apparel except footwear	971	345	611	1,260	33	452	3,672
Leather products and footwear	111	42	59	263	3	357	835
Wood products except furniture	232	61	244	145	15	66	763
Paper products	70	38	68	62	6	40	284
Printing and Publishing	226	56	214	194	10	68	768
Petroleum and Coal	5	7	6	8	6	2	34
Chemicals	336	276	286	1,323	40	283	2,544
Rubber and plastic	177	314	195	546	40	109	1,381
Other non-metallic products	207	374	324	391	172	94	1,562
Metallic products	89	101	55	126	6	85	462
Fabricated metal products	499	248	604	895	47	75	2,368
Machinery except electrical	112	173	431	622	9	78	1,425
Electric machinery	61	159	165	144	6	70	605
Professional and scientific equipment	19	82	107	73	2	15	298
Transport equipment	48	128	64	134	2	33	409
other manufacturing	717	106	327	453	39	143	1,785
Total	5,597	3,238	5,177	9,706	654	3,003	27,375

Table 1.4: Distribution of non-missing observations, across sectors and regions, for the analysis using firms' revenues.

	Region					
	AFR	EAP	ECA	LAC	SAR	Total
Food beverages and tobacco	1,936	553	1,684	2,793	706	7,672
Textiles	272	418	387	1,120	639	2,836
Wearing apparel except footwear	1,199	458	899	1,645	506	4,707
Leather products and footwear	143	55	81	306	386	971
Wood products except furniture	324	97	360	186	103	1,070
Paper products	88	56	95	96	70	405
Printing and Publishing	318	71	347	261	77	1,074
Chemicals	418	380	413	1,582	333	3,126
Rubber and plastic	213	418	326	651	141	1,749
Other non-metallic products	284	522	591	540	133	2,070
Metallic products	125	125	90	156	159	655
Fabricated metal products	654	287	850	1,083	88	2,962
Machinery except electrical	142	188	698	748	112	1,888
Electric machinery	73	215	257	175	71	791
Professional and scientific equipment	21	109	180	81	15	406
Transport equipment	64	158	93	167	55	537
other manufacturing	1,032	148	504	575	195	2,454
Total	7,306	4,258	7,855	12,165	3,789	35,373

Table 1.5: Summary Statistics for the estimate productivities. The means are in hundreds of 2010 International Dollars

	AFR			EAP			ECA			LAC			SAR		
	Mean	σ	Obs.	Mean	σ	Obs.	Mean	σ	Obs.	Mean	σ	Obs.	Mean	σ	Obs.
Food beverages and tobacco	1.55	5.23	1623	5.95	9.42	403	122.5	203.11	1112	23.4	28.56	2172	15.3	38.48	542
Textiles	3.71	10.93	187	5.76	6.62	329	55.32	87.72	284	43.57	42.81	872	17.53	23.24	481
Wearing apparel except footwear	0.66	1.29	1008	20.79	29.24	343	31.96	51.02	601	37.13	41.8	1251	15.29	18.54	448
Leather products and footwear	3.87	7.57	112	21.89	22.83	42	129.24	859.62	59	7.61	6.68	268	12.36	15.48	352
Wood products except furniture	4.23	19.74	240	7.75	11.54	63	105.21	156.87	240	26.93	47.4	143	26.35	43.91	66
Paper products	16.04	39.23	72	8.93	6.74	38	8803.15	47086.7	68	56.6	54.26	62	24.75	33.99	40
Printing and Publishing	0.45	0.8	234	28.07	46.6	56	36.41	75.76	210	184.31	251.72	192	6.89	9.76	68
Chemicals	9.82	31.81	343	18.6	37.73	272	202.89	325.77	284	73.7	86.32	1306	11.97	18.44	279
Rubber and plastic	4.38	13.21	187	66.52	97.62	311	49.36	57.97	193	54.71	39.86	537	5.68	8.1	108
Other non-metallic products	4.94	27.06	215	11.61	19.31	372	74.92	97.92	320	17.42	34.29	388	213.41	362.35	95
Metallic products	16.53	40.68	91	17.62	25.01	99	161.27	534.39	55	17.52	35.56	125	55.78	72.53	85
Fabricated metal products	0.95	2.61	530	32.44	87.44	246	50.73	66.67	594	53.18	55.13	885	14.24	23.62	76
Machinery except electrical	5.83	24.95	124	23.39	38.69	171	267.15	489.27	423	45.49	47.66	620	24.93	38.71	78
Electric machinery	22.76	115.08	63	110.05	165.49	157	115.01	149.2	163	23.05	20.09	142	21.81	80	70
Professional and scientific equip	195.21	277.3	19	55.36	77	82	305.64	412.9	106	144.52	135.2	73	194.1	179.31	15
Transport equip	26.87	33.11	48	58.56	52.58	126	86.75	127.47	64	13.07	31.25	138	21.09	84.54	34
other manufacturing	9.16	45.94	765	12.19	14.42	104	78.03	142.34	324	7.19	8.73	463	56.93	57.57	142
Total	4.78	31.28	5861	27.68	64.97	3214	222.62	5494.41	5100	42.43	67.06	9637	25.63	82.84	2979

Table 1.6: Africa: Parameter estimation and goodness of fit for the Pareto and lognormal distributions. Empirical distribution of productivities based on estimation of the residual from a Cobb-Douglas production technology

		OLS		MLE			MLE mod				Log-normal			
	Obs.	k_s	R^2	k_s	x_{min}	K.S p-value	k_s	x_{min}	K.S p-value	ratio of $x < x_{min}$	m	v	K.S p-value	Monte Carlo p-value
Food beverages and tobacco	1623	0.63	0.9	0.26	0.89	0.00	0.96	98.75	0.00	0.74	3.66	1.49	0.00	
Textiles	187	0.76	0.93	0.37	8.31	0.00	1.04	145.54	0.00	0.57	4.83	1.24	0.39	0.052
Wearing apparel except footwear	1008	0.71	0.88	0.34	1.32	0.00	0.96	31.85	0.00	0.58	3.25	1.31	0.04	
Leather products and footwear	112	0.6	0.84	0.27	3.50	0.00	0.79	97.97	0.00	0.42	4.89	1.47	0.81	0.439
Wood products except furniture	240	0.58	0.91	0.25	1.25	0.00	0.77	174.50	0.00	0.78	4.16	1.62	0.05	0.000
Paper products	72	0.67	0.9	0.30	17.78	0.00	0.88	646.76	0.00	0.65	6.23	1.35	0.27	0.017
Printing and Publishing	234	0.73	0.9	0.36	1.18	0.00	0.95	18.73	0.00	0.52	2.92	1.26	0.36	0.044
Chemicals	343	0.65	0.95	0.31	8.91	0.00	0.72	128.87	0.00	0.40	5.38	1.48	0.01	
Rubber and plastic	187	0.65	0.95	0.33	4.63	0.00	0.72	54.36	0.00	0.37	4.61	1.47	0.00	
Other non-metallic products	215	0.62	0.94	0.29	1.90	0.00	0.70	25.96	0.00	0.25	4.14	1.54	0.03	
Metallic products	91	0.55	0.75	0.15	0.63	0.00	0.89	352.68	0.00	0.33	6.29	1.49	0.29	0.024
Fabricated metal products	530	0.66	0.9	0.30	1.00	0.00	0.86	37.15	0.00	0.62	3.33	1.43	0.14	0.003
Machinery except electrical	124	0.55	0.93	0.28	2.24	0.00	0.61	28.09	0.00	0.24	4.39	1.70	0.02	
Electric machinery	63	0.5	0.86	0.17	0.44	0.00	0.64	48.07	0.01	0.17	4.96	1.85	0.22	0.012
Professional and scientific equip.	19	0.58	0.78	0.35	534.23	0.04	1.17	10564.04	0.00	0.47	9.12	1.31	0.99	0.955
Transport equip.	48	0.86	0.89	0.47	186.02	0.00	0.89	695.75	0.01	0.19	7.36	1.02	0.87	0.553
Other manufacturing	765	0.58	0.91	0.20	0.78	0.00	0.69	82.49	0.00	0.42	4.86	1.64	0.00	
Average		0.64	0.89	0.29	45.59		0.84	778.33			4.96	1.45		

Table 1.7: East Asia Pacific: Parameter estimation and goodness of fit for the Pareto and lognormal distributions. Empirical distribution of productivities based on estimation of the residual from a Cobb-Douglas production technology

		OLS		MLE			MLE mod				Log-normal			
	Obs.	k_s	R^2	k_s	x_{min}	K.S p-value	k_s	x_{min}	K.S p-value	ratio of $x < x_{min}$	m	v	K.S p-value	Monte Carlo p-value
Food beverages and tobacco	403	0.87	0.88	0.27	7.84	0.00	1.29	412.73	0.00	0.61	5.76	1.06	0.46	0.092
Textiles	329	0.96	0.82	0.37	25.57	0.00	1.44	353.29	0.00	0.46	5.93	0.92	0.26	0.017
Wearing apparel except footwear	343	0.97	0.86	0.36	79.90	0.00	1.47	1360.27	0.00	0.53	7.15	0.93	0.11	0.002
Leather products and footwear	42	1.16	0.87	0.60	301.09	0.00	1.37	1036.87	0.00	0.26	7.37	0.76	0.80	0.426
Wood products except furniture	63	0.77	0.79	0.35	25.47	0.00	1.33	367.45	0.00	0.37	6.06	1.08	0.33	0.029
Paper products	38	1.29	0.86	0.67	161.08	0.00	1.47	430.78	0.13	0.16	6.57	0.66	0.77	0.377
Printing and Publishing	56	0.9	0.91	0.47	181.12	0.00	1.35	1621.48	0.00	0.52	7.33	1.01	0.82	0.461
Chemicals	272	0.91	0.87	0.42	89.79	0.00	1.60	2001.69	0.00	0.76	6.90	1.02	0.55	0.148
Rubber and plastic	311	0.92	0.87	0.38	286.16	0.00	1.39	5351.66	0.00	0.66	8.26	0.99	0.45	0.076
Other non-metallic products	372	0.96	0.87	0.35	39.35	0.00	1.22	550.88	0.00	0.42	6.52	0.96	0.22	0.010
Metallic products	99	1.04	0.92	0.62	219.95	0.00	1.52	1513.42	0.00	0.66	7.00	0.89	0.81	0.451
Fabricated metal products	246	0.96	0.9	0.44	173.30	0.00	1.24	1480.11	0.00	0.47	7.41	0.98	0.19	0.007
Machinery except electrical	171	0.96	0.92	0.50	176.33	0.00	1.21	1164.73	0.00	0.48	7.17	0.98	0.45	0.081
Electric machinery	157	0.87	0.87	0.32	276.31	0.00	1.31	5890.42	0.00	0.47	8.71	1.03	0.14	0.003
Professional and scientific equipment	82	0.86	0.88	0.44	313.63	0.00	1.21	2802.60	0.00	0.44	8.04	1.04	0.49	0.100
Transport equipment	126	1.12	0.85	0.52	630.69	0.00	1.49	3914.81	0.00	0.46	8.36	0.79	0.65	0.228
other manufacturing	104	0.92	0.84	0.48	97.41	0.00	1.44	818.60	0.00	0.50	6.65	0.95	0.94	0.738
Average		0.97	0.87	0.45	181.47		1.37	1827.75			7.13	0.94		

Table 1.8: East Europe & Central Asia: Parameter estimation and goodness of fit for the Pareto and lognormal distributions. Empirical distribution of productivities based on estimation of the residual from a Cobb-Douglas production technology

		OLS		MLE			MLE mod				Log-normal			
	Obs.	k_s	R^2	k_s	x_{min}	K.S p-value	k_s	x_{min}	K.S p-value	ratio of $x < x_{min}$	m	v	K.S p-value	Monte Carlo p-value
Food beverages and tobacco	1112	0.78	0.85	0.33	278.38	0.00	1.17	8683.76	0.00	0.65	8.69	1.17	0.19	0.007
Textiles	284	0.79	0.82	0.35	170.75	0.00	1.38	3966.73	0.00	0.58	7.99	1.12	0.78	0.403
Wearing apparel except footwear	601	0.95	0.9	0.42	169.76	0.00	1.31	2574.45	0.00	0.68	7.49	0.99	0.09	0.001
Leather products and footwear	59	0.88	0.95	0.45	110.01	0.00	0.94	460.45	0.01	0.19	6.91	1.30	0.02	
Wood products except furniture	240	0.87	0.9	0.44	563.66	0.00	0.99	3510.19	0.00	0.34	8.62	1.07	0.16	0.004
Paper products	68	0.67	0.8	0.26	3438.73	0.00	1.00	116026.90	0.00	0.38	11.94	1.38	0.26	0.016
Printing and Publishing	210	0.88	0.88	0.40	154.65	0.00	1.36	2775.91	0.00	0.67	7.54	1.04	0.62	0.194
Chemicals	284	0.79	0.81	0.29	330.44	0.00	1.44	14939.70	0.00	0.60	9.29	1.11	0.64	0.213
Rubber and plastic	193	0.9	0.78	0.34	161.90	0.00	1.43	3045.54	0.00	0.45	8.07	0.95	0.63	0.208
Other non-metallic products	320	0.76	0.81	0.31	155.42	0.00	1.33	5973.27	0.00	0.62	8.29	1.15	0.99	0.929
Metallic products	55	0.65	0.92	0.31	144.95	0.00	0.78	2364.67	0.00	0.38	8.23	1.44	0.19	0.006
Fabricated metal products	594	0.94	0.85	0.32	139.47	0.00	1.36	3627.29	0.00	0.59	8.03	0.97	0.12	0.002
Machinery except electrical	423	0.89	0.86	0.38	1070.20	0.00	1.49	33762.05	0.00	0.81	9.58	1.03	0.35	0.044
Electric machinery	163	0.88	0.84	0.36	426.96	0.00	1.39	8455.83	0.00	0.60	8.83	1.00	0.81	0.452
Professional and scientific equipment	106	0.81	0.86	0.41	1435.32	0.00	1.41	25665.57	0.00	0.63	9.71	1.10	0.66	0.236
Transport equipment	64	0.83	0.74	0.36	317.55	0.00	1.57	5243.98	0.00	0.42	8.57	0.98	0.74	0.336
other manufacturing	324	0.82	0.89	0.35	220.82	0.00	1.05	3104.72	0.00	0.44	8.22	1.13	0.14	0.002
Average		0.83	0.85	0.36	546.41		1.26	14363.59			8.59	1.11		

Table 1.9: Latin America and the Caribbean: Parameter estimation and goodness of fit for the Pareto and lognormal distributions. Empirical distribution of productivities based on estimation of the residual from a Cobb-Douglas production technology

		OLS		MLE			MLE mod				Log-normal			
	Obs.	k_s	R^2	k_s	x_{min}	K.S p-value	k_s	x_{min}	K.S p-value	ratio of $x < x_{min}$	m	v	K.S p-value	Monte Carlo p-value
Food beverages and tobacco	2172	0.98	0.83	0.32	63.62	0.00	1.81	3743.14	0.00	0.85	7.32	0.92	0.05	
Textiles	872	0.91	0.74	0.27	74.84	0.00	1.84	4770.79	0.00	0.70	7.99	0.94	0.04	
Wearing apparel except footwear	1251	0.95	0.81	0.33	121.37	0.00	1.69	4004.55	0.00	0.72	7.79	0.93	0.43	0.071
Leather products and footwear	268	0.92	0.7	0.25	10.31	0.00	1.91	704.29	0.00	0.59	6.30	0.88	0.15	0.005
Wood products except furniture	143	1.03	0.87	0.46	186.39	0.00	1.66	2017.19	0.00	0.57	7.41	0.89	0.73	0.332
Paper products	62	1	0.71	0.43	405.45	0.00	1.22	2326.14	0.02	0.16	8.34	0.80	0.74	0.329
Printing and Publishing	192	1.29	0.8	0.38	988.92	0.00	2.06	12703.50	0.00	0.41	9.53	0.70	0.06	0.002
Chemicals	1306	1.01	0.82	0.31	194.52	0.00	2.01	11126.73	0.00	0.82	8.50	0.89	0.27	0.021
Rubber and plastic	537	1.24	0.79	0.46	481.08	0.00	2.35	5880.26	0.00	0.65	8.37	0.70	0.80	0.434
Other non-metallic products	388	0.97	0.88	0.37	65.87	0.00	1.34	884.71	0.00	0.45	6.89	0.95	0.14	0.003
Metallic products	125	0.89	0.82	0.37	63.97	0.00	1.27	931.45	0.00	0.46	6.88	1.00	0.98	0.898
Fabricated metal products	885	1.11	0.84	0.37	260.83	0.00	1.65	4216.79	0.00	0.56	8.24	0.81	0.37	0.045
Machinery except electrical	620	0.97	0.78	0.32	138.30	0.00	2.02	5270.53	0.00	0.72	8.04	0.89	0.54	0.132
Electric machinery	142	1.12	0.85	0.46	188.51	0.00	0.99	680.91	0.28	0.07	7.43	0.79	0.18	0.006
Professional and scientific equipment	73	1.08	0.85	0.53	1543.51	0.00	1.27	5755.48	0.03	0.15	9.25	0.80	0.09	0.001
Transport equipment	138	0.67	0.64	0.21	6.04	0.00	1.26	525.59	0.00	0.33	6.51	1.17	0.03	
other manufacturing	463	0.83	0.76	0.24	6.90	0.00	1.84	988.21	0.00	0.79	6.09	1.03	0.31	0.032
Average		0.99	0.79	0.36	282.38		1.66	3913.54			7.70	0.89		

Table 1.10: South Asia: Parameter estimation and goodness of fit for the Pareto and lognormal distributions. Empirical distribution of productivities based on estimation of the residual from a Cobb-Douglas production technology

		OLS		MLE			MLE mod				Log-normal			
	Obs.	k_s	R^2	k_s	x_{min}	K.S p-value	k_s	x_{min}	K.S p-value	ratio of $x < x_{min}$	m	v	K.S p-value	Monte Carlo p-value
Food beverages and tobacco	542	0.77	0.91	0.38	43.79	0.00	1.24	1569.81	0.00	0.78	6.42	1.21	0.10	0.001
Textiles	481	0.94	0.87	0.45	113.92	0.00	1.67	2221.36	0.00	0.77	6.97	0.97	0.37	0.045
Wearing apparel except footwear	448	1.04	0.88	0.49	128.15	0.00	1.80	2190.74	0.00	0.81	6.90	0.89	0.55	0.142
Leather products and footwear	352	0.86	0.83	0.37	50.71	0.00	1.71	1529.58	0.00	0.75	6.59	1.03	0.98	0.871
Wood products except furniture	66	0.97	0.83	0.55	259.30	0.00	1.18	1248.29	0.00	0.41	7.37	0.92	0.65	0.224
Paper products	40	0.76	0.91	0.43	121.32	0.00	0.91	728.25	0.00	0.33	7.13	1.13	0.47	0.082
Printing and Publishing	68	1.22	0.89	0.48	59.13	0.00	1.59	394.49	0.00	0.40	6.16	0.77	0.62	0.200
Chemicals	279	0.96	0.85	0.47	85.67	0.00	1.67	1212.45	0.00	0.70	6.59	0.95	0.93	0.709
Rubber and plastic	108	0.74	0.85	0.39	21.90	0.00	0.69	93.68	0.00	0.17	5.65	1.18	0.86	0.543
Other non-metallic products	95	0.72	0.74	0.19	53.87	0.00	1.38	16824.12	0.00	0.63	9.33	1.15	0.88	0.589
Metallic products	85	0.86	0.87	0.46	361.42	0.00	1.12	2496.12	0.00	0.39	8.07	1.03	0.93	0.730
Fabricated metal products	76	0.89	0.83	0.45	86.49	0.00	1.51	959.18	0.00	0.58	6.70	0.98	0.49	0.102
Machinery except electrical	78	1.08	0.83	0.46	183.44	0.00	1.21	988.14	0.00	0.23	7.41	0.83	0.95	0.775
Electric machinery	70	0.9	0.92	0.52	113.83	0.00	0.84	313.88	0.01	0.19	6.65	1.10	0.20	0.008
Professional and scientific equipment	15	1.08	0.9	1.06	5494.80	0.83	1.06	5494.80	0.83	0.00	9.56	0.77	0.83	0.473
Transport equipment	34	0.7	0.9	0.46	41.97	0.07	1.11	485.10	0.00	0.53	5.92	1.41	0.78	0.399
other manufacturing	142	0.95	0.82	0.41	323.44	0.00	1.06	1977.84	0.00	0.18	8.24	0.91	0.81	0.435
Average		0.91	0.86	0.47	443.71		1.28	2395.76			7.16	1.01		

Table 1.11: Africa: Parameter estimation and goodness of fit for the Pareto and lognormal distributions. Empirical distribution of productivities using a transformation on firms' revenues.

		MLE			MLE mod				Log-normal			
	Obs.	k_s	x_{min}	K.S p-value	k_s	x_{min}	K.S p-value	ratio of $x < x_{min}$	m	v	K.S p-value	Monte Carlo p-value
Food beverages and tobacco	1623	0.26	0.89	0.00	0.96	98.75	0.00	0.74	3.66	1.49	0.00	
Textiles	187	0.37	8.31	0.00	1.04	145.54	0.00	0.57	4.83	1.24	0.39	0.541
Wearing apparel except footwear	1008	0.34	1.32	0.00	0.96	31.85	0.00	0.58	3.25	1.31	0.04	
Leather products and footwear	112	0.27	3.50	0.00	0.79	97.97	0.00	0.42	4.89	1.47	0.81	0.081
Wood products except furniture	240	0.25	1.25	0.00	0.77	174.50	0.00	0.78	4.16	1.62	0.05	0.003
Paper products	72	0.30	17.78	0.00	0.88	646.76	0.00	0.65	6.23	1.35	0.27	0.097
Printing and Publishing	234	0.36	1.18	0.00	0.95	18.73	0.00	0.52	2.92	1.26	0.36	0.005
Chemicals	343	0.31	8.91	0.00	0.72	128.87	0.00	0.40	5.38	1.48	0.01	0.038
Rubber and plastic	187	0.33	4.63	0.00	0.72	54.36	0.00	0.37	4.61	1.47	0.00	0.167
Other non-metallic products	215	0.29	1.90	0.00	0.70	25.96	0.00	0.25	4.14	1.54	0.03	0.021
Metallic products	91	0.15	0.63	0.00	0.89	352.68	0.00	0.33	6.29	1.49	0.29	0.017
Fabricated metal products	530	0.30	1.00	0.00	0.86	37.15	0.00	0.62	3.33	1.43	0.14	0.002
Machinery except electrical	124	0.28	2.24	0.00	0.61	28.09	0.00	0.24	4.39	1.70	0.02	0.114
Electric machinery	63	0.17	0.44	0.00	0.64	48.07	0.01	0.17	4.96	1.85	0.22	0.775
Professional and scientific equip.	19	0.35	534.23	0.04	1.17	10564.04	0.00	0.47	9.12	1.31	0.99	0.323
Transport equip.	48	0.47	186.02	0.00	0.89	695.75	0.01	0.19	7.36	1.02	0.87	0.852
Other manufacturing	765	0.20	0.78	0.00	0.69	82.49	0.00	0.42	4.86	1.64	0.00	
Average		0.29	45.59		0.84	778.33		0.45	4.96	1.45		

Notes. The values for x_{min} have been divided by 1000

Table 1.12: East Asia Pacific: Parameter estimation and goodness of fit for the Pareto and lognormal distributions. Empirical distribution of productivities using a transformation on firms' revenues.

		MLE			MLE mod				Log-normal			
	Obs.	k_s	x_{min}	K.S p-value	k_s	x_{min}	K.S p-value	ratio of $x < x_{min}$	m	v	K.S p-value	Monte Carlo p-value
Food beverages and tobacco	403	0.27	7.84	0.00	1.29	412.73	0.00	0.61	5.76	1.06	0.46	0.029
Textiles	329	0.37	25.57	0.00	1.44	353.29	0.00	0.46	5.93	0.92	0.26	
Wearing apparel except footwear	343	0.36	79.90	0.00	1.47	1360.27	0.00	0.53	7.15	0.93	0.11	0.001
Leather products and footwear	42	0.60	301.09	0.00	1.37	1036.87	0.00	0.26	7.37	0.76	0.80	0.078
Wood products except furniture	63	0.35	25.47	0.00	1.33	367.45	0.00	0.37	6.06	1.08	0.33	0.035
Paper products	38	0.67	161.08	0.00	1.47	430.78	0.13	0.16	6.57	0.66	0.77	0.239
Printing and Publishing	56	0.47	181.12	0.00	1.35	1621.48	0.00	0.52	7.33	1.01	0.82	0.003
Chemicals	272	0.42	89.79	0.00	1.60	2001.69	0.00	0.76	6.90	1.02	0.55	
Rubber and plastic	311	0.38	286.16	0.00	1.39	5351.66	0.00	0.66	8.26	0.99	0.45	
Other non-metallic products	372	0.35	39.35	0.00	1.22	550.88	0.00	0.42	6.52	0.96	0.22	0.001
Metallic products	99	0.62	219.95	0.00	1.52	1513.42	0.00	0.66	7.00	0.89	0.81	0.507
Fabricated metal products	246	0.44	173.30	0.00	1.24	1480.11	0.00	0.47	7.41	0.98	0.19	0.002
Machinery except electrical	171	0.50	176.33	0.00	1.21	1164.73	0.00	0.48	7.17	0.98	0.45	0.323
Electric machinery	157	0.32	276.31	0.00	1.31	5890.42	0.00	0.47	8.71	1.03	0.14	0.381
Professional and scientific equipment	82	0.44	313.63	0.00	1.21	2802.60	0.00	0.44	8.04	1.04	0.49	0.160
Transport equipment	126	0.52	630.69	0.00	1.49	3914.81	0.00	0.46	8.36	0.79	0.65	0.034
other manufacturing	104	0.48	97.41	0.00	1.44	818.60	0.00	0.50	6.65	0.95	0.94	0.135
Average		0.45	181.47		1.37	1827.75			7.13	0.94		

Notes. The values for x_{min} have been divided by 1000

Table 1.13: Eastern Europe & Central Asia region: Parameter estimation and goodness of fit for the Pareto and lognormal distributions. Empirical distribution of productivities using a transformation on firms' revenues.

		MLE			MLE mod				Log-normal			
	Obs.	k_s	x_{min}	K.S p-value	k_s	x_{min}	K.S p-value	ratio of $x < x_{min}$	m	v	K.S p-value	Monte Carlo p-value
Food beverages and tobacco	1112	0.33	278.38	0.00	1.17	8683.76	0.00	0.65	8.69	1.17	0.19	
Textiles	284	0.35	170.75	0.00	1.38	3966.73	0.00	0.58	7.99	1.12	0.78	
Wearing apparel except footwear	601	0.42	169.76	0.00	1.31	2574.45	0.00	0.68	7.49	0.99	0.09	0.414
Leather products and footwear	59	0.45	110.01	0.00	0.94	460.45	0.01	0.19	6.91	1.30	0.02	0.574
Wood products except furniture	240	0.44	563.66	0.00	0.99	3510.19	0.00	0.34	8.62	1.07	0.16	0.460
Paper products	68	0.26	3438.73	0.00	1.00	116026.90	0.00	0.38	11.94	1.38	0.26	0.895
Printing and Publishing	210	0.40	154.65	0.00	1.36	2775.91	0.00	0.67	7.54	1.04	0.62	0.239
Chemicals	284	0.29	330.44	0.00	1.44	14939.70	0.00	0.60	9.29	1.11	0.64	0.048
Rubber and plastic	193	0.34	161.90	0.00	1.43	3045.54	0.00	0.45	8.07	0.95	0.63	0.011
Other non-metallic products	320	0.31	155.42	0.00	1.33	5973.27	0.00	0.62	8.29	1.15	0.99	0.310
Metallic products	55	0.31	144.95	0.00	0.78	2364.67	0.00	0.38	8.23	1.44	0.19	0.096
Fabricated metal products	594	0.32	139.47	0.00	1.36	3627.29	0.00	0.59	8.03	0.97	0.12	0.180
Machinery except electrical	423	0.38	1070.20	0.00	1.49	33762.05	0.00	0.81	9.58	1.03	0.35	0.041
Electric machinery	163	0.36	426.96	0.00	1.39	8455.83	0.00	0.60	8.83	1.00	0.81	0.001
Professional and scientific equipment	106	0.41	1435.32	0.00	1.41	25665.57	0.00	0.63	9.71	1.10	0.66	0.302
Transport equipment	64	0.36	317.55	0.00	1.57	5243.98	0.00	0.42	8.57	0.98	0.74	0.596
other manufacturing	324	0.35	220.82	0.00	1.05	3104.72	0.00	0.44	8.22	1.13	0.14	0.065
Average		0.36	546.41		1.26	14363.59			8.59	1.11		

Notes. The values for x_{min} have been divided by 1000

Table 1.14: Latin America and the Caribbean: Parameter estimation and goodness of fit for the Pareto and lognormal distributions. Empirical distribution of productivities using a transformation on firms' revenues.

		MLE			MLE mod				Log-normal			
	Obs.	k_s	x_{min}	K.S p-value	k_s	x_{min}	K.S p-value	ratio of $x < x_{min}$	m	v	K.S p-value	Monte Carlo p-value
Food beverages and tobacco	2172	0.32	63.62	0.00	1.81	3743.14	0.00	0.85	7.32	0.92	0.05	
Textiles	872	0.27	74.84	0.00	1.84	4770.79	0.00	0.70	7.99	0.94	0.04	0.057
Wearing apparel except footwear	1251	0.33	121.37	0.00	1.69	4004.55	0.00	0.72	7.79	0.93	0.43	0.046
Leather products and footwear	268	0.25	10.31	0.00	1.91	704.29	0.00	0.59	6.30	0.88	0.15	0.342
Wood products except furniture	143	0.46	186.39	0.00	1.66	2017.19	0.00	0.57	7.41	0.89	0.73	0.473
Paper products	62	0.43	405.45	0.00	1.22	2326.14	0.02	0.16	8.34	0.80	0.74	0.006
Printing and Publishing	192	0.38	988.92	0.00	2.06	12703.50	0.00	0.41	9.53	0.70	0.06	0.025
Chemicals	1306	0.31	194.52	0.00	2.01	11126.73	0.00	0.82	8.50	0.89	0.27	
Rubber and plastic	537	0.46	481.08	0.00	2.35	5880.26	0.00	0.65	8.37	0.70	0.80	0.000
Other non-metallic products	388	0.37	65.87	0.00	1.34	884.71	0.00	0.45	6.89	0.95	0.14	0.000
Metallic products	125	0.37	63.97	0.00	1.27	931.45	0.00	0.46	6.88	1.00	0.98	0.149
Fabricated metal products	885	0.37	260.83	0.00	1.65	4216.79	0.00	0.56	8.24	0.81	0.37	0.004
Machinery except electrical	620	0.32	138.30	0.00	2.02	5270.53	0.00	0.72	8.04	0.89	0.54	0.151
Electric machinery	142	0.46	188.51	0.00	0.99	680.91	0.28	0.07	7.43	0.79	0.18	0.125
Professional and scientific equipment	73	0.53	1543.51	0.00	1.27	5755.48	0.03	0.15	9.25	0.80	0.09	0.009
Transport equipment	138	0.21	6.04	0.00	1.26	525.59	0.00	0.33	6.51	1.17	0.03	0.555
other manufacturing	463	0.24	6.90	0.00	1.84	988.21	0.00	0.79	6.09	1.03	0.31	0.151
Average		0.36	282.38		1.66	3913.54			7.70	0.89		

Notes. The values for x_{min} have been divided by 1000

Table 1.15: South Asia Region: Parameter estimation and goodness of fit for the Pareto and lognormal distributions. Empirical distribution of productivities using a transformation on firms' revenues.

		MLE			MLE mod				Log-normal			
	Obs.	k_s	x_{min}	K.S p-value	k_s	x_{min}	K.S p-value	ratio of $x < x_{min}$	m	v	K.S p-value	Monte Carlo p-value
Food beverages and tobacco	542	0.38	43.79	0.00	1.24	1569.81	0.00	0.78	6.42	1.21	0.10	
Textiles	481	0.45	113.92	0.00	1.67	2221.36	0.00	0.77	6.97	0.97	0.37	
Wearing apparel except footwear	448	0.49	128.15	0.00	1.80	2190.74	0.00	0.81	6.90	0.89	0.55	
Leather products and footwear	352	0.37	50.71	0.00	1.71	1529.58	0.00	0.75	6.59	1.03	0.98	
Wood products except furniture	66	0.55	259.30	0.00	1.18	1248.29	0.00	0.41	7.37	0.92	0.65	0.014
Paper products	40	0.43	121.32	0.00	0.91	728.25	0.00	0.33	7.13	1.13	0.47	0.424
Printing and Publishing	68	0.48	59.13	0.00	1.59	394.49	0.00	0.40	6.16	0.77	0.62	0.106
Chemicals	279	0.47	85.67	0.00	1.67	1212.45	0.00	0.70	6.59	0.95	0.93	0.027
Rubber and plastic	108	0.39	21.90	0.00	0.69	93.68	0.00	0.17	5.65	1.18	0.86	0.034
Other non-metallic products	95	0.19	53.87	0.00	1.38	16824.12	0.00	0.63	9.33	1.15	0.88	0.041
Metallic products	85	0.46	361.42	0.00	1.12	2496.12	0.00	0.39	8.07	1.03	0.93	0.622
Fabricated metal products	76	0.45	86.49	0.00	1.51	959.18	0.00	0.58	6.70	0.98	0.49	0.894
Machinery except electrical	78	0.46	183.44	0.00	1.21	988.14	0.00	0.23	7.41	0.83	0.95	0.112
Electric machinery	70	0.52	113.83	0.00	0.84	313.88	0.01	0.19	6.65	1.10	0.20	0.684
Professional and scientific equipment	15	1.06	5494.80	0.83	1.06	5494.80	0.83	0.00	9.56	0.77	0.83	0.954
Transport equipment	34	0.46	41.97	0.07	1.11	485.10	0.00	0.53	5.92	1.41	0.78	
other manufacturing	142	0.41	323.44	0.00	1.06	1977.84	0.00	0.18	8.24	0.91	0.81	0.081
Average		0.47	443.71		1.28	2395.75			7.16	1.01		

Notes. The values for x_{min} have been divided by 1000

Figure 1.4: Effects of Changes in the Elasticity of Substitution for sector 2

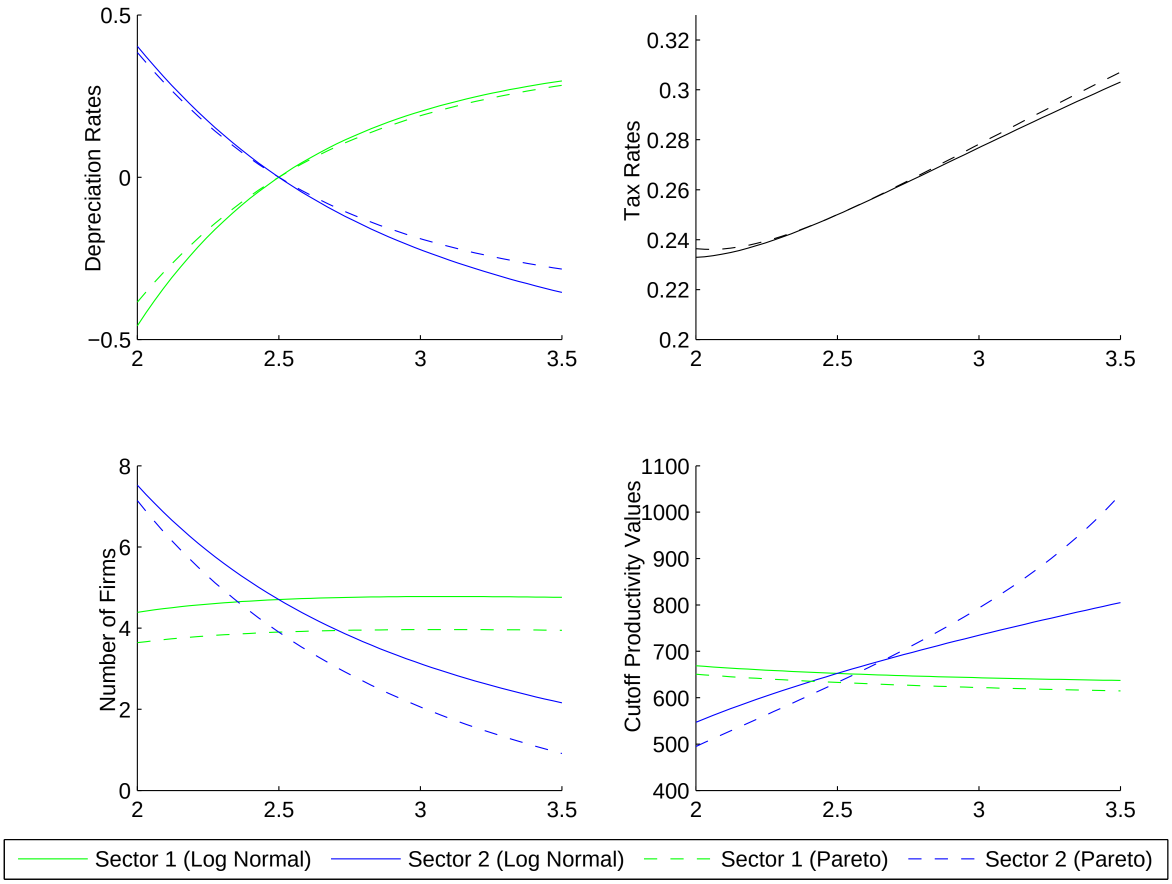


Figure 1.5: Depreciation and tax rates as functions of different variables

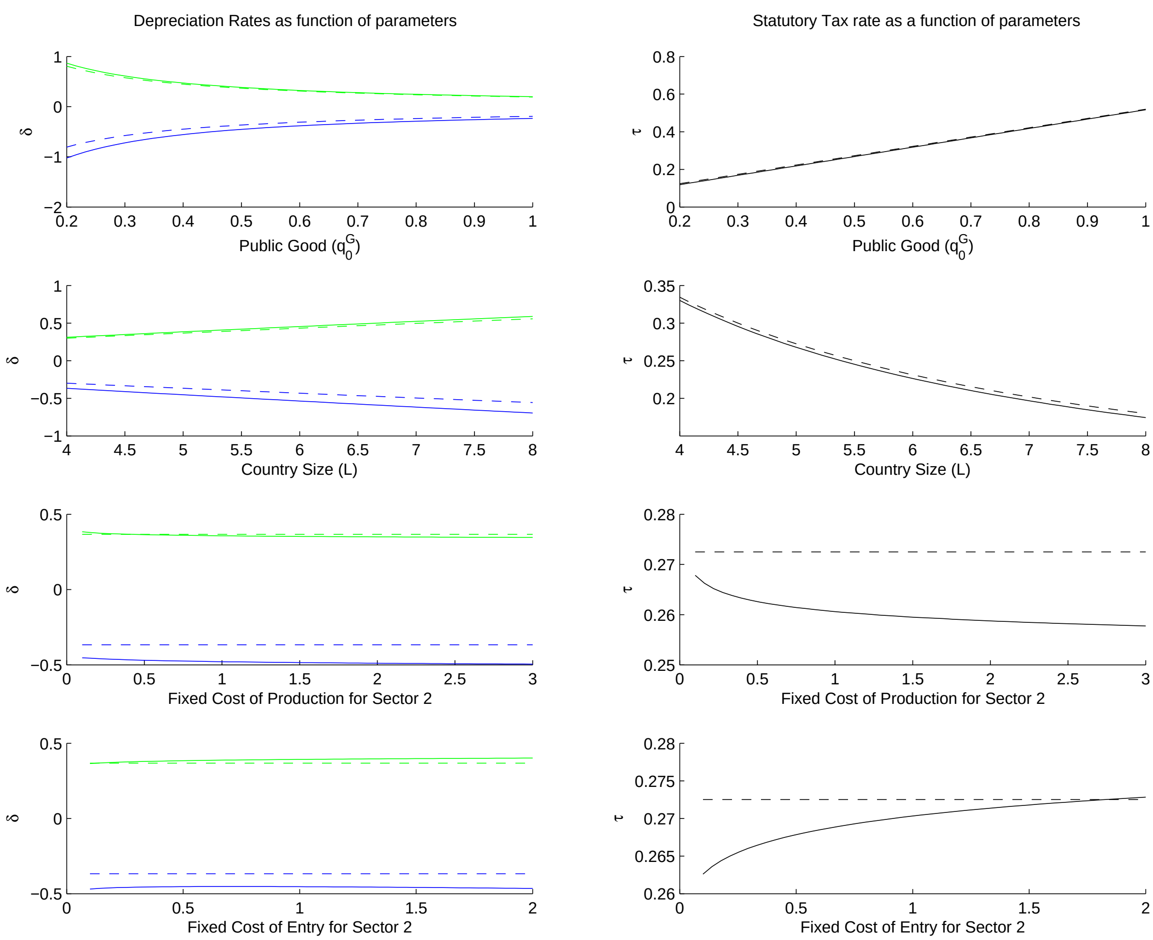


Figure 1.6: Tax revenue and gains from trade using the optimal corporate tax rates based in the closed economy formulas

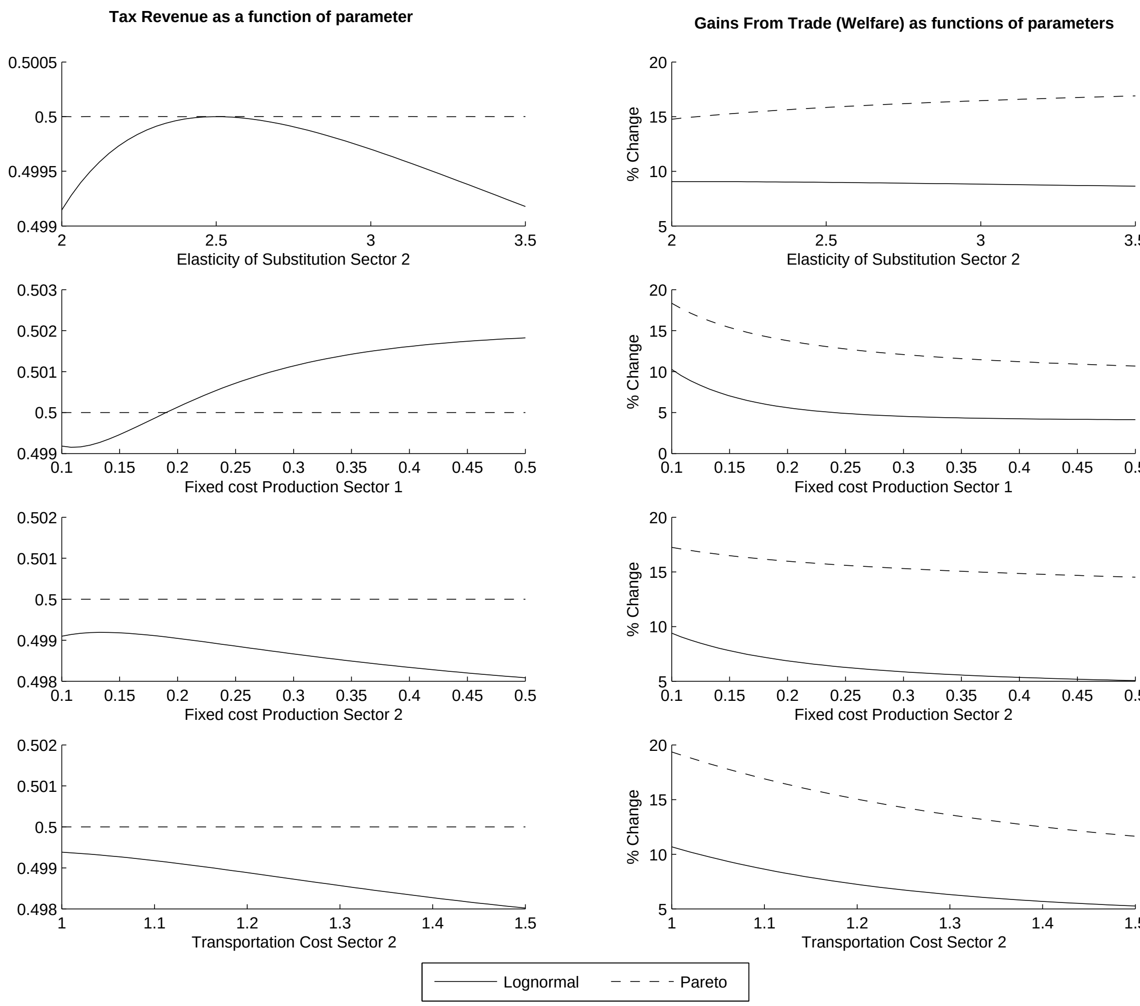


Figure 1.7: Distribution of log sales of firms for 17 sectors in the Africa region

Figure 1.8: Distribution of log sales of firms for 17 sectors in the East and Pacific Asia region

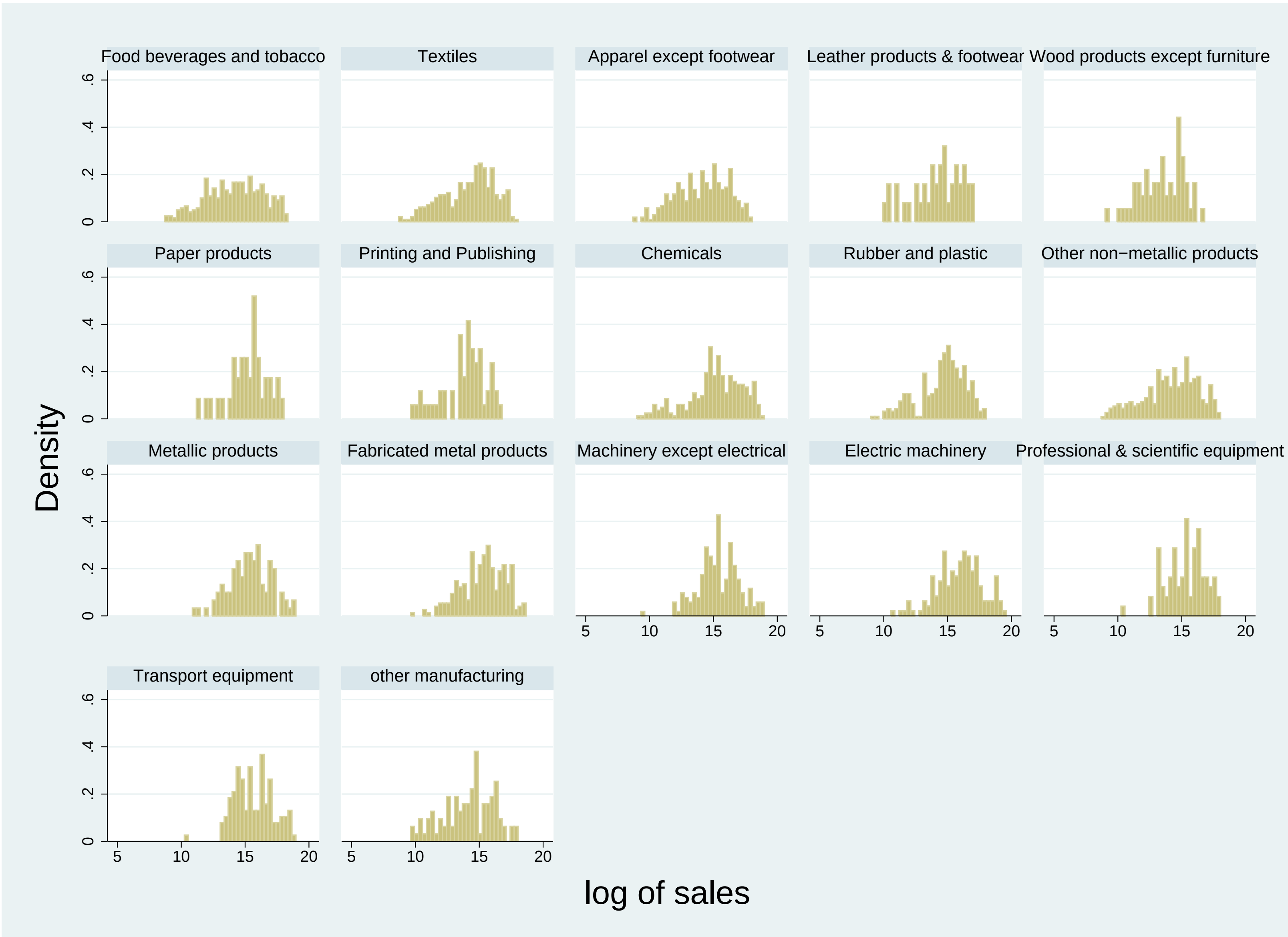


Figure 1.9: Distribution of log sales of firms for 17 sectors in the Eastern Europe and Central Asia region

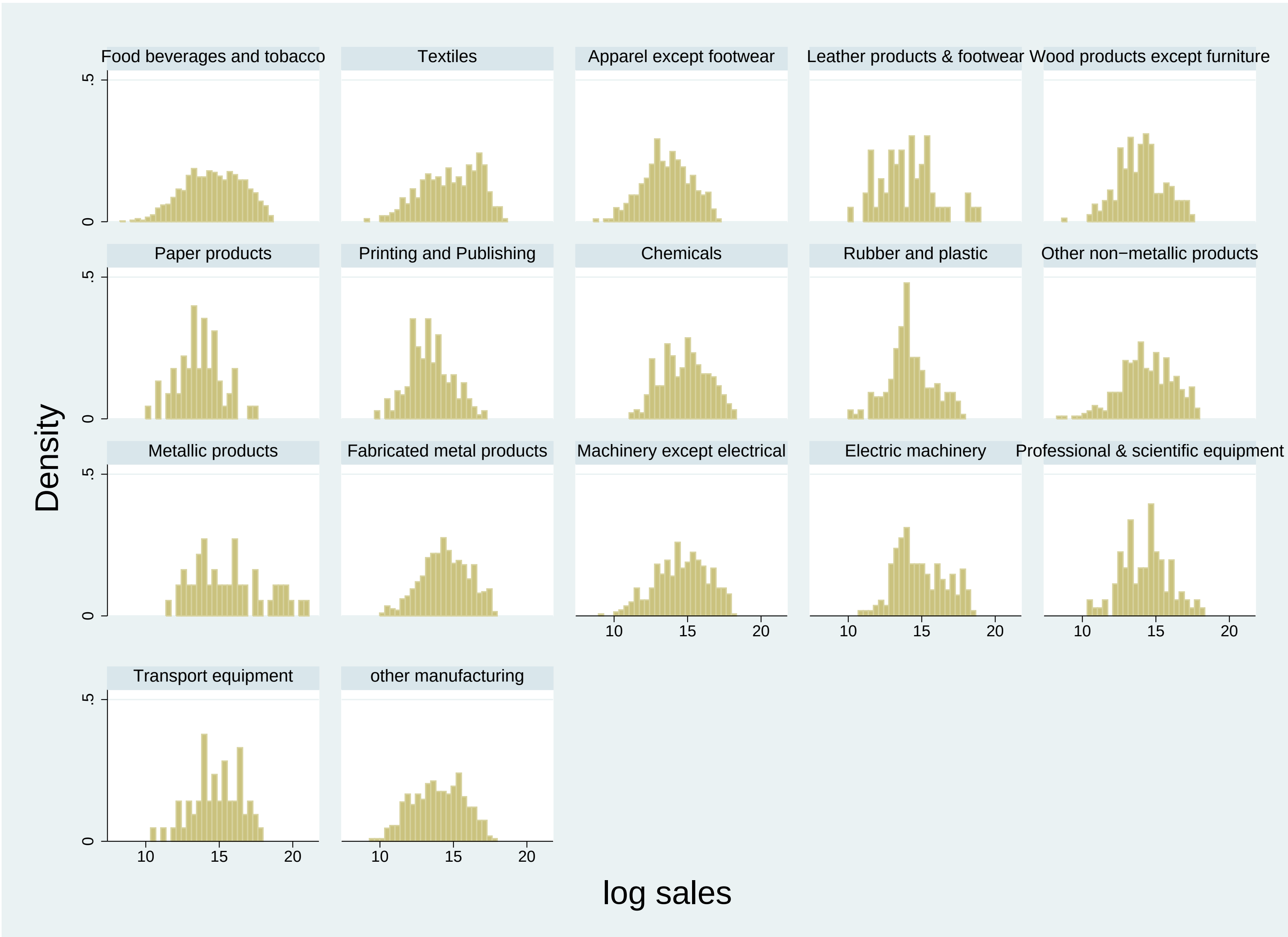


Figure 1.10: Distribution of log sales of firms for 17 sectors in the Latin America region

Figure 1.11: Distribution of log sales of firms for 17 sectors in the South Asia region

Appendix

1.A Closed Economy

Useful Formulas

$$\bar{r}_s = r(\tilde{\varphi}_s) = \sigma u_s f_s h_s^{\sigma_s - 1} \quad (1.A.1)$$

$$\bar{t}_s = t_s(\tilde{\varphi}_s) = \tau \left(u_s f_s h_s^{\sigma_s - 1} - \delta_s w f_s \right) \quad (1.A.2)$$

$$\frac{\partial u_s}{\partial \tau} = \frac{(1-\delta_s)}{(1-\tau)^2} \gtreqless 0 \quad (1.A.3)$$

$$\frac{\partial u_s}{\partial \delta_{s'}} = -\frac{\tau}{1-\tau} < 0 \qquad \text{if s=s', otherwise 0} \quad (1.A.4)$$

$$\frac{\partial \bar{r}_s}{\partial \delta_s} = \sigma_s f_s \left(h_s^{\sigma_s - 1} \frac{\partial u_s}{\partial \delta_s} + u_s \frac{\partial h_s^{\sigma_s - 1}}{\partial \delta_s} \right) \qquad \text{if s=s', otherwise 0} \quad (1.A.5)$$

$$\frac{\partial \bar{r}_s}{\partial \tau} = \sigma_s f_s \left(h_s^{\sigma_s - 1} \frac{\partial u_s}{\partial \tau} + u_s \frac{\partial h_s^{\sigma_s - 1}}{\partial \tau} \right) \quad (1.A.6)$$

$$\frac{\partial h_s^{\sigma_s - 1}}{\partial x} = (\sigma_s - 1) h_s^{\sigma_s - 1} \left[\frac{\partial \varphi_s^*}{\partial x} \frac{1}{\varphi_s^*} \left[\xi^s_{\tilde{\varphi}_s, \varphi_s^*} - 1 \right] \right] \quad (1.A.7)$$

To get $\frac{\partial \tilde{\varphi}}{\partial \varphi^*}$ apply Leibniz rule to the average productivity equation. The simplified result is:

$$\frac{\partial \tilde{\varphi}_s}{\partial \varphi_s^*} = \frac{z(\varphi_s^*) \tilde{\varphi}_s}{(\sigma - 1)(1 - Z_s(\varphi_s^*))} \left[1 - h_s^{1-\sigma} \right] \quad (1.A.8)$$

Elasticities

As mentioned in the paper, let $\xi^s_{x,y}$ be the elasticity of variable x with respect to y for sector s.

$$\xi^s_{\tilde{\varphi}_s,\varphi^*} = \frac{z(\varphi^*_s)\varphi^*_s}{(\sigma-1)(1-Z(\varphi^*_s)}\left[1-h_s^{1-\sigma}\right] \tag{1.A.9}$$

$$\xi^s_{M_s,\delta_{s'}} = \frac{\sum_{i=1}^S \frac{\partial T_i}{\partial \delta_{s'}}\delta_{s'}}{\left(wL+\sum_{i=1}^S T_i - q_0^G\right)} - \left[\frac{-\tau\delta_s}{(1-\delta_s\tau)} + (\sigma-1)\left(\xi_{\varphi^*_s,\delta_{s'}}\left[\xi_{\tilde{\varphi}_s,\varphi^*_s}-1\right]\right)\right] \tag{1.A.10}$$

$$\xi^s_{M_s,\delta_{s'}} = \frac{\sum_{i=1}^S \frac{\partial T_i}{\partial \delta_{s'}}\delta_{s'}}{\left(wL+\sum_{i=1}^S T_i - q_0^G\right)} \qquad \text{if s} \neq \text{s'} \tag{1.A.11}$$

$$\xi^s_{M_s,\tau} = \frac{\sum_{i=1}^S \frac{\partial T_i}{\partial \tau}\tau}{\left(wL+\sum_{i=1}^S T_i - q_0^G\right)} - \left[\frac{(1-\delta_s)\tau}{(1-\tau)(1-\delta_s\tau)} + (\sigma-1)\left(\xi_{\varphi^*,\tau}\left[\xi_{\tilde{\varphi}_s,\varphi^*_s}-1\right]\right)\right] \tag{1.A.12}$$

1.A.1 Optimal Taxes in the Closed Model

The FOCs for δ_i and τ are rewritten into:

$$\alpha_i\left[\frac{\tau\delta_i}{(1-\delta_i\tau)(1-\sigma_i)} - \xi_{\varphi^*_i,\delta_i}\right] = \tilde{\lambda}M_i\tau\delta_i f_i\left[\frac{-w}{1-\delta_i\tau} + (\sigma_i-1)\xi_{\varphi^*_i,\delta_i}(\xi_{\tilde{\varphi}_i,\varphi^*_i}-1)w\right] \tag{1.A.13}$$

$$\sum_{i=1}^S \alpha_i\left(\frac{-(1-\delta_i)\tau}{(1-\tau)(1-\delta_i\tau)(1-\sigma_i)} - \xi_{\varphi^*_{s'},\tau}\right) = \tilde{\lambda}\sum_{i=1}^S\left[M_i\tau w f_i\left((\sigma_i-1)\xi_{\varphi^*_i,\tau}(\xi_{\tilde{\varphi}_i,\varphi^*_i}-1)\delta_i + u_i h_i^{\sigma_i-1} - \delta_i\left(\frac{1-2\tau+\delta_i\tau^2}{(1-\tau)(1-\delta_i\tau)}\right)\right)\right] \tag{1.A.14}$$

Pareto Distribution

Assuming productivities follow a Pareto distribution, i.e:

$$Z_i(\varphi) = 1-\left(\frac{\varphi_{min,i}}{\varphi}\right)^{k_i}$$

Under this distribution, the variables needed to solve the model can be found:

$$\tilde{\varphi}_i = \left(\frac{k_i}{k_i-(\sigma_i-1)}\right)^{\frac{1}{\sigma_i-1}} \varphi_i^* \tag{1.A.15}$$

$$\varphi_i^* = \left[\left(\frac{\sigma_i-1}{k_i-(\sigma_i-1)}\right)\left(\frac{f_i(1-\delta_i\tau)}{\psi f_{e,i}}\right)\right]^{1/k_i} \varphi_{min,i} \tag{1.A.16}$$

$$\xi_{\varphi_i^*,\delta_i} = \frac{-\tau\delta_i}{k_i(1-\delta_i\tau)} = \xi_{\varphi_i^*,\tau} \tag{1.A.17}$$

Using these values we use equation 1.A.13 to find δ_i as a function of τ and parameters.

$$1-\delta_i\tau = \tilde{\lambda}(1-\tau)\rho_i wL$$

Such relation is used to find the optimal tax rate through equation 1.A.14, leading to:

$$1-\tau = \left[\sum_{i=1}^{S}\frac{\alpha_i}{k_i}\right]\left[\tilde{\lambda} wL \sum_{i=1}^{S}\frac{\alpha_i\rho_i}{k_i}\right]^{-1} \tag{1.A.18}$$

This equation implied

Log-normal Distribution

Under this distribution, the variables needed to solve the model must be found through numerical methods. To solve for $\tilde{\varphi}_i$ define:

$$d_i = \frac{(log(\varphi_i^*)-m_i)}{v_i} \tag{1.A.19}$$

$$\Phi(x) = \int_{-\infty}^{x}\frac{1}{\sqrt{2\pi}}\exp(-\frac{1}{2}x^2) \tag{1.A.20}$$

where m_i, v_i are the parameters for the lognormal distribution of productivities for sector i. The function $\Phi(x)$ is the CDF for the standard normal distribution. Using, these variables:

$$\begin{aligned}
\tilde{\varphi}_i^{\sigma_i-1} &= \frac{1}{1-Z_i(\varphi_i^*)}\int_{\varphi_i^*}^{\infty}\varphi^{\sigma_i-1}z(\varphi)d\varphi & (1.A.21)\\
&= \exp\left(m_i(\sigma_i-1)+\frac{((\sigma_i-1)v_i)^2}{2}\right)\frac{\Phi((\sigma_i-1)v_i-d_i)}{\Phi(-d_i)} & (1.A.22)\\
&= A_i g(\varphi_i^*) & (1.A.23)
\end{aligned}$$

Equation 1.A.22 is obtained through various substitutions in the integral, as well as using the symmetry of the normal distribution.[27] The productivity cutoff φ_s^* is found by solving:

$$\frac{A_i g_i(\varphi_i^*)}{(\varphi_i^*)^{\sigma-1}} = \frac{\psi f_{e,i}}{(1-\delta_i\tau)\Phi(-d_i)f_i}+1 \qquad (1.A.24)$$

In order to solve for the optimal rates we must find a formula for $\xi_{\varphi_i^*,\delta_i}$. This is accomplish by using 1.A.7,1.A.9 and the ZP and FE conditions.

$$\begin{aligned}
\xi_{\varphi_i^*,\delta_i} &= \frac{\psi f_{e,i}}{X_i(1-\sigma_i)}\left(\frac{\tau\delta_i}{1-\tau\delta_i}\right) & (1.A.25)\\
X_i &= \psi f_{e,i}+(1-\delta_i\tau)\Phi(-d_i)f_i & (1.A.26)
\end{aligned}$$

Using the above formula, equations 1.A.13 result in the following relationship:

$$\frac{1}{(1-\tau)\rho_i\lambda wL} = \frac{\psi f_{e,i}+\Phi(-d_i)f_i}{X_i}-\frac{\psi f_{e,i}\phi(-d_i)}{X_i\Phi(-d_i)v_i}\xi_{\varphi_i^*,\delta_i} \qquad (1.A.27)$$

while equation 1.A.14 can be simplified to:

$$\begin{aligned}
&\sum_{i=1}^{S}\frac{\alpha_i}{\sigma_i-1}\left(\frac{\tau}{(1-\tau)X_i}\right)(\psi f_{e,i}+(1-\delta_i)\Phi(-d_i)f_i)\\
&\quad=\tilde{\lambda}\tau\sum_{i=1}^{S}M_i w f_i\left[\delta_i\left(-\frac{(\psi f_{e,i}+\Phi(-d_i)f_i)}{X_i}+\frac{\tau}{1-\tau}+\frac{\psi f_{e,i}\phi(-d_i)}{X_i\Phi(-d_i)v_i}\xi_{\varphi_i^*,\delta_i}\right)+u_i h_i^{\sigma-1}\right]
\end{aligned}$$

[27]The step by step derivation can be provided upon request

which simplifies to:

$$1-\tau = \left[\sum_{i=1}^{S} \frac{\alpha_i}{\sigma_i - 1}\right] \left[\tilde{\lambda} w L \sum_{i=1}^{S} \frac{\alpha_i}{\sigma_i} \left(\frac{\psi f_{e,i} + \Phi(-d_i) f_i}{X_i}\right)\right]^{-1} \tag{1.A.28}$$

Thus the solution to the problem is found by solving the system of $S+1$ equations given by 1.A.27 and 1.A.28.

1.B Open Model Equilibrium with Asymmetric Countries

The world consists of N countries whose households have the same utility function form but the parameters (σ, α) are allowed to vary across countries. Firms can export their products by paying an iceberg trade cost θ_s^{ij} in which i is the destination country and j is the source country and. s is the industry. Will keep this notation for the remaining variables in which there is a need to specify the flows. Companies in j that want to export to country i have to pay a fixed cost $f_{ex,s}^{ij}$. We assume that wages across countries are the same which is justified by using a homogeneous good that is freely traded and use this as the numeraire. Since elasticities of substitutions can be heterogeneous across countries, it implies that the markup charged by firms is different in each country leading to the pricing decision rule:

$$p_s^{ij}(\varphi) = \theta_s^{ij} \frac{w}{\rho_s^i \varphi}$$

Let $\pi_{d,s}^j(\varphi)$ be the domestic profit of firms in j selling domestically and $\pi_{ex,s}^{ij}(\varphi)$ represents the profits of the firm from exporting into i.

$$\pi_{d,s}^j(\varphi) = (1-\tau^j)\left(\frac{r_{d,s}^j(\varphi)}{\sigma_s^j} - u_s^j w f_s^j\right)$$
$$\pi_{d,s}^{ij}(\varphi) = (1-\tau^j)\left(\frac{r_{ex,s}^{ij}(\varphi)}{\sigma_s^i} - u_s^j w f_{ex,s}^{ij}\right)$$

1.B.1 Equiibrium and Aggregation

Let $\varphi_{d,s}^j$ be the cutoff productivity to enter the j domestic market while $\varphi_{ex,s}^{ij}$ is the cutoff productivity of the marginal firm that decides to serve the market in country i. Unlike many Melitz type models, the export cutoff productivity is different depending on the destination country. Furthermore, if a country decides to serve a particular market it does not necessarily imply that it will serve all the other markets. Nonetheless, conditions will be imposed to ensure that $\varphi_{ex}^{ij} > \varphi_{d,s}^j \quad \forall i \neq j$. Using $\tilde{\varphi}()$ (equation 1.2.7) we can define the average productivity of all firms producing and selling in j as $\tilde{\varphi}_d^j = \tilde{\varphi}^j(\varphi_d^j)$ and, the productivity of the firms exporting by $\tilde{\varphi}_{ex}^{ij} = \tilde{\varphi}^i(\varphi_{ex}^{ij})$

Let $i \neq j$ then the number of firms (in sector s) that produce in country j be M_s^j and the amount of firms that export into i is represented by $M_{ex,s}^{ij}$. Thus, the total number of varieties in industry s available to consumers in country j is given by $M_{tot}^j = M^j + \sum_{i\neq j} M_{ex}^{ji}$. Thus, the average total productivity in j and the price index is :

$$\tilde{\varphi}_s^j = \left[\frac{1}{M_{tot,s}^j}\left(M_s^j\left(\tilde{\varphi}_s^j\right)^{\sigma_s^j-1} + \sum_{i\neq j}\left(\left(\theta_s^{ji}\right)^{-1}\tilde{\varphi}_{ex,s}^{ji}\right)^{\sigma_s^j-1}\right)\right]$$

$$\mathbb{P}_s^j = \left[\frac{1}{1-Z_s^j(\varphi_{d,s}^j)}\int_{\varphi_{d,s}^j}^{\infty} p_s(\varphi)^{1-\sigma_s^j} M_s^j z_s^j(\varphi) + \sum_{i\neq j}\frac{1}{1-Z_s^i(\varphi_{ex,s}^{ji})}\int_{\varphi_{ex,s}^{ji}}^{\infty} p_{ex,s}^{ji}(\varphi)^{1-\sigma_s^j} M_{ex,s}^{ji} z_s^i(\varphi)\right]^{\frac{1}{1-\sigma_s^j}}$$

$$\mathbb{P}_s^j = \left(M_{tot,s}^j\right)^{\frac{1}{1-\sigma_s^j}} p_s(\tilde{\varphi}_{tot,s}^j)$$

Now, the aggregate and average functions for firm revenues and profits are given by:

$$R_s^j = M_s^j r_{d,s}^j(\tilde{\varphi}_{d,s}^j) + \sum_{i\neq j} M_{ex,s}^{ij} r_{ex,s}^{ij}(\tilde{\varphi}_{ex,s}^{ij})$$

$$\Pi_s^j = M_s^j \pi_{d,s}^j(\tilde{\varphi}_{d,s}^j) + \sum_{i\neq j} M_{ex,s}^{ij} \pi_{ex,s}^{ij}(\tilde{\varphi}_{ex,s}^{ij})$$

$$\bar{r}_s^j = r_{d,s}^j(\tilde{\varphi}_{d,s}^j) + \sum_{i\neq j} \mathrm{p}_{ex,s}^{ij} r_{ex,s}^{ij}(\tilde{\varphi}_{ex,s}^{ij})$$

$$\bar{\pi}_s^j = \pi_{d,s}^j(\tilde{\varphi}_{d,s}^j) + \sum_{i\neq j} \mathrm{p}_{ex,s}^{ij} \pi_{ex,s}^{ij}(\tilde{\varphi}_{ex,s}^{ij})$$

in which $\mathrm{p}_{ex}^{ij} = \dfrac{1-Z_s^j(\varphi_{ex,s}^{ij})}{1-Z_s^j(\varphi_{d,s}^j)}$ is the conditional probability of a firm drawing a productivity that allows them to serve market i from country j. Also, $\mathrm{p}_{ex}^{ij} M_s^j = M_{ex,s}^{ij}$. The above formulas are used to find the average profit as a function of $\varphi_{d,s}^j$ (productivity that generates zero profit from domestic operations) and $\varphi_{ex,s}^{ij}$ (productivity that generates zero profit of exporting to i).

$$\bar{\pi}_s^j = (1-\delta_s^j \tau^j) w \left[f_s^j \left(\left(\frac{\tilde{\varphi}_{d,s}^j}{\varphi_{d,s}^j} \right)^{\sigma_s^j - 1} - 1 \right) + \sum_{i \neq j} \mathrm{p}_{ex}^{ij} f_{ex,s}^{ij} \left(\left(\frac{\tilde{\varphi}_{ex,s}^{ij}}{\varphi_{ex}^{ij}} \right)^{\sigma_s^i - 1} - 1 \right) \right] \quad (1.B.1)$$

to solve or $\varphi_{d,s}^j$ the export cutoffs must be expressed as functions of such variable:

$$\varphi_{ex,s}^{ij} = \left[\left(\frac{\sigma_s^i f_{ex,s}^{ij}}{\sigma_s^j f_s^j} \right) \frac{Y_s^j}{Y_s^i} \frac{M_{tot,s}^i}{M_{tot,s}^j} \right]^{\frac{1}{\sigma_s^i - 1}} \left(\frac{\varphi_{d,s}^j}{\tilde{\varphi}_{tot,s}^j} \right)^{\frac{\sigma_s^j - 1}{\sigma_s^i - 1}} \tilde{\varphi}_{tot,s}^i \theta_s^{ij} \quad (1.B.2)$$

where $Y_s = \alpha_s(wL + \sum \Pi_i^\tau)$ is the income spend in sector s by consumers, in which we assume that taxes collected by the government are redistributed to their citizens. Plugging this formula into equation 1.B.1 gives rise to zero profit condition for the open economy asymmetric model. The fixed entry (equation FEC) remains the same. The export cutoff formula depends on the total number of firms in the destination country as well as the country where the firms is located. The number of firms for sector s in country j is:

$$M_s^j = \frac{\alpha_s^j (wL^j + \sum_{s=1}^S \Pi_s^{\tau,j})}{\sigma_s^j \left(\frac{\bar{\pi}_s^j}{1-\tau^j} + u_s^j f_s^j \right) + w u_s^j \sum_{i \neq j} p_{ex,s}^{ij} f_{ex,s}^{ij} \left(\sigma_s^j + (\sigma_s^i - \sigma_s^j) \frac{\tilde{\varphi}_{ex,s}^{ij}}{\varphi_{ex,s}^{ij}} \right)} \quad (1.B.3)$$

Thus, for each sector, in each country, we solve 2 equations ZPC = FE and 1.B.3 with N auxiliary equations (1.B.2). This leads to a system of $N \times S \times (N+2)$ equations that are solved simultaneously to give rise to the equilibrium of the model. In the case of Pareto distributions, the system of equations can be reduced to $N \times S \times 2$ as the ratio $\tilde{\varphi}_{ex}/\varphi_{ex}$ is constant.

1.C Proposition Proofs

1.C.1 Proof of Proposition 1.2.1

For any non-degenerate distribution the mean of the random variable is greater than the minimum value of the support. Thus $\tilde{\varphi} > \varphi^*$ which implies $h > 1 \implies h^{-1} < 1$. Raising both sides of the inequality by the positive number $\sigma - 1$ is use to show that $1 - h^{1-\sigma}$ is greater than zero. Thus equation 1.A.9 consist of positive factors and hence greater than zero.

For the second part, assume that productivities follow a Pareto distribution with $x_{min,s} = \varphi_{min,s}$ and shape parameter k_s.Then

$$\begin{aligned} \tilde{\varphi}_s &= \left[\frac{k_s}{k_s - (\sigma_s - 1)}\right]^{\frac{1}{\sigma_s - 1}} \varphi_s^* \\ \frac{\partial \tilde{\varphi}_s}{\partial \varphi_s^*} &= \left[\frac{k_s}{k_s - (\sigma_s - 1)}\right]^{\frac{1}{\sigma_s - 1}} \end{aligned}$$

Using the above equations it is clear that $\xi_{\tilde{\varphi},\varphi^*}$ is exactly one.

1.C.2 Proof of Proposition 1.2.2

Assume the government budget constraint is binding and therefore the number of firms in equilibrium is: $M_s = \dfrac{wL}{\sigma_s u_s f_s h_s^{\sigma_s - 1}}$. Let $s \neq s'$, then the binding budget assumption implies that equation 1.A.11 is equal to zero for any distribution of productivities.

Now assume that $s = s'$ for some $s' \in S$. For a any productivity distribution, equation $1.A.10$ simplifies to:

$$\xi_{M_s,\delta_{s'}} = -\left[\frac{-\tau\delta_s}{(1-\delta_s\tau)} + (\sigma_s - 1)\left(\xi_{\varphi_s^*,\delta_{s'}}\left[\xi_{\tilde{\varphi}_s,\varphi_s^*} - 1\right]\right)\right]$$

Proposition 1.2.1 says that $\xi^P_{\tilde{\varphi},\varphi^*} \equiv 1$, therefore:

$$\xi_{M_s,\delta_{s'}} - \xi^P_{M_s,\delta_{s'}} = -(\sigma_s - 1)\left(\xi_{\varphi_s^*,\delta_{s'}}\left[\xi_{\tilde{\varphi}_s,\varphi_s^*} - 1\right]\right)$$

The term $(\sigma-1)\xi_{\varphi^*_{s'},\delta_{s'}}$ is less than zero since the productivity cutoff is negatively related to the depreciation rate for its sector. Using the appropriate assumptions on $\xi_{\tilde{\varphi}_s,\varphi^*_s}$ gives the inequalities between both elasticities.

It remains to show that the elasticity spawn from a Pareto distribution is greater than zero. The formula for such elasticity is:

$$\xi^P_{M_{s'},\delta_{s'}} = \frac{\tau\delta_{s'}}{1-\delta_{s'}\tau}$$

by assumption, $\delta_s\tau < 1$ for all sectors, and hence $\xi^P_{M_s,\delta_s}$ is positive.

1.C.3 Proof of Proposition 1.2.3

Only the first bullet point is proved as the second one follows a similar argument. Under a binding government constraint, equation 1.A.12 simplifies to:

$$\begin{aligned}
\xi_{M_s,\tau} &= -\frac{(1-\delta_s)\tau}{(1-\tau)(1-\delta_s\tau)} - (\sigma_s-1)\left(\xi_{\varphi^*,\tau}\left[\xi_{\tilde{\varphi}_s,\varphi^*_s}-1\right]\right) \\
\xi^P_{M_s,\tau} &= -\frac{(1-\delta_s)\tau}{(1-\tau)(1-\delta_s\tau)}
\end{aligned}$$

If $\delta_s \leq 1$, then clearly $\xi^P_{M_s,\tau} \leq 0$, with strict inequality if $\delta_s < 1$. Since $\xi_{\varphi_{s'},\delta_{s'}} = \xi_{\varphi_{s'},\tau}$ (this is shown in the next proof), I use a similar argument for the proof of proposition 1.2.2 to establish the inequalities between ξ_M and ξ^P_M. Assuming $\xi_{\tilde{\varphi},\varphi^*} < 1$ and proposition 1.2.2, the following equality is obtained:

$$\xi_{M_s,\tau} < \xi^P_{M_s,\tau} \leq 0$$

On the other hand, if $\xi_{\tilde{\varphi},\varphi^*} < 1$ then $\xi_{M_s,\tau} > \xi^P_{M_s,\tau}$; and therefore the sign of the elasticity of firms to taxes under a distribution that is not Pareto is indeterminate. The exception being $\delta = 1$, which then implies such elasticity to be positive since $\xi^P_{M,\tau} = 0$

1.C.4 Proof of Proposition 1.3.1

The first step is to show the following equality between elasticities

Claim: $\xi_{\varphi_i^*,\delta_i} = \xi_{\varphi_i^*,\tau}$

Proof. The ZPC and FEC conditions imply that the equilibrium φ_s^* must solve the equation:

$$h_s^{\sigma-1} = \frac{\psi F_{e,s}}{(1-Z_s(\varphi_s^*))(1-\delta_s\tau)f_s} + 1$$

Take the derivative with respect to τ as well as δ_s. The ratio of such derivatives is:

$$\frac{\frac{\partial h_s^{\sigma-1}}{\partial \tau}}{\frac{\partial h_s^{\sigma-1}}{\partial \delta_s}} = \frac{z_s(\varphi_s^*)\frac{\partial \varphi^*}{\partial \tau}(1-\delta_s\tau) + (1-Z_s(\varphi_s^*))\delta_s}{z_s(\varphi_s^*)\frac{\partial \varphi^*}{\partial \delta_s}(1-\delta_s\tau) + (1-Z_s(\varphi_s^*))\tau}$$

By equation 1.A.7:

$$\frac{\frac{\partial h_s^{\sigma-1}}{\partial \tau}}{\frac{\partial h_s^{\sigma-1}}{\partial \delta_s}} = \left(\frac{\partial \varphi_s^*}{\partial \tau}\right)\left(\frac{\partial \varphi_s^*}{\partial \delta_s}\right)^{-1}$$

Set the last two equation equal to each other and rearrange to obtain:

$$\begin{aligned} \tau\left(\frac{\partial \varphi_s^*}{\partial \tau}\right) &= \delta_s\left(\frac{\partial \varphi_s^*}{\partial \delta_s}\right) \\ \xi_{\varphi_s^*,\tau} &= \xi_{\varphi_s^*,\delta_s} \end{aligned}$$

□

After proving the above claim, the FOCs (eq. 1.3.4 and 1.3.5) are re-written into:

$$\alpha_{s'}\left(\frac{\tau\delta_{s'}}{(1-\delta_{s'}\tau)(1-\sigma_i)} - \xi_{\varphi_{s'}^*,\delta_{s'}}\right) = \tilde{\lambda} M_{s'}\left(\xi_{M_{s'},\delta_{s'}}\bar{t}_{s'} + \frac{\partial \bar{t}_{s'}}{\partial \delta_{s'}}\delta_{s'}\right) \quad (1.C.1)$$

$$\sum_{i=1}^{S}\alpha_i\left(\frac{-(1-\delta_i)\tau}{(1-\tau)(1-\delta_i\tau)(1-\sigma_i)} - \xi_{\varphi_{s'}^*,\tau}\right) = \tilde{\lambda}\left[\sum_{i=1}^{S} M_i\left(\xi_{M_i,\tau}\bar{t}_i + \frac{\partial \bar{t}_{i'}}{\partial \tau}\tau\right)\right] \quad (1.C.2)$$

Adding equation 1.C.1 across all sectors and using the equality of the claim results in:

$$\begin{aligned}\sum_{i=1}^{S}\alpha_i\left(\frac{\tau(1-\delta_i\tau)}{(1-\delta_i\tau)(1-\tau)(1-\sigma_i)}\right) &= \tilde{\lambda}\sum_{i=1}^{S}M_i\left[\left(\xi_{M_i,\delta_i}-\xi_{M_i,\tau}\right)\bar{t}_i+\left(\frac{\partial\bar{t}_i}{\partial\delta_i}\delta_i-\frac{\partial\bar{t}_i}{\partial\tau}\tau\right)\right]\\ \sum_{i=1}^{S}\frac{\alpha_i\tau}{(1-\tau)(1-\sigma_i)} &= \tilde{\lambda}\sum_{i=1}^{S}M_i\left[\left(\frac{\tau}{1-\tau}\bar{t}_i\right)+\left(\frac{\partial\bar{t}_i}{\partial\delta_i}\delta_i-\frac{\partial\bar{t}_i}{\partial\tau}\tau\right)\right] \quad (1.C.3)\end{aligned}$$

Next, the remainder derivatives are computed:

$$\begin{aligned}\frac{\partial\bar{t}_i}{\partial\delta_i}\delta_i &= \tau\delta_i w f_i\left(\frac{\partial u_i}{\partial\delta_i}h_i^{\sigma_i-1}+\frac{\partial h_i^{\sigma_i-1}}{\partial\delta_i}u_i-1\right)\\ \frac{\partial\bar{t}_i}{\partial\tau}\tau &= \tau w f_i\left[\left(\frac{\partial u_i}{\partial\tau}h_i^{\sigma_i-1}+\frac{\partial h_i^{\sigma_i-1}}{\partial\tau}u_i\right)\tau+u_i h_i^{\sigma_i-1}-\delta_i\right]\\ \frac{\partial\bar{t}_i}{\partial\delta_i}\delta_i-\frac{\partial\bar{t}_i}{\partial\tau}\tau &= \tau w f_i\left[h_i^{\sigma_i-1}\left(\frac{\partial u_i}{\partial\delta_i}\delta_i-\frac{u_i}{\tau}\tau\right)+u_i\left(\frac{\partial h_i^{\sigma_i-1}}{\partial\delta_i}\delta_i-\frac{\partial h_i^{\sigma_i-1}}{\partial\tau}\tau\right)-u_i h_i^{\sigma_i-1}\right]\\ &= \tau w f_i\left[h_i^{\sigma-1}u_i\left(\frac{-\tau}{1-\tau}\right)+0-u_i h_i^{\sigma_i-1}\right]\\ &= \tau w f_i\left(h_i^{\sigma_i-1}u_i\frac{-1}{1-\tau}\right)\end{aligned}$$

Replacing terms in equation 1.C.3 gives the formula for λ

$$\begin{aligned}\sum_{i=1}^{S}\frac{\alpha_i}{\sigma_i-1} &= \tilde{\lambda}\left[\sum_{i=1}^{S}-M_i\bar{t}_i+\frac{\alpha_i(wL)}{\sigma_i}\right]\\ \tilde{\lambda} &= \frac{\sum_{i=1}^{S}\frac{\alpha_i}{\sigma_i-1}}{wL\sum_{i=1}^{S}\frac{\alpha_i}{\sigma_i}-p_0^G q_0^G} \quad (1.C.4)\end{aligned}$$

Proof of Proposition 1.3.6

1. Pareto Economy: Assume $k_i=\bar{k},\sigma_i=\bar{\sigma} \quad i\in S$, then $1-\tau=\left(\tilde{\lambda}wL\bar{\rho}\right)^{-1}$. From the optimality equation for δ:

$$\delta_i=\frac{1-\tilde{\lambda}\bar{\rho}wL(1-\tau)}{\tau}=\frac{0}{\tau}=0 \qquad \forall i$$

The equation above is valid since $\tau > 0$.

2. Log-normal Economy: Assume sectors are completely symmetric, hence no sector subscript will be needed for the model parameters. Equation 1.A.28 implies:

$$
\begin{aligned}
1-\tau &= \frac{1}{\rho\tilde{\lambda}wLA} \\
A &= \frac{\psi F_e + \Phi(-d)f}{X}
\end{aligned}
$$

Replacing $(1-\tau)$ in equation 1.A.27, leads to:

$$
\frac{1}{A} = A - \frac{\psi F_e \phi(-d)}{X\Phi(-d)v}\xi_{\tilde{\varphi}^*,\delta} = A - B
$$

There are 3 possible case for δ, with each determining is A if above, below, or equal to 1. We show that cases of $\delta \neq 0$ produce a contradiction.

Case 1: Assume $\delta > 0$. This implies $A > 1$ and $1/A < 1$. Using the formula for the elasticity, we can see that $B < 0$. Hence, the equality can't hold as the LHS is less than one, while the RHS is greater than 1.

Case 2: Assume $\delta < 0$. Just as the above case, the equality can't hold since $A < 1, 1/A > 1$ and $B > 0$.

Case 3: Assume $\delta = 0$. In this case, $A = 1 \implies 1/A = 1$. Since $\delta = 0$, the elasticity $\xi_{\tilde{\varphi}^*,\delta}$ is equal to 0. Hence, the equality holds as $1 = 1$. Therefore, the only solution to the optimal tax rate problem is $\delta = 0$ for all sectors.

Proof of Proposition 1.3.5

Dividing 1.A.28 and 1.A.14:

$$
\frac{1-\tau^{log}}{1-\tau^{P}} = \left[\frac{\sum \frac{\alpha_i}{\sigma_i - 1}}{\sum \frac{\alpha_i}{k_i}}\right] \times \left[\left(\sum_{i=1}^{S} \frac{\alpha_i}{\sigma_i}\frac{\sigma_i - 1}{k_i}\right) \div \sum_{i=1}^{S} \frac{\alpha_i}{\sigma_i}\left(\frac{\psi f_{e,i} + \Phi(-d_i) f_i}{X_i}\right)\right] \tag{1.C.5}
$$

The first factor of the above equation is greater than one since $k > \sigma - 1$ for all sectors. The second factor is also greater than one since $\delta\tau < 1$. Therefore $\tau^{log} < \tau^{P}$.

Chapter 2

David versus Goliath: Who Bears the Burdens of Corporate Tax? with Nam Vu

2.1 Introduction

The welfare effects of corporate taxes have been a central issue in economic debate. Raising corporate taxes provides governments with the financial flexibility they need to build and maintain basic components of the economy. But doing so may impose significant welfare costs on the economy. This long-enduring schism poses a dilemma for governments seeking to raise corporate taxes to meet their budgets. That massive increase in income inequality in the past three decades, particularly during the Great Recession, has refueled an interest in the effects of corporate taxes on income inequality.[1]

How do corporate taxes affect income inequality in this increasingly integrated world? The paper presented here seeks to provide further insight into the short-run effects of corporate taxation while maintaining the long-run properties consistent with salient features of economic data. To this purpose we study a dynamic open economy framework that contains financial frictions across countries, trade costs, and corporate taxation. In particular, we propose a two-country model in which a representative household worker provides labor and consumes goods from both countries. The second agent is a representative capitalist who provides capital to firms across the globe for a claim in their after tax profits. Unlike standard real business cycle models, firms in our model engage in monopolistic competition which allows them to charge consumers a mark-up over the marginal cost; hence the positive profits, which are subject to a corporate tax at source that is used to finance government expenditures. We adopt the Ramsey framework in which the government expenditure is exogenously determined. Furthermore, we assume that such expenditure has no direct effect on the utility of the agents in the economy. Trade between countries and capital transfers across borders

[1] See, for example, Maloney and Schumer (2010) for a congressional report on the issue.

are costly relative to their domestic equivalents.

The literature on the welfare effects of corporate taxes has been rather divided. One strand of literature (started by Harberger (1962)) has argued, theoretically, that we should expect the burden of an increase in corporate taxes to fall on investors, who own the firms' assets. However, recent empirical studies such as Arulampalam et al. (2007), Felix (2007), and to a larger extent Desai et al. (2007)), have shown that workers bear the lion's share of the burden from increases in corporate income tax. More recent theoretical literature has attempted to reconcile such a dichotomy between past theory and empirics by introducing more realistic assumptions to the model (Harberger (2008)), an example of which is the use of open economy frameworks to study the effects of corporate taxes changes.

Our source of novelty hinges on several aspects. The model not only generates the dynamics and long run effects that are in line with some previous theories, but also exhibits properties consistent with empirical studies. Increases in corporate taxes reduce output and capital stock in the country that raises the tax while output and capital stock follow the opposite path in the other country. While output decreases only in one country, the capitalists in both countries suffer from the impacts of an unexpected tax increase. These spillover effects become more pronounced as countries become more integrated.

The setup of the model results in another contribution in terms of providing a theoretical foundation for the idea that raising corporate taxes affects individuals asymmetrically. In particular, we show that an increase in corporate taxes result in distinctively different effects on individuals whose income depends solely on wages and those whose income does not. Individuals who claim ownership in firms recover *far* quicker than individuals who depend solely on wages as their main sources of income.

Workers' wages in the long run are negatively related to international finance costs; that is, long run wages increase when its openness to foreign investment increases. While our result is quite striking for an inverse relationship is usually expected, it is well-supported by the empirical evidence in the literature. For example, Chari et al. (2012), using Mexican data, find that manufacturing wages increase by a fifth, three years following the liberalization to foreign capital inflows. Corporate taxes negatively affect the wages of workers at source in the long run as well as the short run. In the short run, wages decrease because a portion of the financial burden of the firm owners, also called the capitalists in our model, is shifted to workers; moreover, another part of this burden is also exported to workers in the other country.[2]

Related Literature

This paper is related to the literature of corporate taxation, more specifically, to the literature analyzing the allocation of the burdens of corporate taxes. A widely used theoretical framework for this literature is the seminal paper by Harberger (1962), which used a closed economy setting. Subsequent papers based on Harberger (1962) have extended such an environment into a more realistic open economy setting (Harberger (1995, 2008), Randolph (2006), Gravelle and Smetters (2006) among others). Most of these papers agree that the open economy is necessary for generating the implication that corporate tax burden falls more heavily on workers; though, as argued by Harberger (1995), this result can also be obtained under certain parameters on his closed economy model. Our paper deviates from this large literature by assuming incomplete capital mobility across borders in an open dynamic setting. The empirical evidence supporting this assumption on incomplete market is overwhelming (see, for example, Kollmann et al. (2014), or Hall (2011)).

Recent empirical studies have shown that workers bear a lion's share of the corporate tax burdens (for example, Arulampalam et al. (2007), Felix (2007), and to a larger extent Desai et al. (2007)). Yet the mechanism for this result is unclear. Specifically, Clausing (2013) conducts a VAR analysis of OECD countries, showing no robust linkages between wages and corporate income taxes; this result implies no conclusive evidence that corporate

[2]This burden transfer property can also be found in Kotlikoff and Summers (1987) and Harberger (1995); while Gravelle and Smetters (2001) argue that in the long run the burden either falls on domestic capital, or is exported.

taxes have a negative impact on workers welfare. A source of their contrasting results lies in the dynamic nature of their analysis while most of the earlier studies (both empirical and theoretical) have based their conclusions on long-run properties. To this purpose, our model provides a structural model in a dynamic setting that can be used for analysis along both the long-run and the short-run dimensions. Specifically, both the long-run and the short-run implications of our model are not only consistent with empirical studies, but also dovetail nicely with salient features in other aspects of the trade economic literature.

Our paper is also related to the vast literature on the international business cycle (for example, Backus et al. (1992) and Baxter and Crucini (1995)). In particular, the model presented here deviates from this literature by allowing for cross-border frictions and the asymmetry in the types of agents; that is, ones that hold assets and ones that do not. Therefore, another source of novelty in our approach lies in its application of an extension of a well-established type of dynamic model to the study of the asymmetric effects of corporate taxes.

The paper is also related to the literature on law of one price deviations in the sense that it provides a theoretical foundation to support the plethora of empirical evidence in the literature on deviations from the law of one price, or the lack thereof. In particular, propositions 2.3.4 and 2.3.5 show that it is difficult to sustain the law of one price under plausible model restrictions, a conclusion that dovetails nicely with the current empirical literature on the law of one price.[3]

We proceed as follows. Section 2.2 describes the baseline set-up of the model, in which we also discuss the features that set ours apart from other two-country models in the literature. Section 2.3 examines the properties of the steady-states conditions of the model, evaluating the link between these properties and the current policy debate on the role of financial integration and corporate taxes policy on income inequality. Section 2.4 studies the short-run dynamics of the model. Specifically, we examine the properties of the impulse responses of selected macroeconomic aggregates to random shocks to corporate tax rates and financial

[3]See, for example, Crucini and Shintani (2008) for a detailed discussion on the topic.

frictions. Section 2.5 concludes.

2.2 Model

Our model assumes two types of households in each country: one household provides labor to firms and has access to basic financial instruments (bonds) and a capitalist who does not provide physical labor but relies in its capital investments to generate income. The capitalist has access to a worldwide financial market in which she can invest in the producing firms of any country; such an investment grants her a claim into a share of after tax profits for the next period that is proportional to her ownership of the firm.

Workers

A lifetime utility maximizing laborer lives in each country. He gets positive utility from consuming a composite good M, which is an Armington aggregation of the two available goods in this economy: one good produced by the firm in country H (the home good) and another good produced by the firm in country F (the foreign good). To afford his consumption he provides labor to the firm in the country where he resides; in exchange for his services he receives a wage ω_t. We assume labor is immobile, thus households born in H (F) can only offer their services to the home (foreign) firm at a market-prevailing wage rate ω_t^H (ω_t^F). The household worker can choose to save part of his income by holding bonds which pay him a default free interest rate $r_{b,t}^j$, where j is the country of residence of the worker. The household workers problem is to maximize

$$\max E \sum_{t=1}^{\infty} \beta^t \left[M_t^j + log(N_t^j) \right] \tag{2.2.1}$$

subject to

$$\sum_{i=1}^{N} p_{i,t}^{j} m_{i,t}^{j} + b_{w,t+1}^{j} = \omega_t^j L_t^j + (1 + r_{b,t}^{j}) b_{w,t} + T_t^j \tag{2.2.2}$$

$$1 = L_t^j + N_t^j \tag{2.2.3}$$

$$M_t^j = \left[\sum_{i=1}^{N} \left(m_i^j \right)^{\varepsilon} \right]^{1/\varepsilon} \tag{2.2.4}$$

Here $b_{w,t+1}^{j}$ is the amount of bonds purchased by the worker in country j at time t. Bonds mature after one period and yield interest income of $r_{b,t}^{j} b_{w,t}^{j}$ to the worker at time $t+1$. The term T_t^j is a lump sum transfer that the worker receives (gives) from (to) the government. The amount of the transfer is equal to the difference between the tax revenue from corporate taxes and government spending for the period (G_t^j).[4] Lastly, $p_{i,t}^{j}$ is the price of a good produced in country i and sold in country j; the notation for the quantity of goods m_i^j is define in a similar manner.

Let P^j be the implied price index of the preferences in country j, then the optimal consumption of each good can be written as:

$$m_{i,t}^{j} = \left(\frac{p_{i,t}^{j}}{P_t^j} \right)^{-\sigma} M_t^j \qquad \forall i \tag{2.2.5}$$

$$P_t^j = \left[\sum_{i=H,F} \left(p_i^j \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{2.2.6}$$

where σ is the elasticity of substitution between the goods.[5]

[4]The transfer can be either or positive thus it some periods it can be a wealth transfer from the capitalist to the workers and in other periods it will be a lump sum tax to the worker. The baseline specification of the model is calibrated such that T_t^j is positive for all t and for both countries.

[5] $\sigma = \dfrac{1}{1-\varepsilon}$

Capitalist

Another infinitely lived type of household lives in each country. While different from the worker type in terms of sources of income, her utility function is similar to that of the worker type household in the sense that their consumption indices both admit an Armington aggregation formula of goods produced at home and abroad. Instead of providing labor to firms, the capitalist provides the capital needed for production of the consumption goods. The return for her investment is a share of after-tax profits from the firms in which she invested.

The timing of the capitalist problem can be summarized as follows. Take the capitalist in the Home country as an example. First, she determines the levels of consumption of home c_H^H and foreign c_F^H goods, as well as the levels of investment in firms in both home I_H^H and foreign I_H^F countries. Her income comes from the return of investment made in the *previous* period, which depends on their level of ownership, that is determined by their corresponding share of capital in the home s_H^H and in the foreign s_H^F firms. It is helpful to recall that, in terms of notation, here we use superscript to denote the destination and under-script to denote the origin; for example, s_H^F reads the share of capital at *foreign* firms that are owned by capitalists from the *home* country.

Investment across border carries a cost of $\eta_j^i > 1$ for $i \neq j$ and it is identical to unity for investments originating and ending in the same country. In our model, the investment costs affect capital flows in the following way:

$$k_{i,t+1}^j = \frac{1}{\eta_i^j} I_{i,t}^j + (1-\delta) k_{i,t}^j \tag{2.2.7}$$

The international investment costs η_i^j from country i to country j are designed to capture all costs associate with investing overseas. For example, investors from the U.S. have to pay additional fees to buy stocks in exchanges from other countries.[6] These fees lead to increases in the price of the same capital unit for the U.S. investors while investing abroad. Direct

[6] The investor is likely to incur monitoring costs of their international investments. Such costs are better modeled as costs on the capital stock and not the flow; a feature that our model currently abstracts from.

estimation of these cost is difficult as they encompass variables that are both quantitative (additional fees) and qualitative in nature (accessibility and ease of investment). Bribery may also increase the cost of investment abroad, especially in the case of emerging economies which tend to have higher rates of corruption; this is not to say that developed countries are free of this problem as lobbying could be considered a form of corruption.

The proportion of after-tax profits that belong to each capitalist depends on the proportion of its investment (net of cross country investment costs), with respect to the total capital provided to the firm from all sources for that period. This proportion is denoted by the variable $s^i_{j,t} \leq 1$ and the exact formula is given in equations 2.2.11 below. In what follows, we proceed by expressing the capitalist problem as well as the capital evolution equations.

$$\max E \sum_{t=1}^{\infty} \beta^t C^j_t \tag{2.2.8}$$

such that

$$\sum_{i=1}^{N} p^j_{i,t} c^j_{i,t} + \sum_{i=1}^{N} I^i_{j,t} = \sum_{i=1}^{N} s^i_{j,t} (1 - \tau^i_t) \pi^i_t \tag{2.2.9}$$

$$C^j_t = \left[\sum_{i=1}^{N} \left(c^j_{i,t} \right)^{\varepsilon} \right]^{1/\varepsilon} \tag{2.2.10}$$

Here the budget constraint, that is, equation 2.2.9, implies that the capitalist type agents do not work, but rather finance their consumption and investment decision using incomes from the investment in home and foreign firms in the last period. One key insight from this equation is that, the income of the capitalists depend on both the share of ownership realized at time t (which is a state variable at time t)

$$s^i_j = \frac{k^i_{j,t}}{K^i_t} \tag{2.2.11}$$

$$K^j_t = \sum_{i=1}^{N} k^j_{i,t} \tag{2.2.12}$$

and the firms' profits realized at time t.

2.2.1 Firms and Government

There is a representative firm in each country that is responsible for the production of a consumption good. The technology for the firm follows a Cobb-Douglas form with labor and capital as inputs. The firm sells its product in the Home market as well as the Foreign market. Both countries possess markets characterized by monopolistic competition. The representative firm of each country maximizes profits by choosing the optimal price after the cost minimization problem

$$\max \quad p_t Y_t - \omega_t L_t - r_t K_t \tag{2.2.13}$$

$$Y_t = A_t (K_t)^{\alpha} (N_t)^{1-\alpha} \tag{2.2.14}$$

where Y_t is the quantity supplied at t; ω_t and r_t denote wages and rental rates of capital. Here we omit the country subscripts for notational convenience. Profit maximization (under monopolistic competition) along with the cost minimization implies that the firm in country j charges an optimal price to residents of j of:

$$p_t^j = \frac{1}{\varepsilon}\Omega_t^j \tag{2.2.15}$$

$$\Omega_t^j = \frac{1}{A_t^j}\left(\frac{\omega_t^j}{1-\alpha}\right)^{1-\alpha}\left(\frac{r_t^j}{\alpha}\right)^{\alpha}, \tag{2.2.16}$$

in which Ω_t^j denotes the marginal costs of firms in country j at time t. A firm in country j pays an iceberg trade cost of $\theta_j^i > 1$ for $j \neq i$ to ship to residents in country i. Thus prices as specified in the household section are given by:

$$p_{j,t}^i = \theta_{j,t}^i p_{j,t}^j \tag{2.2.17}$$

We use the Ramsey approach and assume that governments consumes an exogenous given amount G_t^j of the domestically produced good. This expenditure is financed by corporate tax revenue and any left over money is transfer to the workers. If the tax revenues is lower than governments expenditures at time t, then the government imposes a lump sum tax on workers to cover the deficit. Therefore the following equation holds in all periods

$$T_t^j = \tau_t^j \pi_t^j - G_t^j p_t^j, \tag{2.2.18}$$

and the rate of growth of government spending is exogenously driven by the following process:

$$\begin{aligned} \Delta \log G_t^j &= \log G_t^j - \log G_{t-1}^j && (2.2.19) \\ \Delta \log G_t^j &= (1-\rho_g)\Delta \log \bar{G} + \rho_g \Delta \log G_t^j + v_t^j && (2.2.20) \\ \tau_t^j &= (1-\rho_\tau)\bar{\tau} + \rho_\tau \tau_t^j + v_t^j && (2.2.21) \end{aligned}$$

Here $v_t^j \sim N(0, \sigma_G^2)$ denotes the innovations to fiscal policy in country $j = H, F$ at time t, $\Delta \log G_t^j$ denotes the rate of growth of government spending as in equation (2.2.21). Turning to the details on the production process for intermediate goods firms, here we assume that productivity is exogenously driven in the following manner:

$$\log A_t^j = \rho \log A_{t-1}^j + u_t^j, \tag{2.2.22}$$

$$\forall j = 1, \ldots, N$$

where the innovation term u_t^j is assumed to follow $N(0, \sigma_A^2)$.

2.2.2 Equilibrium

The equilibrium is a collection of prices and allocations of consumptions and output, such that

1. The problems for workers equations (2.2.2), (2.2.4), and (2.2.5) are satisfied.

2. The problems for capitalists as in equations (2.2.9), (2.2.11), (2.2.7), (2.2.12), and (2.2.10) are satisfied.

3. The profit maximizing problem for firms is satisfied; that is equations (2.2.15), (2.2.16), and (2.2.17).

4. Government's budget is balanced; that is, equations (2.2.18), (2.2.20), (2.2.19) and (2.2.21) are satisfied.

Additionally, the relative size of the economies is fixed in the steady state and is subject to a global macroeconomic shock. This condition ensures that the model reaches the steady state through one path; thus avoiding a sunspot solution.

$$\frac{Y^H}{Y^F} = \Xi + \varepsilon_t \tag{2.2.23}$$

2.3 Steady State Analysis

We continue our discussion by examining some key insights of the model presented in section 2.2 by studying its steady state. In particular, we put an emphasis on the capital allocation across countries and wages given a particular set of financial costs, trade costs and taxes for each country. We provide proofs to the propositions presented in the appendix.

Proposition 2.3.1. *Let $i \neq j$ then:*

- *An increase in τ^j increases r^j but has no effect on r^i.*
- *r^j does not depend on η^i_j.*
- *Increasing the financial cost of investing abroad raises the interest rate at the target country. Thus if η^F_H was to increase then r^F would also increase.*

- *The derivative of r^j w.r.t the country's corporate tax is greater than the derivative of such interest rate w.r.t the cross country investment cost (η_i^j).*

The first proposition concerns properties of the rental rates on capital. In particular, the long run properties of interest rates depend solely in variables decided at the country where the interest rate is paid.[7] Higher taxes along with higher cross border investment costs reduce the available capital in the economy which leads to higher interest rates and a lower optimal capital stock for the firm. This observation builds upon and results in a salient feature of the model in which financial integration is beneficial over the long term for interest rates. In particular, lowering financial transaction costs results in lower interest rates, a key channel in which the economy can expand and recover quickly upon a recession. Not only can a lower interest rate induce domestic production but also encourages investment from abroad. Further expanding this argument, the last bullet point shows the interaction between taxes and financial integration and show that these elements are important in order to correctly forecast the effects of government policies on key variables, such as the interest rate.

Next, we present and interpret the distribution of ownership of firms which are given by:

$$s_H^H = \frac{\eta_F^H}{1+\eta_F^H} \qquad s_F^H = \frac{1}{1+\eta_F^H}$$
$$s_F^F = \frac{\eta_H^F}{1+\eta_H^F} \qquad s_H^F = \frac{1}{1+\eta_H^F}$$

Interpreting these ownership shares becomes easier by noting that $\eta_j^j = 1$. In terms of notation, the numerator in all proportions represent the net cost to invest into the target country from the perspective of the other investor, while the denominator is the sum of the net costs for both investors. When the cost of investing into a country increases, the ownership of the firm shifts toward the domestic capitalist. Such effect occurs for two reasons. First, an increase in η_i^j decreases the net returns to investment made by capitalist at i, hence a reduction in their investments. Second, an increase in the interest rates reduces profits and thus gives less

[7]Is quite likely that the financial costs to investing abroad are functions of variables from the source as well as the recipient country.

incentives to invest in the firm for all investors alike. This second channel is complemented by the subsequent proposition:

Proposition 2.3.2. *Increases in financial cost of investment into a country raises the ownership of domestic investors in the firm while reducing the foreign ownership.*

Increases in ownership are driven by a reduction in the total K that firms required in equilibrium. This reduction in capital demand is a consequence of higher rental rates of capital resulting from a higher η. One natural implication from this result is that, when the international financial market is more integrated as a result of low financial costs, domestic firms can better position themselves in terms of attracting foreign investors. This increase in foreign flow of investment can further reduce the interest rates and enhance the effects that we have previously seen in proposition 2.3.1.

We next turn our attention to some propositions on the Purchasing Power Parity (PPP), which in the case of our model, boils down to the ratio of price indexes P^F/P^H. For notational convenience, we denote such a ratio as Q which, in the steady state, depends on *all* exogenous parameters of the model. The range of possible values for Q is pin down by the trade costs as illustrated in proposition 2.3.3. We begin our analysis of PPP and the law of one price by first establishing this theoretical range of possible values of the steady state equilibrium value(s) of Q in the following proposition:

Proposition 2.3.3. *Let θ_H^F , θ_F^H be strictly greater than one. Then Q is bounded below by $\frac{1}{\theta_F^H}$ and bounded above by θ_H^F.*

The theoretical bounds on Q in proposition 2.3.3 suggest that higher trade costs can lead to greater divergence and variability in the aggregate price ratio across the two countries. Intuitively, increasing the cost of importing into the foreign country increases the upper limit for the solution of Q. Given the preferences of the consumers (in the case of no home bias in taste), the price index at the foreign country will increase relative to that of H, therefore a greater Q is a possible solution to the model, all else equal. On the other hand, increasing θ_F^H

makes foreign goods at the home country more expensive, which raises P^H, *ceteris paribus*. In this case, P^F is less likely to increase and this result translates in to a decrease in the lower bound of Q.

It is important to note that this property holds given the assumption that consumers do not prefer (in a home-bias sense) domestic goods over foreign ones (or vice-versa). The range of the solution for a general case with asymmetric countries is plotted in figure 2.1 while figure 2.2 presents the case for symmetric countries. This last figure suggests that cross-country price equality ($Q = 1$) can be achieved achieved when countries are completely symmetric. In stark contrast, a large portion of the literature points to trade costs as the cause for PPP inequality. We present an alternative proposition in which PPP is possible even in the presence of trade costs.

Proposition 2.3.4. *If H and F are symmetric with respect to* $\tau < 1$, $\eta \geq 1$, *and* θ*; then* $Q = 1$ *is the solution to the equilibrium problem. Furthermore, the result is independent of trade cost being equal or larger than one.*

Specifically, proposition 2.3.4 implies that even in a world economy with no perfect trade in goods, PPP equalization is possible if all other parameters are symmetric, including shipping cost. This result is not surprising since it implies that countries are mirrors of each other and thus there is no reason to expect any price differential.

Proposition 2.3.5. *If trade cost are symmetric and greater than one and the two countries are asymmetrical with respect to taxes and international finance cost then* $Q \neq 1$.

Proposition 2.3.5 implies that a world with perfect trade in goods does not lead to PPP equalization. This proposition along with 2.3.4 imply that disparities in PPP are not a sole consequence of trade costs. In short, perfect trade in goods is neither a necessary nor sufficient condition for equal PPP across countries. This result provides an implicit theoretical foundation for a long-established empirical result in the international micro-price literature that the law of one price is rarely obeyed.

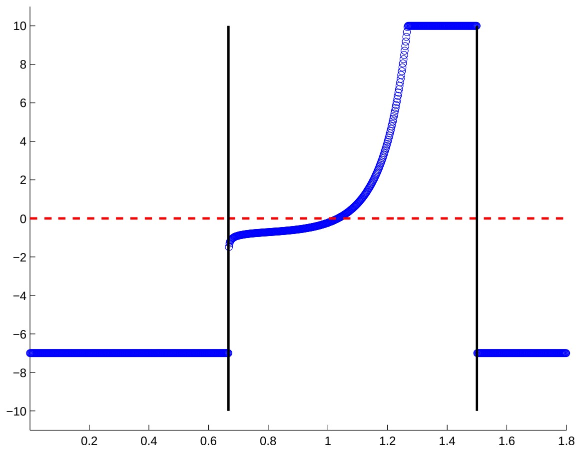


Figure 2.1: Purchasing Power Parity: A General Case

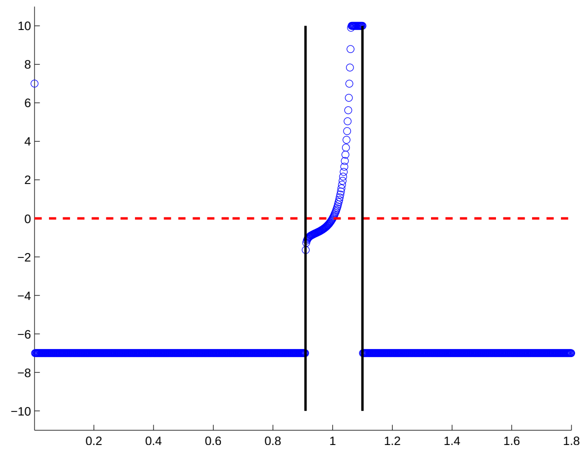


Figure 2.2: Purchasing Power Parity Obeyed

Note: This figure plots the value for the cross-country relative price ratio Q in the steady state. Figure 2.1 uses the baseline calibration, the details of which are summarized in table 2.2. Figure 2.2 represents the case of complete symmetry; that is, the iceberg trade costs and the international finance costs to and from the two countries are identical. The horizontal axis denotes the values of the steady state terms of trade Q and the vertical axis denotes the absolute difference between left and right hand sides of the non-linear equation that we use to numerically calculate the steady state value of Q. The details of such an equation are provided in the appendix.

Proposition 2.3.6. *An increase in the real exchange rate Q leads to an increase in the ratio between Home and Foreign gross profits.*

In the context of our model, one natural question remains to what extent do these implications on the relative price ratio Q affect profit in each firm, one of the key channel that affects capitalists' incomes. Proposition 2.3.6 implies that the profit of the home country must increase relative to that of the Foreign firm when there is an increase in the cross-country price ratio $Q = P^F/P^H$. Intuitively, when the prices in the foreign country become more expensive relative to home, the ratio of the nominal profit between the home and the foreign firms increase.

2.4 Main Result: Asymmetry in Consumption Responses to Corporate Tax Increases

We continue our discussion of the properties of the steady states with a focus on the interaction between an increase in corporate taxes and other macroeconomic aggregates. To do so, we first present our choice of reasonable parameters for the model with connection to some empirical data on corporate taxation in the U.S. and Germany in section 2.4.1. We next study the long-run implications of an asymmetric increase in corporate tax income in section 2.4.2. Turning to the short-run implications in section 2.4.3, we pay special attention to the properties of the impulse responses of aggregate variables, conditional on an asymmetric increase in the innovation to corporate income taxes.

2.4.1 Calibration

We select the target tax rate $\bar{\tau}^j$ for home and foreign countries such that they match the effective corporate tax rates from Germany (lowest effective corporate tax in our panel) and the US (high effective tax relative to Germany).[8] These countries are chosen for two reasons. First, they are large economies in the sense that a change in one country's policy will most likely influence the world economy. Second, having a low and a high tax country allows us to study the differences in impulse reactions under these two extremes. The literature does not provide any consensus for the values of η_F^H and η_H^F, thus for this particular exercise we chose a value of 1.2 for the baseline specification. In other words, it is $\approx 20\%$ more costly to invest broad than into one's own country.[9] Similarly, we consider symmetric ice-berg trade costs $\theta_F^H = \theta_H^F$ and set their value to 1.1; that is, for every unit of good sold abroad the producer must ship 1.1 units of the good.

Turning to the remaining parameters, we follow the standard literature. In particular, the discount rate is $\beta = 0.96$ for both countries; the share of capital in the production function α is 0.33; the depreciation rate is $\delta = 0.025$; the elasticity of substitution between home and foreign variety of one good σ is equal to 3, implying a mark-up $1/\varepsilon = 3/2$.[10] Table 2.2

[8]Table 3.1 summarizes the effective tax rates for selected economies from 1990-2011.

[9]As mentioned earlier, the "cost" could be monitoring cost and not necessarily just costs on the flow of investment. Here we do not consider a completely symmetric case because this case is trivial and has been well-studied in the literature and thus is not the focus of the study presented here.

[10]$\sigma = \frac{1}{1-\varepsilon}$. The value for the elasticity of substitution across goods ranges from 1.4 to 4.5 in the literature; see Nevo (1997) or Nakamura and Steinsson (2013) for details.

summarizes the values for the baseline specification.

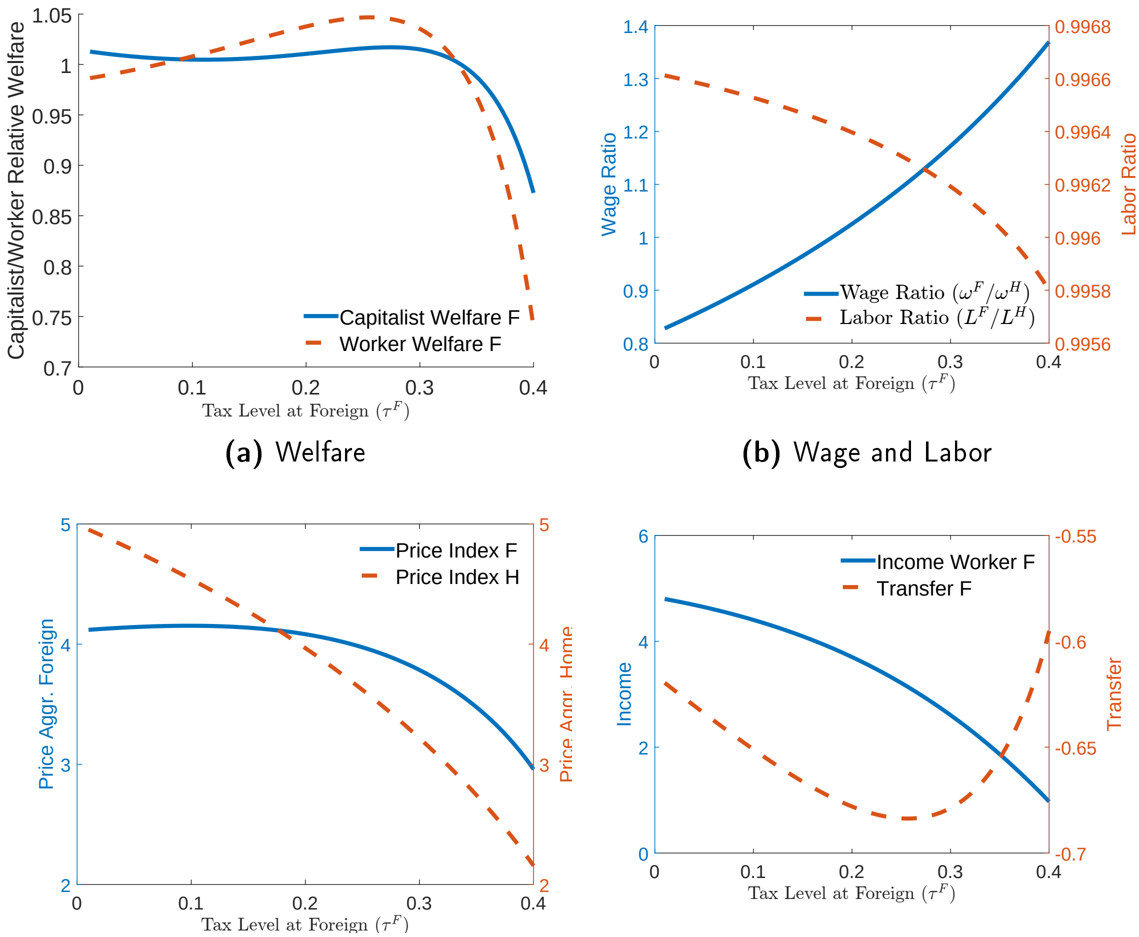
Upon obtaining the policy function using the method developed by Uhlig, we simulate the model for 2,000 periods and discard the first 200. We set the standard errors of the innovations to tax rate at 0.01; thus, we can interpret all the impulses as responses to one percent increase in the level of tax rates from home or foreign authority, depending on the figure. Since our focus is on the dynamic responses of effective tax rates, we pay special attention to studying the impulse responses of orthogonal innovations to tax rate from home and foreign countries. In particular, we first generate the dynamic responses of selected variables under the baseline specification as presented in table 2.2.

2.4.2 Asymmetry in Welfare in the Long Run: Some Steady State Implications

Figure 2.1a plots the level of welfare, defined as the post-transfer level of the aggregate consumption basket for workers and capitalists, under the baseline specification in table 2.2. One key take-away from the figure is that both capitalists and workers tend to suffer when there is an increase in corporate taxes. This result dovetails nicely with the recent empirical literature on the effects of corporate taxes (for example, Arulampalam et al. (2007), Felix (2007), and to a larger extent Desai et al. (2007)) in the sense that a large share of the welfare costs of corporate taxes falls on workers.

Another insight from figure 2.1a is that workers tend to experience a higher welfare loss than the capitalists type. One key mechanism of this decrease in workers' welfare is illustrated in figure 2.1b, in which an increase in corporate taxes leads to an increase in the relative labor costs in the long run and hence, a decrease in employment. Because the only source of incomes for workers come from wages, such a decrease in labor tends to imply a decrease in workers income (as in figure 2.1d). It is helpful to note that while these workers do receive transfers from corporate tax revenues, the size of this transfer decreases with the level of corporate taxes. The overall effect, which tends to kick in when corporate tax is sufficiently high to offset transfers, is that workers are left with lower disposable income to spend on

Figure 2.1: Asymmetry in Welfare: Varying Corporate Taxes



(a) Welfare

(b) Wage and Labor

(c) Price

(d) Income and Transfer

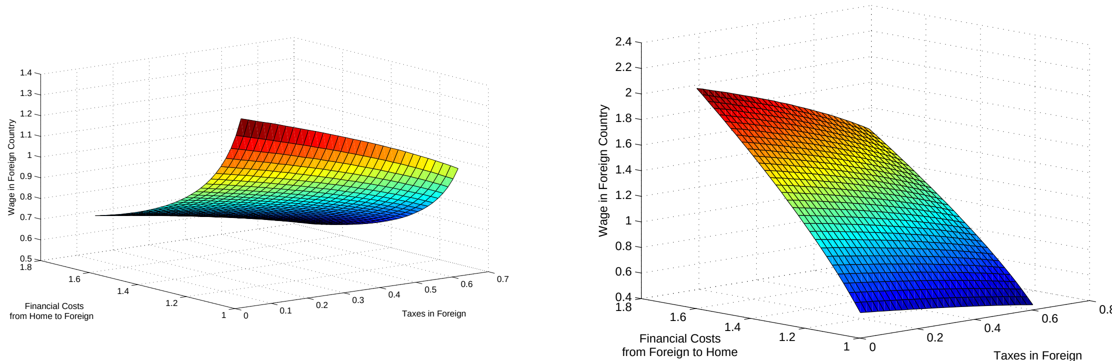
consumption and hence, a sharp decrease in the level of welfare (as seen in figure 2.1a).

Turning to issues on the labor market, we note the following implication:

Remark 2.4.1. *The steady state ratio of wages ω^F/ω^H increases with τ^F and decreases with τ^H. Moreover, wages and international financial cost (into the country) posses a negative relationship in the long run.*

Remark 2.4.1 states that, in the long run, wages increase as a result of more financial integration; that is, when η_F^H is smaller. This result provides a theoretical basis for some empirical findings in the literature (see, for example, Chari et al. (2012)). In particular, under baseline case in which the two countries are more financially integrated, an orthogonal shock

Figure 2.2: Wage: Sensitivity to Tax Level



(a) Wages in Foreign Country

Note: Here wage in the foreign country is a function of taxes in the foreign country and financial costs from the *home* to the *foreign* country.

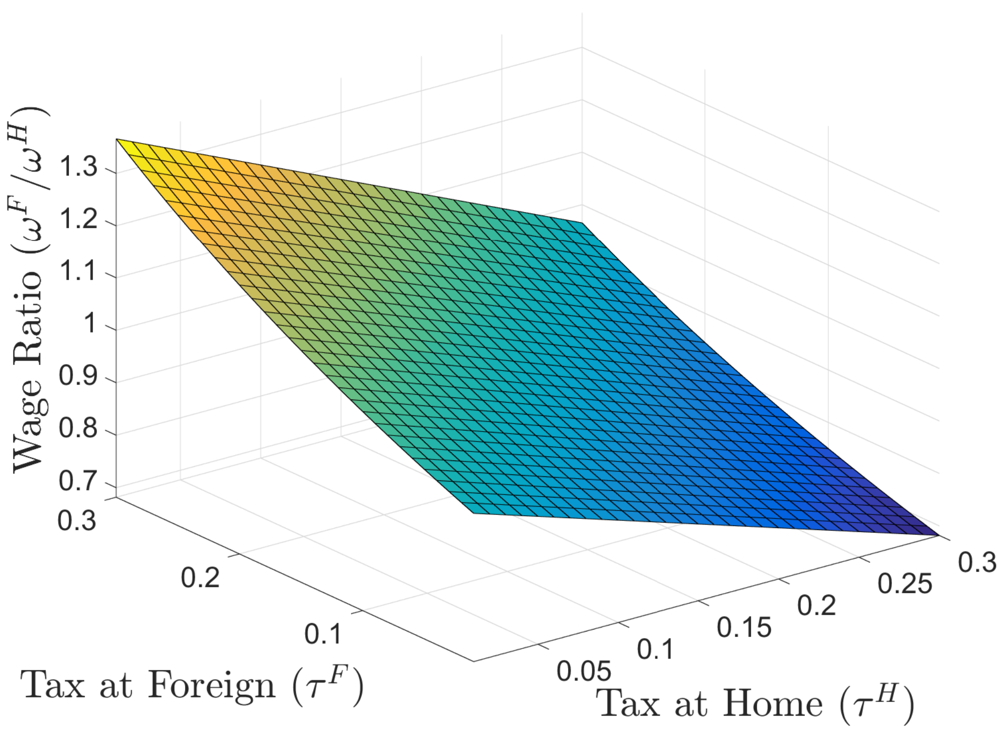
(b) Wages in Foreign Country

Note: Here wage in the foreign country is a function of taxes in the foreign country and financial costs from the *foreign* to the *home* country.

to both tax rates and exchange rate creates a more pronounced increase in wages than in the case of high financial costs. We illustrate the properties stated by remark 2.4.1 in figure 2.2a and figure 2.2b. In particular, we solve for wages in the foreign country as a function of taxes in the foreign country and (2.2a) financial costs from the home to the foreign country and (2.2b) financial costs from the foreign to the home country. Here we assume that financial costs of investing across domestic and foreign market are *asymmetric*. The intuition behind such an assumption is that investment costs tend to vary greatly across countries.

Figure 2.3 plots the ratio of equilibrium wages in foreign over home countries against the level of tax rates at foreign and home, respectively. This ratio can be interpreted as the relative costs of labor between foreign and home countries. One key insight from the figure is that the relative costs of labor at the foreign country (ω^F/ω^H) is monotonically *increasing* in the level of corporate taxes in the foreign country (τ^F) and is *decreasing* with respect to the level of tax at the home country (τ^H). In other words, an increase in tax level tends to make labor more costly, relative to the labor cost in the other country.

Figure 2.3: Wage Ratio ω^F/ω^H: Sensitivity to Tax Level



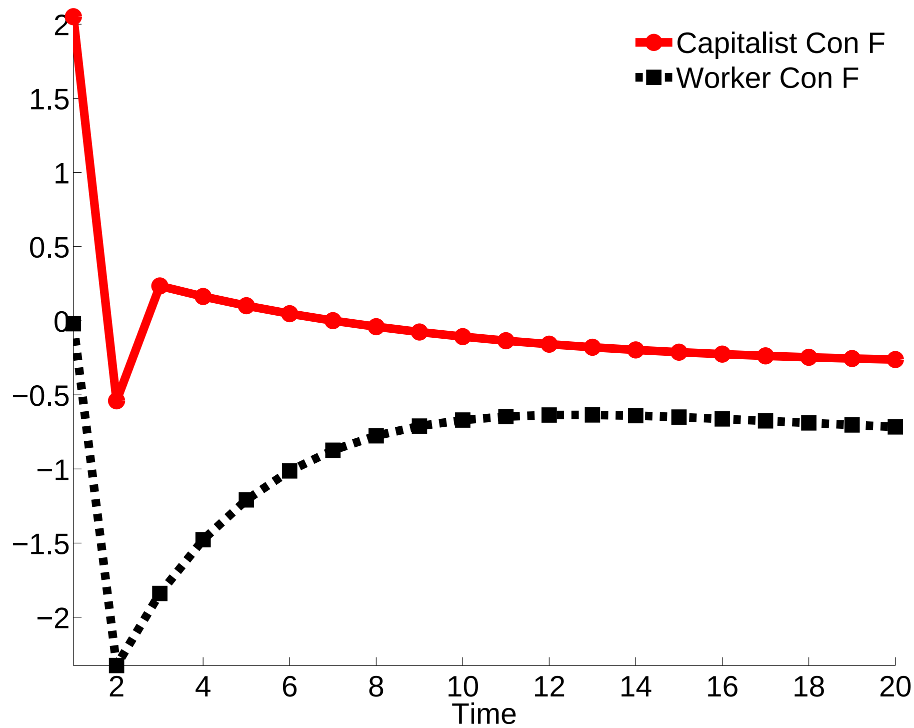
Note: This figure plots the wage in the foreign country over wage in the home country with respect to corporate taxes. Here we solve for the steady state equilibrium, conditional on the level of corporate tax at home and foreign countries. Other parameters are calibrated to the baseline specifications.

2.4.3 The Effects of Corporate Taxes in the Short Run: an Impulse Response Analysis

Figure 2.4 shows that when there is an increase in corporate tax, agents who hold assets, that is, capitalists, tend to be better off than agents who do not hold assets, that is, workers. Consumption by capitalists slightly decreases with a delay upon an increase in the innovation to corporate tax rates. This behavior is in stark contrast with the impulses responses of consumption by workers. Specifically, an one standard deviation increase in corporate tax rates (roughly 1 percent) leads to a 0.5 percent decrease in consumption for capitalists and this deviation quickly returns to its long-term mean thereafter. In stark contrast, the consumption by workers decreases by more than two percent and the effects tends to last more than 10 quarters. One natural question thus arises in terms of what mechanism may have caused this dichotomy between the two types of workers.

The mechanism for the results in figure 2.4 is illustrated in figure 2.5a, which plots the

Figure 2.4: Asymmetry in Consumption Responses



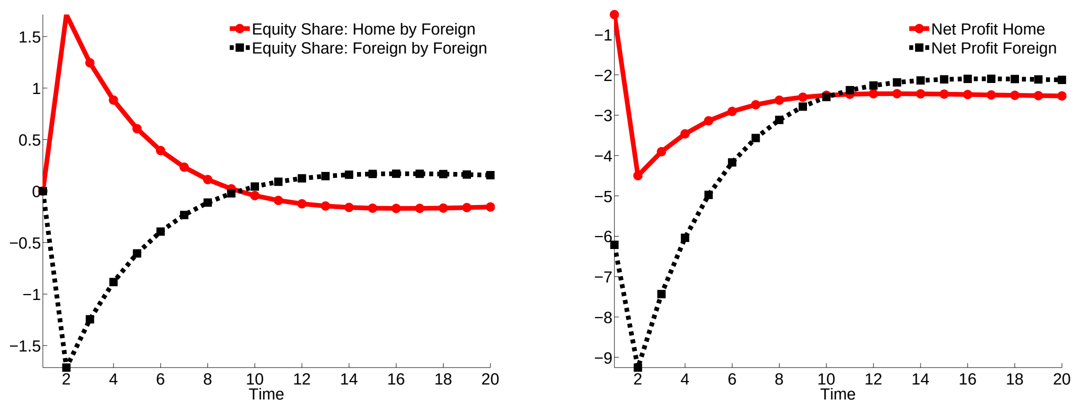
Note: Impulse responses of Workers and Capitalists consumption to innovations to foreign tax rates. Under baseline specification. The vertical axis denotes the percentage deviation from the steady states.

impulse responses of equity share by foreign investor to home and foreign countries. One key take-away from this figure is that the foreign investors tend to decrease their ownership in their domestic market; that is, in the foreign firms. At the same time, they ramp up their ownership share in the home firms, thereby diverting their risk from the domestic market to the international market. This behavior is consistent with the mechanisms we have seen in the static analysis, in which capitalists tend to divert their ownerships share from the economy that has relatively high level of cross-border financial friction. Naturally, the magnitude of this shift depends on the relative level of corporate taxes across countries when such an increase in tax rate is initiated.

Another channel through which capitalists are affected by an increase in corporate taxes is through the reduction in after-tax profits. Figure 2.5b shows that net profit at home tends to

Figure 2.5: Impulse Responses to Increase in Tax Rates

(a) Asymmetry in Equity Shares Responses **(b)** Responses of After-tax Net Profit

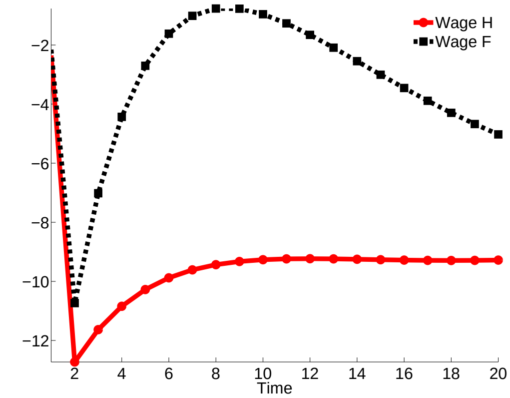


Note: [Left] Impulse responses of equity shares in Home and Foreign companies by Foreign Capitalists to an increase in foreign tax rates. Under baseline specification. The vertical axis denotes the percentage deviation from the steady states. **[Right]** Impulse responses of net profits to an increase in foreign tax rates. Under baseline specification. The vertical axis denotes the percentage deviation from the steady states.

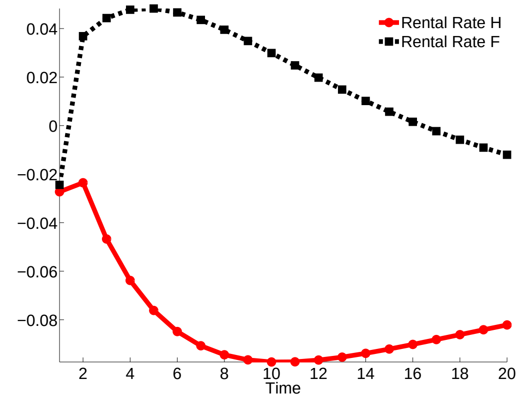
suffer less from an increase in corporate taxes than net profit at the foreign firms does. These effects are more pronounced for country F due to $\tau^F > \tau^H$ at the baseline specification. One most striking feature from the impulse response functions is the co-movement across countries of rental rates and wages (figure 2.6). While this result contrasts the proposition that of the previous section in which steady state interest rates were found to be an increasing function of taxes at *source*, in the dynamic setting, the spillover effects are presented on the interest rates.

This spillover effect is an implication of the FOCs for the capitalists with respect to capital allocation. Investing abroad or domestically is discounted at the same stochastic rate λ_{t+1}/λ_t, which is a function of both tax rates and other exogenous variables. Hence a shock to τ^F changes this stochastic rate which changes the stochastic discount rate used to decide k_H^H and k_F^H. A more intuitive explanation goes as follows: investors realize an unexpected increase in corporate profit tax rate that effectively reduces their incomes; since both firms compete for capital in the world market, they pay higher interest since the capitalist now has fewer resources as well as lower expected returns. On the other hand, the movements of the

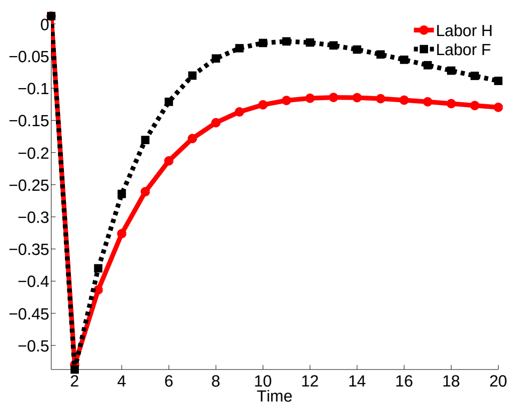
Figure 2.6: Impulse Responses to Increase in Tax Rates



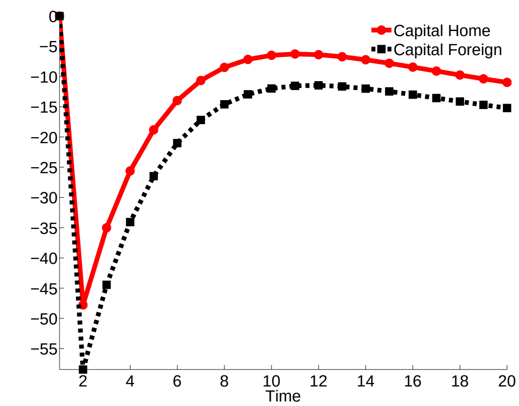
(a) Wage



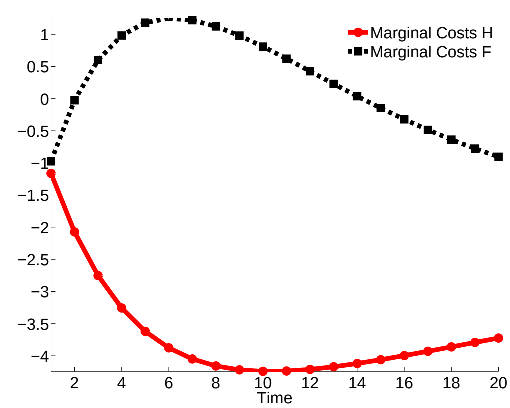
(b) Rental Rates



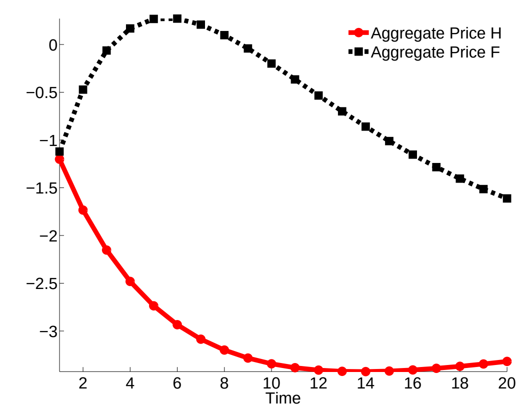
(c) Labor



(d) Capital



(e) Marginal Costs



(f) Price Level

aggregate capital stocks K^H and K^F are in line with the properties of the steady states in the sense that higher taxes reduced the level of capital stock in that country. Since our model abstracts from investment adjustment costs, the corresponding impulse responses tend to be less persistent.

The impulses responses of capital and labor in figure 2.6d and 2.6c confirm the convention that an increase in corporate tax rates can cause a significant decrease in employment and capital investment; a salient, yet undesirable, implication of which is a large decrease in real consumption in the country that initiates such a change in corporate tax, as evidenced in figure 2.4.

2.5 Conclusion

The recent Great Recession reminds us that financial integration can have a profound impact on trade patterns and outputs across countries. We re-evaluated this link, extending an otherwise standard two-country model to include cross-border financial frictions and corporate taxes. We found that the benefits of financial integration are not symmetric across different types of agents, which imply that financial integration may not necessarily lead to a preferable outcome for workers whose primary source of income is wages. This result is also deeply rooted in the debates whether financial openness is truly beneficial to developing countries, where most workers earn the majority of their incomes through salaried work.

Another contribution of the paper is to provide a theoretical foundation to support the empirical evidence that raising corporate taxes can result in distinctively different effects on individuals whose incomes depend solely on salaries and those who do not. In particular, we examined the properties of the model in both static and dynamic settings, showing that an orthogonalized increase in the innovation in corporate tax can result in a larger loss for capitalists in absolute value. However, these individuals who also claim ownership in firms tend to recover *far* quicker than individuals of the worker type.

One key feature of the recent Great Recession beginning in 2008 is that while investors lose money quickly, they also tend to recover much faster than do salaried workers. If an increase in corporate taxes can be considered equivalent to a shock in firm's profit, the theoretical results presented in our model can provide an alternative explanation to the varying degrees to which a shock to financial system can negatively affect individuals of different levels of dependence on salaries as their sole income. The message is thus that, while financial integration can help stimulate trade and financial flows across countries, such a perk does come at an unfortunate cost of potentially increasing the inequality between individuals who hold substantial capital and those who do not.

Table 2.1: Summary Statistics for Statutory Tax Rate τ and Two Different EATRs

	Means			Std. Deviation		Correlation	
	τ	τ^a_{nop}	τ^a_{gop}	τ^a_{nop}	τ^a_{gop}	$\rho_{n,g}$	$\rho_{s,g}$
Austria	32.06	17.41	9.31	2.51	1.36	0.97	0.19
Australia	33.05	32.99	21.01	5.19	3.60	0.97	-0.45
Belgium	37.52	24.92	12.92	6.19	2.56	0.98	-0.12
Canada	35.02	19.40	13.00	3.13	2.15	0.98	-0.21
Finland	28.64	22.09	12.42	8.68	4.43	0.66	0.09
France	35.57	26.84	14.71	5.66	2.94	0.95	0.33
Great Britain	30.73	21.24	14.01	3.53	2.53	0.92	-0.36
Germany	**45.70**	11.06	**6.74**	2.36	1.45	0.95	0.19
Italy	41.91	23.93	14.75	3.84	2.18	0.90	0.46
Japan	44.41	**37.74**	17.61	8.38	4.41	0.86	0.81
Netherlands	32.35	21.58	13.65	4.10	2.50	0.98	0.64
Norway	30.07	32.00	**22.10**	6.77	7.10	0.98	-0.39
Poland	28.65	30.92	16.04	16.86	6.68	0.96	0.90
Portugal	33.43	26.68	14.82	2.97	1.72	0.91	-0.15
Spain	33.98	24.80	14.33	9.35	4.96	0.99	0.30
Sweden	28.81	23.70	13.81	4.42	2.30	0.89	-0.49
Switzerland	30.15	21.02	10.25	4.39	1.82	0.89	-0.60
United States	39.36	25.71	**15.04**	3.01	2.19	0.97	-0.08
Overall(Panel)	34.55	24.73	14.36	8.72	5.02	0.84	-0.01

Note: Effective corporate tax rates computed under Mendoza et al. (1994a) methodology. τ_{GOP} uses gross operating surplus while τ_{NOP} used net operating surplus. Data is restricted to 1990-2011 to ensure comparability. Data comes from the OECD National Accounting Tables.

Table 2.2: Calibration under Baseline Specification

Parameters	Value	Notes	Description
α	0.33	Backus, Kydland, and Kehoe (1992)	Capital Share
β	0.98	Backus, Kydland, and Kehoe (1992)	Discount rates for annual data
δ	0.025	Backus, Kydland, and Kehoe (1992)	Depreciation rates for capitals
ϕ	3	Nakamura and Steisson (2007)	Labor dis-utility
θ_F^H	1.1	Our calibration	Ice-berg trade costs from Foreign to Home
θ_H^F	1.1	Our calibration	Ice-berg trade costs from Home to Foreign
η_F^H	1.2	Our calibration	Cross-country capital mark-ups from Foreign to Home
η_H^F	1.2	Our calibration	Cross-country capital mark-ups from Home to Foreign
$\bar{\tau}^H$	0.06	German effective tax	Steady-state corporate taxes rate at Home
$\bar{\tau}^F$	0.15	USA effective tax	Steady-state corporate taxes rate at Foreign
σ	3	Nakamura and Steisson (2007)	Elasticity of substitution between domestic and imported goods
ρ_H	0.7	Our calibration	Persistence of productivity process for Home
ρ_F	0.7	Our calibration	Persistence of productivity process for Foreign

Appendix

2.A Summary of Equations

2.A.1 For Workers

We consider the following utility function

$$\mathbb{E}\sum_{t=1}^{\infty}\beta^t\left[M_t^j+log(N_t)\right] \tag{2.A.1}$$

subject to

$$\sum_{i=1}^{N}p_i^j m_i^j+b_{w,t+1}^j=\omega_t^j L_t^j+(1+r_{b,t}^j)(b_{w,t})+T_t^H \tag{2.A.2}$$

$$M_t^j=\left[\sum_{i=1}^{N}\left(m_i^j\right)^{\varepsilon}\right]^{1/\varepsilon} \tag{2.A.3}$$

$$1=L_t+N_t \tag{2.A.4}$$

The set of variables for country $j=H,F$ for the worker type includes

1. Five (5) choice variables from the first orders condition; namely, $\{\lambda_w, m_H, m_F, b_w, L\}$.

$$\left[\sum_{i=1}^{N}\left(m_{i,t}^j\right)^{\varepsilon}\right]^{1/\varepsilon-1}\left(m_{i,t}^j\right)^{\varepsilon-1}=\lambda_{w,t}^j p_{i,t}^j \qquad \forall i=j \tag{2.A.5}$$

$$\left[\sum_{i=1}^{N}\left(m_{i,t}^j\right)^{\varepsilon}\right]^{1/\varepsilon-1}\left(m_{i,t}^j\right)^{\varepsilon-1}=\lambda_{w,t}^j p_{i,t}^j \qquad \forall i\neq j \tag{2.A.6}$$

$$\lambda_{w,t}^j\omega_t^j=N_t^{-1} \tag{2.A.7}$$

$$\lambda_{w,t+1}^j\beta(1+r_{b,t+1}^j)=\lambda_{w,t}^j \tag{2.A.8}$$

The budget constraint is

$$\sum_{i=1}^{N} p_i^j m_i^j + b_{w,t+1} = (1-\tau_{L,t})\omega_t^j L_t^j + (1+r_{b,t}^j)(b_{w,t}) + T_t^H \tag{2.A.9}$$

2. Two (2) auxiliary variables; namely, $\{M, X_w\}$.

$$M_t^j = \left[\sum_{i=1}^{N}\left(m_i^j\right)^{\varepsilon}\right]^{1/\varepsilon} \tag{2.A.10}$$

$$X_{w,t}^j = (1-\tau_L^H)\omega_t^j L_t^j + (1+r_{b,t}^j)b_t^j - b_{t+1}^j + T_t^H \tag{2.A.11}$$

2.A.2 For Capitalists

Utility:

$$\mathbb{E}\sum_{t=1}^{\infty}\beta^t\left[C_t^j\right] \tag{2.A.12}$$

such that

$$\sum_{i=1}^{C} p_{i,t}^j c_{i,t}^j + b_{t+1} + \sum_{i=1}^{C} I_{j,t}^i = \sum_{i=1}^{C} s_{j,t}^i(1-\tau_t^i)\pi_t^i + (1+r_{b,t}^j)b_t \tag{2.A.13}$$

$$s_j^i = \frac{k_{j,t}^i}{K_t^j} \qquad \forall i \neq j \tag{2.A.14}$$

$$K_t^j = \sum_{i=1}^{C} k_{i,t}^j \tag{2.A.15}$$

$$C_t^j = \left[\sum_{i=1}^{C}\left(c_i^j\right)^{\varepsilon}\right]^{1/\varepsilon} \tag{2.A.16}$$

Since cross-border capital investment requires additional costs, the capital evolution process can be written as follows:

$$\frac{1}{\eta_i^j} I_{i,t}^j = k_{i,t+1}^j - (1-\delta)k_{i,t}^j \tag{2.A.17}$$

Where the financial costs of holding capital overseas $\eta^i_j > 1$ if $i \neq j$ and identical to one when $i = j$ The set of variables for the capitalists include:

1. Six (6) choice variables; namely, $\{n_H, n_F, \lambda_c, k^H, k^F, b_c,\}$. It is helpful to note that since the conditions for workers imply the aggregate price index (which does not need to be in the system of equation), only one of the two first order conditions for capitalists and the CES aggregator for capitalist consumption are sufficient.

$$\lambda^j_{c,t} p^j_{i,t} = \left[\sum_{i=1}^{C} \left(c^j_{i,t}\right)^{\varepsilon}\right]^{1/\varepsilon-1} \left(c^j_{i,t}\right)^{\varepsilon-1} \qquad \forall i = j \tag{2.A.18}$$

$$\lambda^j_{c,t} p^j_{i,t} = \left[\sum_{i=1}^{C} \left(c^j_{i,t}\right)^{\varepsilon}\right]^{1/\varepsilon-1} \left(c^j_{i,t}\right)^{\varepsilon-1} \qquad \forall i \neq j \tag{2.A.19}$$

$$\lambda^j_{c,t} = \beta\,\mathbb{E}\left[\lambda^j_{c,t+1}(1+r^j_{b,t+1})\right] \tag{2.A.20}$$

$$\forall i = H \quad 1 = \beta\,\mathbb{E}\left\{\frac{\lambda^j_{c,t+1}}{\lambda^j_{c,t}}\left[\frac{(1-s^i_{j,t+1})}{\eta^i_j K^i_{t+1}}(1-\tau^i_t)\pi^i_t + (1-\delta)\right]\right\} \tag{2.A.21}$$

$$\forall i = F \quad 1 = \beta\,\mathbb{E}\left\{\frac{\lambda^j_{c,t+1}}{\lambda^j_{c,t}}\left[\frac{(1-s^i_{j,t+1})}{\eta^i_j K^i_{t+1}}(1-\tau^i_t)\pi^i_t + (1-\delta)\right]\right\} \tag{2.A.22}$$

$$\sum_{i=1}^{C} p^j_{i,t} c^j_{i,t} + b_t + \sum_{i=1}^{C} I^i_{j,t} = \sum_{i=1}^{C} s^i_{j,t-1}(1-\tau^i_{t-1})\pi^i_{t-1} + (1+r^j_{b,t})b_{t-1} \tag{2.A.23}$$

2. Six (6) auxiliary variables; namely, $\{X_c, s^H, s^F, I_H, I_F, C\}$.

$$X_{c,t} = \sum_{i=1}^{C} p^j_{i,t} n^j_{i,t} \tag{2.A.24}$$

$$s^i_j = \frac{k^i_{j,t}}{K^i_t} \qquad \forall i \neq j \tag{2.A.25}$$

$$s^i_j = \frac{k^i_{j,t}}{K^i_t} \qquad \forall i = j \tag{2.A.26}$$

$$k^i_{j,t+1} = \frac{1}{\eta^i_j} I^i_{j,t} + (1-\delta) k^i_{j,t} \qquad \forall i \neq j \tag{2.A.27}$$

$$k^i_{j,t+1} = \frac{1}{\eta^i_j} I^i_{j,t} + (1-\delta) k^i_{j,t} \qquad \forall i = j \tag{2.A.28}$$

$$C^j_t = \left[\sum_{i=1}^{C} \left(n^j_i \right)^{\varepsilon} \right]^{1/\varepsilon} \tag{2.A.29}$$

$$\tag{2.A.30}$$

2.A.3 For Firms

The set of variables for firms include:

1. Three (3) choice variables; namely, $\{p^H_t, K^j_t, \omega^j_t\}$.

$$p^j_t = \frac{1}{\varepsilon} \Omega^j_t \tag{2.A.31}$$

$$w^j_t = \Omega^j_t A^j_t (1-\alpha) \left[\frac{K^j_t}{L^j_t} \right]^{\alpha} \tag{2.A.32}$$

$$r^j_t = \Omega^j_t A^j_t \alpha \left[\frac{L^j_t}{K^j_t} \right]^{1-\alpha} \tag{2.A.33}$$

2. Four (4) auxiliary variables; namely, $\{p^i_j, \Omega^j, \pi^j, Y^j\}$.

$$Y^j_t = A^j_t (K^H)^{\alpha} (L^H)^{1-\alpha} \tag{2.A.34}$$

$$p^i_{j,t} = \theta^i_{j,t} p^j_{j,t} \tag{2.A.35}$$

$$\pi^j_t = \frac{1}{\sigma - 1} \Omega^j_t A^j_t \left(\frac{w^j_t}{r^j_t} \frac{\alpha}{1-\alpha} \right)^{\alpha} L^j_t \tag{2.A.36}$$

2.A.4 National Variables

The set of national variables include (5) variables; namely $\{P^j, B^j, w^j, r^j, r_b^j\}$.

$$B_t^j = b_{w,t}^j + b_{c,t}^j \tag{2.A.37}$$

$$K_t^j = \sum_{i=1}^{N} k_{i,t}^j \tag{2.A.38}$$

$$P_t^j = \left[\sum_{i=1}^{N} \left(p_i^j\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{2.A.39}$$

2.A.5 Government and Productivity Variables

Four (05) exogenous/government variables; that is, $\{A, T, G, \Delta G, \tau\}$

$$T_t^j = \tau_t^j \pi_t^j - p_j^j G_t^j \tag{2.A.40}$$

$$b_{w,t}^j + b_{c,t}^j = 0 \tag{2.A.41}$$

$$\log A_t^j = \rho_A \log A_{t-1}^j + u_t^j \tag{2.A.42}$$

$$\Delta \log G_t^j = \log G_t^j - \log G_{t-1}^j \tag{2.A.43}$$

$$\Delta \log G_t^j = \rho_g \Delta \log G_t^j + v_t^j \tag{2.A.44}$$

$$\tau_t^j = (1-\rho_\tau)\bar{\tau} + \rho_\tau \tau_t^j + v_t^j \tag{2.A.45}$$

2.B Solutions to the steady states

From the budget constraint for capitalists, it follows that:

$$s_H^H = \frac{\eta_F^H}{1+\eta_F^H} \qquad s_F^H = \frac{1}{1+\eta_F^H} \tag{2.B.1}$$

$$s_F^F = \frac{\eta_H^F}{1+\eta_H^F} \qquad s_H^F = \frac{1}{1+\eta_H^F} \tag{2.B.2}$$

From the market clearing condition for capital, it follows that

$$c = \frac{r^F}{r^H} \tag{2.B.3}$$

$$r^F = \frac{[1-\beta(1-\delta)]\left[1+\eta_H^F\right](\sigma-1)\alpha}{\beta(1-\tau^F)} \tag{2.B.4}$$

$$r^H = \frac{[1-\beta(1-\delta)]\left[1+\eta_F^H\right](\sigma-1)\alpha}{\beta(1-\tau^H)} \tag{2.B.5}$$

$$\frac{K^F}{K^H} = \left(\frac{1-\tau^F}{1-\tau^H}\right)\left(\frac{1+\eta_F^H}{1+\eta_H^F}\right)\left(\frac{\omega^F L^F}{\omega^H L^H}\right) \tag{2.B.6}$$

$$\pi^i = \left(\frac{1}{\sigma-1}\right)\left(\frac{\omega^i L^i}{1-\alpha}\right) \tag{2.B.7}$$

$$K^H = \left(\frac{1-\tau^H}{1+\eta_F^H}\right)\left(\frac{\beta}{1-\beta(1-\delta)}\right)\left(\frac{\omega^H L^H}{(\sigma-1)(1-\alpha)}\right) \tag{2.B.8}$$

$$K^F = \left(\frac{1-\tau^F}{1+\eta_H^F}\right)\left(\frac{\beta}{1-\beta(1-\delta)}\right)\left(\frac{\omega^F L^F}{(\sigma-1)(1-\alpha)}\right) \tag{2.B.9}$$

$$k_H^H = \left(\frac{1-\tau^H}{(1+\eta_F^H)^2}\right)\left(\frac{\beta\eta_F^H}{1-\beta(1-\delta)}\right)\left(\frac{\omega^H L^H}{(\sigma-1)(1-\alpha)}\right) \tag{2.B.10}$$

$$k_F^H = \left(\frac{1-\tau^H}{(1+\eta_F^H)^2}\right)\left(\frac{\beta}{1-\beta(1-\delta)}\right)\left(\frac{\omega^H L^H}{(\sigma-1)(1-\alpha)}\right) \tag{2.B.11}$$

$$k_F^F = \left(\frac{1-\tau^F}{(1+\eta_H^F)^2}\right)\left(\frac{\beta\eta_H^F}{1-\beta(1-\delta)}\right)\left(\frac{\omega^F L^F}{(\sigma-1)(1-\alpha)}\right) \tag{2.B.12}$$

$$k_H^F = \left(\frac{1-\tau^F}{(1+\eta_H^F)^2}\right)\left(\frac{\beta}{1-\beta(1-\delta)}\right)\left(\frac{\omega^F L^F}{(\sigma-1)(1-\alpha)}\right) \tag{2.B.13}$$

Given the formula for the price indices, it follows that

$$p_F^F = p_H^H\left(\frac{(\theta_H^F)^{1-\sigma}-Q^{1-\sigma}}{(Q\theta_F^H)^{1-\sigma}-1}\right)^{1/(1-\sigma)} \tag{2.B.14}$$

$$\frac{P^H}{p_H^H} = \left[\frac{\left(\theta_F^H\theta_H^F\right)^{1-\sigma}-1}{\left(Q\theta_F^H\right)^{1-\sigma}-1}\right]^{1/(1-\sigma)} \tag{2.B.15}$$

$$\frac{p_F^F}{P^F} = \frac{1}{Q}\left[\frac{\left(\theta_H^F\right)^{1-\sigma}-Q^{1-\sigma}}{\left(\theta_F^H\theta_H^F\right)^{1-\sigma}-1}\right]^{1/(1-\sigma)} \tag{2.B.16}$$

$$P^F = QP^H \tag{2.B.17}$$

Steady states capitalist consumption income, outputs and total consumption are:

$$X_c^H = a_1\omega^H L^H + a_2\omega^F L^F + r_b^H b_c^H \qquad (2.B.18)$$

$$X_c^F = b_1\omega^F L^F + b_2\omega^H L^H + r_b^F b_c^F \qquad (2.B.19)$$

$$Y^H = \left(\frac{L^H}{1-L^H}\right)\left(\frac{1}{\varepsilon(1-\alpha)}\right)\left[\frac{\left(\theta_F^H\theta_H^F\right)^{1-\sigma}-1}{\left(Q\theta_F^H\right)^{1-\sigma}-1}\right]^{1/(1-\sigma)} \qquad (2.B.20)$$

$$Y^F = \left(\frac{L^F}{1-L^F}\right)\left(\frac{Q}{\varepsilon(1-\alpha)}\right)\left[\frac{\left(\theta_F^H\theta_H^F\right)^{1-\sigma}-1}{\left(\theta_H^F\right)^{1-\sigma}-Q^{1-\sigma}}\right]^{1/(1-\sigma)} \qquad (2.B.21)$$

$$Y^H = \left[\left(\frac{1-\tau^H}{1+\eta_F^H}\right)\left(\frac{\beta}{1-\beta(1-\delta)}\right)\left(\frac{P^H}{(1-L^H)(\sigma-1)(1-\alpha)}\right)\right]^{\alpha} A^H L^H \qquad (2.B.22)$$

$$Y^F = \left[\left(\frac{1-\tau^F}{1+\eta_H^F}\right)\left(\frac{\beta}{1-\beta(1-\delta)}\right)\left(\frac{P^F}{(1-L^F)(\sigma-1)(1-\alpha)}\right)\right]^{\alpha} A^F L^F \qquad (2.B.23)$$

in which,

$$a_1 = s_H^H\left(\frac{(1-\tau^H)}{(\sigma-1)(1-\alpha)}\right)\left(1-\frac{\delta\beta}{(1+\eta_F^H)(1-\beta(1-\delta))}\right) \qquad (2.B.24)$$

$$a_2 = s_H^F\left(\frac{(1-\tau^F)}{(\sigma-1)(1-\alpha)}\right)\left(1-\frac{\eta_H^F\delta\beta}{(1+\eta_H^F)(1-\beta(1-\delta))}\right) \qquad (2.B.25)$$

$$b_1 = s_F^F\left(\frac{(1-\tau^F)}{(\sigma-1)(1-\alpha)}\right)\left(1-\frac{\delta\beta}{(1+\eta_H^F)(1-\beta(1-\delta))}\right) \qquad (2.B.26)$$

$$b_2 = s_F^H\left(\frac{(1-\tau^H)}{(\sigma-1)(1-\alpha)}\right)\left(1-\frac{\eta_F^H\delta\beta}{(1+\eta_F^H)(1-\beta(1-\delta))}\right) \qquad (2.B.27)$$

Alternative equations for Y Use $Y = C + I + G + N_x$ and the first two equation for Y from above. Also define: $\tilde{\beta} = \dfrac{\beta}{1-\beta(1-\delta)}$ and $\tilde{\sigma} = (\sigma-1)(1-\alpha)$.

$$\left[\left(\frac{1-\tau^H}{1+\eta_F^H}\right)\frac{\tilde{\beta}\omega^H}{\tilde{\sigma}}\right]^{\alpha} L^H = G^H + \delta k_H^H + \eta_H^F k_H^F + \frac{(p_H^H)^{-\sigma}}{(P^H)^{1-\sigma}}\left\{\omega^H L^H\left(1+\frac{\tau^H}{\tilde{\sigma}}+a_1\right) - p_H^H G^H \ldots\right.$$

$$\left. + a_2\omega^F L^F + \left(\frac{\theta_H^F}{Q}\right)^{1-\sigma}\left[\omega^F L^F\left(1+\frac{\tau^F}{\tilde{\sigma}}+b_1\right) - p_F^F G^F + b_2\omega^H L^H\right]\right\}$$

$$\left[\left(\frac{1-\tau^F}{1+\eta_H^F}\right)\frac{\tilde{\beta}\omega^F}{\tilde{\sigma}}\right]^{\alpha} L^F = G^F + \delta k_F^F + \eta_F^H k_F^H + \frac{(p_F^F)^{-\sigma}}{(P^F)^{1-\sigma}}\left\{\omega^F L^F\left(1+\frac{\tau^F}{\tilde{\sigma}}+b_1\right) - p_F^F G^F \ldots \right.$$

$$\left. + b_2\omega^H L^H + \left(\theta_F^H Q\right)^{1-\sigma}\left[\omega^H L^H\left(1+\frac{\tau^H}{\tilde{\sigma}}+a_1\right) - p_H^H G^H + a_2\omega^F L^F\right]\right\}$$

To find Q we employ two more equations. First we fix ω^H to be unity, which allows us to express the equilibrium labor of both countries by the following formulas:

$$1-L^H = \left(\frac{1}{\varepsilon(1-\alpha)}\right)\left[\frac{(\theta_F^H\theta_H^F)^{1-\sigma}-1}{(Q\theta_F^H)^{1-\sigma}-1}\right]^{\frac{1}{1-\sigma}}\left[\left(\frac{1-\tau^H}{1+\eta_F^H}\right)\frac{\tilde{\beta}\omega^H}{(\sigma-1)(1-\alpha)}\right]^{-\alpha} \quad (2.B.28)$$

$$1-L^F = \left(\frac{Q}{\varepsilon(1-\alpha)}\right)\left[\frac{(\theta_F^H\theta_H^F)^{1-\sigma}-1}{(\theta_H^F)^{1-\sigma}-Q^{1-\sigma}}\right]^{\frac{1}{1-\sigma}}\left[\left(\frac{1-\tau^F}{1+\eta_H^F}\right)\frac{\tilde{\beta}\omega^F}{(\sigma-1)(1-\alpha)}\right]^{-\alpha} \quad (2.B.29)$$

The ratio of the previous two equations paired with the labor supply conditions yield the following relation between the foreign wage and the real exchange rate:

$$\left(\frac{\omega^F}{\omega^H}\right)^{1-\alpha} = \left[\frac{(1-\tau^F)(1+\eta_F^H)}{(1-\tau^H)(1+\eta_H^F)}\right]^{\alpha}\left[\frac{(Q\theta_F^H)^{1-\sigma}-1}{(\theta_H^F)^{1-\sigma}-Q^{1-\sigma}}\right]^{1/(\sigma-1)} \quad (2.B.30)$$

The above equation uses the relationship

$$\frac{1-L^F}{1-L^H} = Q\frac{\omega^H}{\omega^F} \quad (2.B.31)$$

We notice that

$$\frac{P^F}{P^H} = Q = \left[\frac{(\Omega^H)^{1-\sigma}+(\theta_F^H\Omega^F)^{1-\sigma}}{(\Omega^F)^{1-\sigma}+(\theta_H^F\Omega^H)^{1-\sigma}}\right]^{1/(1-\sigma)} \quad (2.B.32)$$

noting that the marginal cost can be written as a function of wages, labor, and Q.

Pinning down the unique steady state

There are five equations that help us pin down the unique steady state. The ***first*** equation is the feasibility condition for home country; that is,

$$\left[\left(\frac{1-\tau^H}{1+\eta_F^H}\right)\frac{\tilde{\beta}\omega^H}{\tilde{\sigma}}\right]^{\alpha} L^H = G^H + \delta k_H^H + \eta_H^F k_H^F + \frac{(p_H^H)^{-\sigma}}{(P^H)^{1-\sigma}}\left\{\omega^H L^H\left(1+\frac{\tau^H}{\tilde{\sigma}}+a_1\right) - p_H^H G^H \ldots\right.$$

$$\left. + a_2\omega^F L^F + \left(\frac{\theta_H^F}{Q}\right)^{1-\sigma}\left[\omega^F L^F\left(1+\frac{\tau^F}{\tilde{\sigma}}+b_1\right) - p_F^F G^F + b_2\omega^H L^H\right]\right\}$$

The ***second*** equation governs the relative sizes of the two economies, in which case the feasibility condition for the foreign economy is implicitly implied. This equation writes

$$\frac{\left[\left(\frac{1-\tau^H}{1+\eta_F^H}\right)\frac{\tilde{\beta}\omega^H}{\tilde{\sigma}}\right]^{\alpha} L^H}{\left[\left(\frac{1-\tau^F}{1+\eta_H^F}\right)\frac{\tilde{\beta}\omega^F}{\tilde{\sigma}}\right]^{\alpha} L^F} = \Xi$$

in which Ξ denotes the relative size of the home economy w.r.t. the foreign economy. The ***third*** and ***fourth*** equations use the conditions that labor market must be clear at each of the country because labor is immobile by assumption.

$$\begin{aligned}
1-L^H &= \left(\frac{1}{\varepsilon(1-\alpha)}\right)\left[\frac{(\theta_F^H\theta_H^F)^{1-\sigma}-1}{(Q\theta_F^H)^{1-\sigma}-1}\right]^{\frac{1}{1-\sigma}}\left[\left(\frac{1-\tau^H}{1+\eta_F^H}\right)\frac{\tilde{\beta}\omega^H}{(\sigma-1)(1-\alpha)}\right]^{-\alpha} \\
1-L^F &= \left(\frac{Q}{\varepsilon(1-\alpha)}\right)\left[\frac{(\theta_F^H\theta_H^F)^{1-\sigma}-1}{(\theta_H^F)^{1-\sigma}-Q^{1-\sigma}}\right]^{\frac{1}{1-\sigma}}\left[\left(\frac{1-\tau^F}{1+\eta_H^F}\right)\frac{\tilde{\beta}\omega^F}{(\sigma-1)(1-\alpha)}\right]^{-\alpha}
\end{aligned}$$

The ***fifth*** equation comes from the definition of Q itself; that is, an alternative to the balance trade condition, we notice that

$$\frac{P^F}{P^H} = Q = \left[\frac{(\Omega^H)^{1-\sigma}+(\theta_F^H\Omega^F)^{1-\sigma}}{(\Omega^F)^{1-\sigma}+(\theta_H^F\Omega^H)^{1-\sigma}}\right]^{1/(1-\sigma)} \tag{2.B.33}$$

noting that the marginal cost can be written as a function of wages, labor, and Q. All in all, this system of ***five*** equations solves for the steady state values of $\{\omega^H, \omega^F, L^H, L^F, Q\}$.

2.C Proof of Steady State Properties

Proof of 2.3.1

Proof. Let $j \neq i$. Taking the derivatives of the capital rental rate for home and foreign with respect to foreign corporate taxes yields

$$\begin{aligned}
\frac{\partial r^j}{\partial \tau^j} &= \frac{[1-\beta(1-\delta)]\left[1+\eta_i^j\right](\sigma-1)\alpha}{\beta(1-\tau^j)^2} > 0 \\
\frac{\partial r^j}{\partial \eta_i^j} &= \frac{[1-\beta(1-\delta)](\sigma-1)\alpha}{\beta(1-\tau^j)} > 0
\end{aligned}$$

The strict inequalities hold since we assume that $0 \leq \tau^j < 1$ for $j = H, F$ and η_j^i is strictly greater than one. The above equations prove the first two bullet points of the proposition. Given that both values are strictly greater than zero we take their ratio and get $(1+\eta_i^j)/(1+\tau^j)$ which is always greater than one. □

Proof of 2.3.2

Proof.

$$\frac{\partial s_j^j}{\partial \eta_i^j} = -\frac{\partial s_i^j}{\partial \eta_i^j} = \frac{1}{(1+\eta_i^j)^2} > 0$$

□

Proof of proposition 2.3.3

Proof. The steady state solution appendix shows that the formula for foreign wage is

$$\left(\frac{\omega^F}{\omega^H}\right)^{1-\alpha} = \left[\frac{(1-\tau^F)(1+\eta_F^H)}{(1-\tau^H)(1+\eta_H^F)}\right]^{\alpha}\left[\frac{(Q\theta_F^H)^{1-\sigma}-1}{(\theta_H^F)^{1-\sigma}-Q^{1-\sigma}}\right]^{1/(\sigma-1)} \quad (2.C.1)$$

To ensure that $\omega^F \in \mathbb{R}^+$ we must restrict the second bracket of the above equation to be strictly positive. Such restriction is fulfill with two different cases:

- **Case 1:** $Q < \theta_H^F$ and $Q > 1/\theta_F^H$
- **Case 2:** $Q > \theta_H^F$ and $Q < 1/\theta_F^H$

However case 2 is not possible in our model. Given that $\theta \geq 1$, case 2 implies that Q is greater than one and also strictly less than one, a contradiction. Therefore, wages are positive real numbers only when $Q \in (1/\theta_F^H \; ; \; \theta_H^F)$ □

Proof of proposition 2.3.4

Proof. Assume countries are symmetric in θ, η, τ then the ratio of marginal costs is:

$$\frac{\Omega^F}{\Omega^H} = \left(\frac{\omega^F}{\omega^H}\right)^{1-\alpha} = \left[\frac{(Q\theta)^{1-\sigma} - 1}{(\theta)^{1-\sigma} - Q^{1-\sigma}}\right]^{1/(\sigma-1)}$$

Multiply and divide equation 2.B.33 by Ω^H and use the above ratio to obtain:

$$Q = \frac{1}{Q^{1-\sigma}}$$

Thus, if $\sigma \neq 1$ then $Q = 1$ is the steady state solution to the ration of prices indexes. □

Proof of proposition 2.3.6

Proof. Take the ratio of Home and Foreign outputs combined with the formulas for profit to obtain:

$$\frac{Y^H}{Y^F} = \frac{\pi^H}{\pi^F}\left[\frac{\left(\theta_H^F\right)^{1-\sigma} - Q^{1-\sigma}}{\left(Q\theta_F^H\right)^{1-\sigma} - 1}\right]^{\frac{1}{1-\sigma}}$$

Since the ratio of outputs is constant then the total derivative of the expression above is given by:

$$0 = \frac{\partial\left(\pi^H/\pi^F\right)}{\partial Q}\left[\frac{\left(\theta_H^F\right)^{1-\sigma} - Q^{1-\sigma}}{\left(Q\theta_F^H\right)^{1-\sigma} - 1}\right]^{\frac{1}{1-\sigma}} dQ + \frac{(1-\sigma)\left(1-\left(\theta_H^F\theta_F^H\right)^{1-\sigma}\right)}{\left(\left(Q\theta_F^H\right)^{1-\sigma} - 1\right)^2}\frac{\pi^H}{\pi^F}dQ$$

Using the bounds of Q as well as $\theta \geq 1$ it can be easily shown that $\frac{(1-\sigma)\left(1-\left(\theta_H^F\theta_F^H\right)^{1-\sigma}\right)}{\left(\left(Q\theta_F^H\right)^{1-\sigma} - 1\right)^2} < 0$. Thus, if dQ is positive, i.e the prices in the foreign country become more expensive relative to those of Home, then $\frac{\partial\left(\pi^H/\pi^F\right)}{\partial Q}$ must be positive in order to balance the equation i.e, the profit of the home country firm must increase relative to that of the Foreign firm.

□

Chapter 3

Do large companies pay lower taxes? Evidence using harmonized balance sheets from companies in 11 European countries

3.1 Introduction

Comparing corporate taxes across the world is a difficult endeavor due to: (i) lack of a standard metric that assesses the true tax burden, (ii) different accounting standards across nations. The choice of metric to measure corporate tax is critical since each metric provides us with different pictures of the same issue. For example, the latest report by the non-partisan think thank “Tax Foundation" ranks the U.S at the top of corporate tax rates in the world with an *statutory* corporate tax rate of 39 %, a significant 14 % higher than the OECD average. In contrast, a contemporary report by the General Accounting Office of the U.S finds that the average U.S large firm has an *effective* tax rate of 12.6% on their profits, a staggering less than one third of the rate stated in the tax code. Effective corporate tax rates are a simple concept (taxes paid over a measure of profit) that relies on using firms’ balance sheet information that is prepared using the accounting standards required by the country of operation; therefore, the items used to compute the effective tax rate might not be measuring the same variables across countries. This issue is especially problematic as the source of most discrepancies is found in the computation of amortization of capital for the company, which in turn is one of the main drivers for the differences between effective and statutory corporate tax rates.

In this paper I estimate effective average corporate tax rates (EATR), that are comparable across a small set of European countries, and answer the question of whether large firms get preferential tax treatment relative to small firms. I find that at the national level there is some evidence for differences between effective tax rates faced by large and small firms; however, analysis by economic sectors does result in stronger evidence for preferential tax treatment of larger firms. Additionally, effective tax rates are substantially different between sectors and across countries. This stylized fact helps to support the idea that governments might be engage in an optimization problem in which they decide the rates of their tax instruments in a way that exploits the characteristics of their economic sectors.

I also present the most important differences and advantages of using effective tax rates obtained from firm level data and: the statutory corporate tax rate and, another measure of EATR that is popular in the literature. For illustration purposes, Figure 3.1 shows a clear downward pattern for the statutory tax rates of multiple developed countries.[1] This strong downward pattern isn't observed in the time series of the EATRs obtained in the BACH database and neither in those computed using the methodology of Mendoza et al. (1994b), hereby referred as MRT. At the national level, the EATRs from the BACH database and those computed under MRT exhibit similar patterns but significant difference at the levels. Moreover, because the MRT rates use national account data, it isn't possible to analyze the question regarding the preferential treatment of larger firms with respect to taxes.

3.2 Effective Average Tax Rates from National Accounts

Mendoza, Razin and Tesar (1994) is the pioneer paper to formulated a set of metrics to estimate actual tax burdens on economic agents using readily available aggregate macroeconomic data; and their method has been widely used in academic and policy environments due to its simplicity and data availability.[2] Their formula follows the principles outlined for their calculation of capital taxes at the household level, which in the case of corporations is reduced to the simple ratio of taxes paid on profits and net operating profit.

The reliance of MRT in national account data, while convenient, has an often overlooked problem rooted in changes and differences in accounting standards across time and countries. The main problem generated by the lack of accounting harmonization is comparability across time and/or countries. For example, subsequent updates and studies (including this one) to

[1] The data for the statutory tax rates is taken from KPMG annual tax reports and supplemented with data from the International Fiscal Studies Center.

[2] Devereux et al. (2002) is another popular methodology to estimate effective *marginal* tax rates but it uses micro data with a forward looking approach.

MRT have found EATRs consistently below the original rates published in 1994. These discrepancies between rates highlight one of the main problems of using macro-backward methods: they are susceptible to revisions of data and, most importantly, changes in accounting procedures for national accounts can make pre and post change rates non-comparable.

An important breaking point in the comparability of corporate EATRs from national data occurred in 1993 when a major revision of the National Accounting standards was introduced. Most countries (a notable exception is the US) generate their national accounts based on the Standard National Accounting system (SNA), created by United Nations' statistical department.[3] The system had its first major update in 1993, the previous version was SNA 1968, and brought major changes relevant to the estimation of effective average corporate tax rates. These changes included new rules for computations of fixed capital consumption and, the separation of corporations from unincorporated enterprises. This modification was very important to the estimation of corporate EATR since, prior to SNA 1993, gross operating surplus (a measure of a corporation's profits) and *mixed income* (a measure of unincorporated firms' profit) was reported as a single measure. The term mixed income reflects the significant share of entrepreneur's income that comes from their labor input into the firm, while the remaining comes from capital investments. Thus, treating mixed income and gross surplus as similar measures of firms' profits net of labor cost is erroneous and therefore I restrict my analysis to national account data that is compliant with SNA 1993 to maintain consistency across time.

3.2.1 EATRs from National Account data

Many previous studies based on MRT use the ratio of taxes paid on relative to net operating surplus (NOP), which is problematic if we are interested in making comparisons across countries. Net operating profit is defined as gross operating surplus (GOP) minus the con-

[3] The United States uses the NIPA account system which is developed by the BEA. The system follows the main guideline of the SNA, and *annual* national accounts are created to be comparable to other OECD countries. i.e follow the SNA standard

sumption of fixed capital, but the computation of this last factor isn't standard across nations.[4] SNA provides guidelines to determine depreciation rates, but these are ranges or upper/lower rates instead of exact numbers, leaving the final decision to the national authority.

Table 3.1 contains the summary statistics for the statutory tax rate (τ), EATR using NOP (τ_{nop}) and, EATR using GOP (τ_{gop}); while figure 3.2 presents the time series of these different tax measures. Both τ_{nop}, τ_{gop} have significantly lower means than the statutory rate and they are always below the statutory tax rate in the time series, except for a handful of points. These discrepancies between what is ought and what is paid by corporations is quite large since the effective rate is around 30 to 60 percent of the statutory rate. This issue has been key in fueling the public discomfort towards the current state of corporate taxation.

In the introduction I use the US to highlight the stark differences in assessing the corporate tax environment depending on the measure use; I build on this and show that the ranking of countries, according to their tax, changes with each measure i.e, the difference between statutory rates and effective rates is not a common linear factor across countries. From table 3.1 we can readily observe that the top country in terms of taxation switches for each tax measure. A Friedman test shows that the rankings for each measure are statistically different from each other.[5] The case of Germany is rather striking going from the top taxing country, when using statutory rates, to bottom place, when using any of the two effective rates. The German case seems extreme so as a check I conduct the Friedman test in the sample without Germany, resulting in the same conclusion.

Unsurprisingly, both effective average tax rates are highly correlated (0.84 average correlation) but the variance of τ^a_{nop} is more than twice than that of τ^a_{gop}. The extra source of variability is likely to come from the changes in depreciation rates since this is the only dif-

[4] Gross operating surplus is equal to gross value added minus labor cost, subsidies and other taxes on production. Labor costs include wages, salaries and employer's social contributions (employee contribution to pension funds, etc). Net operating surpluses are found in national accounts instead of net operating *profits* (pre tax) which are found in companies balance sheets. The main difference between both is the depreciation of capital: consumption of fixed capital for national accounts (economic depreciation) versus amortization for the balance sheets (fiscal depreciation). Balance sheet profits also include appreciation of inventory while operating surpluses don't.

[5] See Friedman (1940)

ference between NOP and GOP. On the other hand, statutory tax rates have a much lower variability since once a rate is set it maintains that value for an average of 3 years.

To avoid that countries idiosyncratic depreciation schemes make the estimated EATR non-comparable across countries, I use GOP as the denominator when computing the EATR. Using gross operating profits has the disadvantage of underestimating the tax burden on corporate profits, but improves comparability of the estimated tax rates across the countries which is a key property of the EATR estimated from firm level data in the next section.

3.3 EATR using firm level data

Using the concept of the previous section I proceed to calculate the effective average tax rates using balance sheet data from European companies. By using this particular data it is possible to compute EATRs for different economic sectors and business size; moreover, companies balance sheets are harmonized which allows for meaningful comparisons of the obtained EATRs across countries. A brief description of the database used is provided in the next subsection.

3.3.1 The new BACH database

In 1985 the General Directorate of Economic and Financial Affairs of the European Commission embarked in the mission of creating reliable data for analysis of European companies' financial structure, independently of where they operate. To achieve this goal, the Banks for the Accounts of Companies Harmonized (BACH) database was created.[6]

The BACH database contains relatively harmonized balance sheets for non-financial companies of 11 European countries. The data is aggregated at the sector level (using NACE rev2

[6] BACH database: ECCBSO, Banco de España, Banco de Portugal, Banque de France, Czech National Bank (in cooperation with the Czech Statistical Office), National Bank of Belgium, National Bank of Poland (calculations of National Bank of Poland on the basis of the data from the Central Statistical Office), Centraal Bureau voor de Statistiek (the Netherlands), Centrale dei Bilanci - Cerved srl, Deutsche Bundesbank, Statec Luxembourg, National Bank of Slovakia (calculations based on data from the Ministry of Finance), Oesterreichische Nationalbank

classification, see table 3.3) and broken into company sizes.[7] Aggregation of the data is done using weighted averages (based on firms turnover) but quantile values are also provided when the amount of firms ensures confidentiality.[8] The weighted average values have a bias towards large firms but using the median values, when available, avoids this problem.

Table 3.2 presents the countries and years included in the latest BACH database as well as the maximum coverage rate of the surveys with respect to firms, employees and, turnover. The database covers 11 countries for the years 2000 to 2014 with Netherlands providing the least years of coverage (2009 to 2014). The surveys cover a respectable percent of operating firms with Belgium and Portugal covering almost all of them. The Czech Republic, Germany and France survey less than 30 % percent of firms but these account for most of the revenue generated and/or the number of employees. Hence, the data for Germany and France might suffer from oversampling of larger firms.

3.3.2 Effective Average Corporate Tax inferred from BACH

The breadth of data found in BACH allows for the computation of different measure of EATRs; however, I choose tax on profits over gross operating profit, thereby maintaining consistency with the EATRs presented in the previous section.[9] Comparability is essential to explore difference between EATRs obtained from firm level data and those from national accounts. On one hand, small differences between the effective rates indicates that the MRT method using macro level data is preferable because of the accessibility of data. On the other hand, large and consistent differences between the effective rates would suggest that EATRs inferred from aggregated data provide a misleading picture of the corporate tax envi-

[7]The BACH database classifies firms by net turnover amounts and not by number of employees. A small firm in the context of BACH is a firm whose turnover is less than 10 million €, while a large firm is defined as firms with turnovers above 50 million €. Because of this definition weighted averages based on turnovers, the aggregate figures are bias toward high grossing firms and industries.

[8]The minimum number of firms for the release of quartile data is 6 for all countries except Germany which requires a minimum of 12 firms. The Czech Republic doesn't report quantile values.

[9] I also present tables and results for the ratio that uses turnover as the denominator. This ratio was used as a check because of concerns of the variability of profits during the Great Recession. Results and conclusions using the ratio with turnover aren't much different but important differences are stated in the main body of the paper.

ronment.[10]

Unlike previous studies, I also compute the effective rates using data of the *median* firm, instead of only relying in the aggregated data through weighted averages, with the goal of reducing bias towards larger firms. The trade off of using quantile data is an increase in missing observations due to the confidentiality restrictions. This issue is further exacerbated when trying to compute effective tax rates by firm size, which are the key variables necessary to answer if larger firms are paying lower taxes relative to other firms. The EATR using quantile data is denoted by τ_q and the EATR using weighted averages is denoted by τ_{wa}.

When taxes paid and/or GOP are negative it can result in a misleading sign of the ratios τ_{wa}, τ_q. The following table presents the number of cases in the dataset that have to be addressed:

		Tax paid	
		+	-
GOP	+	✓	✓
	-	94 (7)	2 (1)

Number of cases that for which the sign of the EATRs isn't directly interpretable. The values in parentheses are for quantile data.

When taxes paid and gross operating profit are negative it produces a positive EATR that could be misinterpreted as a positive tax rate. Since the company received subsidies (negative taxes), I keep this observations and assume that the rate of subsidy is equal to the tax rate charged on positive profits; furthermore, this issue appears in only 2 out of 12504 observations, for the weighted average data, and 1 out of 11427 for the median firm value data.[11]

The next problem is less straightforward to interpret and occurs when a positive tax is assessed in negative GOP. The resulting EATR is negative which is misinterpreted as an effec-

[10] Nicodeme (2001) also uses gross operating profits to calculate effective tax rates for corporations using an older version of the BACH database. However, he is more concerned about the stability of net operating profits rather than comparability with effective rates obtained from national accounts.

[11] There are less observations in the dataset for the quantile data since the Czech Republic doesn't report this type of data

tive subsidy to the firms even though they paid taxes. The number of observations presenting this problem is relative low at 94, for the case of weighted average aggregate data, and only 7 cases for quantile data. From this problematic observations the “arts and entertainment" sector (R in NACE classification) account for 54 (1) observations. For this reason I eliminate sector R from all countries and assign a missing value for the remaining problematic observations instead of assigning an arbitrary positive value for τ_{wa}, τ_q.

After solving the issues mentioned I calculate different measures of effective corporate tax rates and present the summary statistics of the rates for the overall economy and all firms in Table 3.5. The first property of the average effective tax rate (across time), regardless of denominator used, is that they are significantly lower than the statutory tax rate; a similar property of the effective rates constructed with MRT method. Furthermore, τ_q is statistically different and smaller than τ_{wa} in all countries; Figure 3.4 shows that this is consistent across time and regardless of firm size. The time series plot also shows that the trends for the overall effective corporate tax rate aren't equal across the European countries in the sample, which suggests that the race to the bottom observed in the statutory tax rates isn't translating into the effective rate. As expected, the effective rates using turnover as denominator for the ratio are much lower than τ_{wa}, τ_q.

3.3.3 Differences between MRT, τ_w^a and τ_q^a

The EATR based on national accounts (MRT) differ in their levels substantially across the years with those obtained from BACH, but the sign of the difference is not consistent across the countries as seen in Figure 3.3. This figure presents the estimated rates for MRT and τ_{wa}, τ_q (all sectors, all firms size) showing that there is no consistent pattern for the difference across these rates; for some cases τ_{wa}, τ_q behaves as an envelope to MRT but for others they are below/above MRT, making the national account rates a lower/upper bound on the rates obtained from firm level data.

To complement the analysis I compute the difference between τ_{MRT} and τ_{wa}^a (Δ_1), as well as τ_{MRT} and τ_q^a (Δ_2), with descriptive statistics shown in Table 3.4. On average τ_{MRT} is higher than both EATRs from BACH in Belgium, Portugal and Spain; below both measures only in Italy and in between both measures for the rest of countries. Looking at Δ_1, we can observe that for Italy and Germany the EATR from the national accounts tends to underestimate τ_{wa}^a by around 9%, close to a third of the average statutory tax rate level for the period. The rest of countries have average absolute differences below 4% and paired t-tests reject the null that $\tau_{wa} = MRT$ for all countries but Belgium. Turning to Δ_2, we observe that absolute differences are over 5% and most countries have on average τ_q^a below τ_{MRT}, this property doesn't hold when using τ_{wa}^a. Paired t-tests confirm that there is enough evidence to support the hypotheses that $\tau_q^a < \tau_{MRT}$ for all countries but Italy.

3.3.4 Effective Tax Rates: all economy versus sectors

Another advantage of using BACH is that harmonization allows for direct comparisons of the EATRs across the countries, hence I am not restricted to describing only the intra-country patterns. The inferred BACH effective tax rates show that there are differences across sectors, not only at levels but also trends, suggesting that governments have tax policies that allocate the tax burden unevenly across sectors.

Figures 3.5 and 3.6 provide the times series of τ_{wa}, τ_q for the agricultural, manufacturing, construction and, wholesale sectors. From these graphs we can clearly see that the agricultural sector has the lowest effective tax rate for all countries, but Slovakia; however, the levels are very different across the countries with a negative time trend, except for Portugal which shows an upward trend. Another commonality across countries happens in the construction and wholesale sectors which is tax at a higher effective tax rate than the overall economy in most countries. However, unlike the agricultural sector, there is no specific sector that is consistently tax the most across the set of European countries in the data.

A surprising result is that there is no evidence of a “race to the bottom" for the manufacturing sector, which is often argued as the one that is more prone for competition for FDI.

For most countries, the EATR for manufacturing is pretty stable over this time period, with Austria being the only case in which an upward trend is observed when using median firm data.

3.4 Taxation discrimination by size

A topic that often shows in taxation policy debates is whether large firms pay lower taxes than smaller firms. To test this claim, I compare the mean differences of τ^a_{wa}, τ^a_q by business size using a one tail Welch's t-test for unpaired data with unequal variance. Table 3.6 shows the results for the null hypothesis that small business paid less taxes than large firms, for both τ^a_{wm} and τ^a_q, while table 3.7 contains the results for the null that small business face a lower effective tax rate than medium size businesses.

At the whole economy level, there is enough evidence that large firms paid lower effective tax rates than smaller firms in half of the countries (Belgium, Spain, France, Italy and Portugal), a rather unexpected result. When τ_q is used we can only reject the null for Belgium, which also rejected the null with τ_{wa}.

Conducting the analysis at by sectors provides a clearer picture that contrasts the results obtained at the economy wide level. One interesting example is that of Germany and Austria, which failed to reject the null at the economy wide level, yet close to 40% of their sectors show that large firms had lower effective tax rates than small firms. For countries that rejected the null at the economy wide level, we see that Belgium and Italy provide advantageous tax environments for larger firms in most of their sectors.

Most countries provide favorable tax conditions for large business operating in the I.T, technology and, service sectors. Specifically, all countries provide evidence to reject that smaller firms are paying lower taxes in the “Administrative and support service" sector, followed closely by the I.T and scientific sectors. On the contrary, the mining sector was the least favorable to larger firms. These observations suggest that governments are trading tax revenues for technology and shifting some of that tax burden to extractive sectors (mining and energy).

Finally, I carry the same analysis but for the null hypothesis that smaller firms have an effective tax rate lower than the medium firm. Surprisingly, there is only evidence for Austria, Italy and Portugal that medium firms are paying lower taxes than smaller firms. Combining this result with those for large firms suggests that Italy and Portugal have a linear negative relationship between effective taxes and size; however, the rest of countries seem to only give favorable tax environments for the very large firms. Nonetheless, there is some consistency regarding the technology and service sectors which show a favorable tax environment for the medium firm in most countries, but not as consistent as it was for the case of larger firms.

3.5 Conclusions

Balance sheet data for companies in 11 European countries provides evidence that governments tax larger companies at lower rate in certain economic sectors, but in the overall economy there is no evidence of this behavior in *all* countries. At the economy wide level I find that larger companies are taxed effectively lower in 5 countries; however, the story changes when the analysis is done at the sector level, where I find evidence in several sectors of favorable taxation of larger companies in all countries. This suggests that government use discriminatory tax policies based not solely company's size but also on the economic sector.

Consistently across countries, the technology and service sectors foster tax advantageous environments for large firms. Thus there seems that a common policy of the European countries analyzed is to trade tax revenue for technological improvements; perhaps expecting spillovers effects that would increase productivity for all.

Surprisingly, there is a lack of evidence to support that larger companies faced lower effective tax rates in the manufacturing sector. This results runs contrary to expectations since we often hear governments concerns of losing manufacturing jobs to other countries via FDI; thus we would expect the manufacturing sector to be the *one* with a favorable tax environment for large firms across countries. However, the data doesn't support such view and coupled with the tax advantages for large firms in the technology and service sectors, there seems that the governments of these 11 European countries bet on technological improvements to foster jobs at home.

Finally, I showed that the choice of measure for corporate taxes is critical as each measure paints a different picture of the tax environment. The statutory corporate tax rate showed that countries engaged in a competition that lead to significant reductions in corporate tax rates through the past decades. However, this dramatic decline in statutory rates is significantly dampen (or erased for some countries) when effective corporate tax rates, from national account data, are used. Moreover, not all effective tax rates are alike as demonstrated by the statistical significant differences of the effective rates obtained from firm level data and those calculate from national account data. The effective tax rates from firm level data also showed that time trends in certain sectors are not similar to that of the whole economy; furthermore, we can observe sectors whose effective tax rates move in opposite directions across time.

Table 3.1: Summary Statistics for the two different EATRs, data restricted to 1990-2011 to ensure comparability.

	Means			Std. Deviation		Correlation	
	τ	τ^a_{nop}	τ^a_{gop}	τ^a_{nop}	τ^a_{gop}	$\rho_{n,g}$	$\rho_{s,g}$
Austria	32.06	17.41	9.31	2.51	1.36	0.97	0.19
Australia	33.05	32.99	21.01	5.19	3.60	0.97	-0.45
Belgium	37.52	24.92	12.92	6.19	2.56	0.98	-0.12
Canada	35.02	19.40	13.00	3.13	2.15	0.98	-0.21
Finland	28.64	22.09	12.42	8.68	4.43	0.66	0.09
France	35.57	26.84	14.71	5.66	2.94	0.95	0.33
Great Britain	30.73	21.24	14.01	3.53	2.53	0.92	-0.36
Germany	**45.70**	11.06	6.74	2.36	1.45	0.95	0.19
Italy	41.91	23.93	14.75	3.84	2.18	0.90	0.46
Japan	44.41	**37.74**	17.61	8.38	4.41	0.86	0.81
Netherlands	32.35	21.58	13.65	4.10	2.50	0.98	0.64
Norway	30.07	32.00	**22.10**	6.77	7.10	0.98	-0.39
Poland	28.65	30.92	16.04	16.86	6.68	0.96	0.90
Portugal	33.43	26.68	14.82	2.97	1.72	0.91	-0.15
Spain	33.98	24.80	14.33	9.35	4.96	0.99	0.30
Sweden	28.81	23.70	13.81	4.42	2.30	0.89	-0.49
Switzerland	30.15	21.02	10.25	4.39	1.82	0.89	-0.60
United States	39.36	25.71	15.04	3.01	2.19	0.97	-0.08
Overall(Panel)	34.55	24.73	14.36	8.72	5.02	0.84	-0.01

Table 3.2: Coverage of the BACH database by different measures.

Country	Years	% total firms	% total turnover	% employees
Austria	2000-13	53.88		
Belgium	2000-14	99.6		99.67
Czech Rep.	2002-13	15.08		
Germany	2000-14	10.62	77.41	
Spain	2000-14	38.27		66.62
France	2000-14	30.08	81.58	78.19
Italy	2000-14	100	100	
Netherlands	2009-14	69.17		
Poland	2005-14	(*)	(*)	(*)
Portugal	2000-14	96.94	99.52	99.28
Slovakia	2005-13	63.74	92	81

(*)Poland provides exhaustive coverage

Table 3.3: Sectors in BACH database

NACE Code	Description
Z0	Total NACE (includes M701, but excludes K642)
Zc	Total NACE (without K642 and M701)
A	Agriculture, forestry and fishing
B	Mining and quarrying
C	Manufacturing
D	Electricity, gas, steam and air conditioning supply
E	Water supply, sewerage, waste management and remediation act.
F	Construction
G	Wholesale and retail trade; repair; repair of motor vehicles and motorcycles
H	Transportation and storage
I	Accommodation and food service activities
J	Information and communication
K642	Activities of holding companies
L	Real estate activities
M	Professional, scientific and technical activities
Mc	Total M (without M701)
M701	Activities of head offices
M702	Management consultancy activities
N	Administrative and support service activities
P	Education
Q	Human health and social work services
R	Arts, entertainment and recreation
S	Other service activities

Table 3.4: Summary Statistics for τ_{MTR}, τ^a_{wa} and τ^a_q

Country	**Stats**	τ_{MTR}	τ^a_{wa}	τ^a_q	Δ_1	Δ_2	Δ_3
BEL	min	11.34	12.20	10.80	-0.87	-1.25	-1.45
	mean	13.96	13.54	11.79	0.42	2.18	1.76
	max	15.65	14.66	13.65	1.68	3.91	3.15
	σ	1.52	0.93	0.72	0.86	1.88	1.44
FRA	min	9.18	15.95	7.21	-6.77	1.93	6.28
	mean	15.91	19.37	9.86	-3.46	6.05	9.52
	max	19.99	21.29	13.90	-0.59	8.38	11.16
	σ	2.83	1.74	2.12	1.87	1.84	1.49
GER	min	2.76	12.81	3.15	-13.15	-0.68	8.88
	mean	6.55	15.03	4.32	-8.48	2.23	10.71
	max	8.58	17.21	5.79	-6.07	5.13	12.47
	σ	1.82	1.25	0.87	1.76	1.44	1.06
ITA	min	11.75	18.83	18.79	-15.97	-13.30	-1.26
	mean	13.76	23.11	22.00	-9.35	-8.24	1.11
	max	16.76	27.96	27.43	-2.56	-2.89	3.63
	σ	1.79	3.16	2.68	3.80	3.42	1.64
POL	min	8.50	11.76	1.52	-3.79	6.56	8.58
	mean	10.86	12.94	2.79	-2.13	7.87	10.15
	max	12.42	13.78	4.94	0.66	9.24	11.07
	σ	1.51	0.80	1.17	1.55	0.97	1.02
POR	min	13.53	10.99	4.27	-0.23	7.36	5.50
	mean	15.11	12.41	5.71	2.69	9.37	6.70
	max	17.76	14.24	7.19	6.64	12.24	7.88
	σ	1.63	1.00	0.98	1.95	1.66	0.86
SPA	min	8.00	6.83	0.00	-1.39	7.78	0.88
	mean	15.75	11.86	4.44	3.89	11.31	7.42
	max	24.79	18.03	7.06	9.19	19.58	11.91
	σ	5.13	3.75	2.64	3.05	3.68	2.97

Table 3.5: Summary statistics for the effective corporate tax rates from BACH database. The variables τ represented ratios using gross operating profit while $\tilde{\tau}$ represent ratios that used turnover.

	Obs	Mean	σ	Min	Max		Obs	Mean	σ	Min	Max
Austria						**Italy**					
τ_{wm}	1178	10.38	4.26	0	39.82	τ_{wm}	1095	25.7	8.11	-0.28	56.45
τ_q	1157	4.46	3.02	0	26.38	τ_q	1104	19.58	7.29	4.72	95.65
$\tilde{\tau}_{wm}$	1180	1.24	0.77	0	8.34	$\tilde{\tau}_{wm}$	1103	2.59	1.52	-0.68	25.08
$\tilde{\tau}_q$	1157	0.47	0.41	0	3.73	$\tilde{\tau}_q$	1104	1.73	0.88	0.19	7.69
Belgium						**Netherlands**					
τ_{wm}	1201	13.75	5.56	0	33.54	τ_{wm}	428	13.86	4.78	1.18	31.56
τ_q	1189	10.23	5.7	0.1	45.94	τ_q	432	3.71	5.19	0	27.7
$\tilde{\tau}_{wm}$	1210	1.92	1.52	0	21.33	$\tilde{\tau}_{wm}$	430	1.5	1.05	0.09	10.63
$\tilde{\tau}_q$	1189	1.6	1.57	0.02	8.7	$\tilde{\tau}_q$	432	0.31	0.63	0	4.16
Czech Rep.						**Poland**					
τ_{wm}	1013	11.24	6.22	-15.32	36.11	τ_{wm}	837	9.07	3.38	-1.9	22.16
τ_q						τ_q	811	5.09	4.49	0	24.4
$\tilde{\tau}_{wm}$	1017	1.38	1.32	-6.4	18	$\tilde{\tau}_{wm}$	844	1.16	0.66	-1.02	6.42
$\tilde{\tau}_q$	51	0.36	0.21	0	0.7	$\tilde{\tau}_q$	811	0.46	0.46	0	3.6
Germany						**Portugal**					
τ_{wm}	1231	12.63	6.48	-3.41	44.69	τ_{wm}	1091	12.5	6.63	-28.03	54.95
τ_q	1265	4.28	3.54	0	15.62	τ_q	1064	6.46	3.9	0	46.51
$\tilde{\tau}_{wm}$	1265	1.47	2.21	-1.31	28.21	$\tilde{\tau}_{wm}$	1097	1.58	1.45	-19.46	10.61
$\tilde{\tau}_q$	1265	0.35	0.41	0	2.99	$\tilde{\tau}_q$	1064	0.7	0.76	0	7.57
Spain						**Slovakia**					
$\tilde{\tau}_{wm}$	1190	9.72	17.1	-175.7	102.38	τ_{wm}	624	13.72	7.32	-6.42	54.74
$\tilde{\tau}_q$	1176	5.15	4.82	-24.1	55.51	τ_q	663	4.93	6.59	0	73.68
$\tilde{\tau}_{wm}$	1196	1.25	2.79	-37.53	25.14	$\tilde{\tau}_{wm}$	641	1.36	0.99	-1.04	9.29
$\tilde{\tau}_q$	1176	0.48	0.82	-12.36	7.58	$\tilde{\tau}_q$	663	0.38	0.53	0	4.56
France											
τ_{wm}	1278	18.72	6.49	-6.85	45.21						
τ_q	1287	9.23	5.84	0	36.93						
$\tilde{\tau}_{wm}$	1287	1.89	1.31	-1.8	12.9						
$\tilde{\tau}_q$	1287	0.72	0.54	0	3.52						

Table 3.6: Welch's t-test with null hypothesis: $H_0 : \tau_{small} < \tau_{large}$. Top rows are for aggregated data via weighted averages and bottom rows are for data for the median firm.

	All Sectors	A	B	C	D	E	F	G	H	I	J	L	Mc	N	Q
Austria	x	x	x	x	x	x	$\checkmark^{3}$	x	x	x	$\checkmark^{3}$	$\checkmark^{3}$	$\checkmark^{2}$	$\checkmark^{3}$	$\checkmark^{1}$
	x		x	x	x	x	$\checkmark^{3}$	x	x	x	$\checkmark^{3}$	$\checkmark^{3}$	x	x	$\checkmark^{3}$
Belgium	$\checkmark^{3}$	x	$\checkmark^{3}$	$\checkmark^{3}$	x	$\checkmark^{3}$	x	x	x	x	$\checkmark^{3}$	$\checkmark^{2}$	$\checkmark^{3}$	$\checkmark^{3}$	$\checkmark^{3}$
	$\checkmark^{3}$			x	$\checkmark^{2}$	$\checkmark^{3}$	x	x	x	x	$\checkmark^{2}$		x	x	
Czech Rep.	x	x	x	x	x	x	x	x	x	x	$\checkmark^{3}$	x	x	$\checkmark^{3}$	$\checkmark^{3}$
Germany	x		x	x	x	$\checkmark^{3}$	x	x	$\checkmark^{3}$	x	$\checkmark^{3}$	x	$\checkmark^{3}$	$\checkmark^{3}$	$\checkmark^{3}$
	x		x	$\checkmark^{3}$	x	$\checkmark^{3}$	x	x	$\checkmark^{3}$	x	$\checkmark^{3}$	x	$\checkmark^{2}$	$\checkmark^{3}$	x
Spain	$\checkmark^{2}$	$\checkmark^{2}$	x	x	x	$\checkmark^{3}$	x	x	x	$\checkmark^{2}$	x	x	$\checkmark^{2}$	$\checkmark^{1}$	$\checkmark^{2}$
	x	x	x	x	x	x	x	x	x	x	x	$\checkmark^{2}$	x	x	x
France	$\checkmark^{3}$	x	x	x	x	x	x	x	x	$\checkmark^{3}$	x	$\checkmark^{2}$	$\checkmark^{3}$	$\checkmark^{3}$	$\checkmark^{3}$
	x	x	x	x	x	x	x	x	x	x	x	$\checkmark^{2}$	x	x	x
Italy	$\checkmark^{3}$	$\checkmark^{2}$	x	$\checkmark^{3}$	x	x	$\checkmark^{2}$	$\checkmark^{3}$	$\checkmark^{3}$	x	$\checkmark^{3}$	x	$\checkmark^{3}$	$\checkmark^{3}$	
	x	x	x	$\checkmark^{1}$	x	x	x	x	x	x	$\checkmark^{2}$	x	x	x	
Poland	x	x	x	x	x	x	x	x	x	x	$\checkmark^{3}$	x	x	$\checkmark^{2}$	$\checkmark^{3}$
	x	x	x	x	x	x	x	x	x		x	x	x	x	
Portugal	$\checkmark^{2}$	$\checkmark^{1}$	x	x	x	x	x	$\checkmark^{3}$	x	x	$\checkmark^{3}$	x	$\checkmark^{3}$	$\checkmark^{3}$	
	x			x	x	x	x	x	x	x	x	x	x	x	x

Notes: Empty cells if no data available for one of the groups being tested
[1] Null rejected at significance level of 0.10
[2] Null rejected at significance level of 0.05
[3] Null rejected at significance level of 0.01

Table 3.7: Welch's t-test with null hypothesis: $H_0 : \tau_{small} < \tau_{medium}$. Top rows are for aggregated data via weighted averages and bottom rows are for data for the median firm.

	All Sectors	A	B	C	D	E	F	G	H	I	J	L	Mc	N	P	Q
Austria	$\checkmark^{3}$	x	x	x	x	$\checkmark^{3}$	$\checkmark^{3}$	x	x	x	$\checkmark^{3}$	$\checkmark^{3}$	x	$\checkmark^{3}$	$\checkmark^{3}$	$\checkmark^{2}$
	$\checkmark^{2}$	x	x	x	x	x	$\checkmark^{2}$	x	x	x	$\checkmark^{3}$	$\checkmark^{3}$	$\checkmark^{2}$	x	$\checkmark^{1}$	$\checkmark^{3}$
Belgium	x	x	$\checkmark^{3}$	x	$\checkmark^{3}$	$\checkmark^{3}$	x	x	x	x	$\checkmark^{2}$	$\checkmark^{2}$	$\checkmark^{3}$	$\checkmark^{3}$		x
	x	x	x	x	$\checkmark^{2}$	$\checkmark^{3}$	x	x	x	x	x	$\checkmark^{3}$	x	x		x
Czech Rep.	x	x	$\checkmark^{1}$	$\checkmark^{1}$	x	$\checkmark^{3}$	x	x	x	$\checkmark^{2}$	$\checkmark^{3}$	$\checkmark^{1}$	x	$\checkmark^{3}$	$\checkmark^{3}$	$\checkmark^{3}$
Germany	x	x	x	x	x	$\checkmark^{3}$	x	x	x	x	x	$\checkmark^{3}$	$\checkmark^{2}$	$\checkmark^{3}$	$\checkmark^{2}$	$\checkmark^{3}$
	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Spain	x	x	x	x	x	$\checkmark^{2}$	x	x	x	$\checkmark^{2}$	x	$\checkmark^{3}$	$\checkmark^{1}$	x	x	x
	x	x	x	x	x	$\checkmark^{1}$	x	x	x	x	x	$\checkmark^{1}$	x	x	x	x
France	x	x	x	x	x	x	x	x	x	$\checkmark^{2}$	x	$\checkmark^{3}$	$\checkmark^{2}$	x	x	$\checkmark^{3}$
	x	x	x	x	x	x	x	x	x	$\checkmark^{3}$	x	$\checkmark^{3}$	x	x	x	$\checkmark^{3}$
Italy	$\checkmark^{3}$	$\checkmark^{3}$	x	$\checkmark^{3}$	x	$\checkmark^{3}$	x	$\checkmark^{2}$	$\checkmark^{3}$	x	$\checkmark^{3}$	x	x	$\checkmark^{3}$		
	x	$\checkmark^{1}$	x	$\checkmark^{1}$	x	x	x	x	x	x	x	x	x	x		
Poland	x	x	x	x	x	x	x	x	x	x	$\checkmark^{2}$	x	x	$\checkmark^{3}$	x	$\checkmark^{2}$
	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	$\checkmark^{2}$
Portugal	$\checkmark^{3}$	$\checkmark^{2}$	x	x	x	$\checkmark^{2}$	$\checkmark^{2}$	$\checkmark^{3}$	$\checkmark^{1}$	$\checkmark^{3}$	$\checkmark^{2}$	$\checkmark^{3}$	$\checkmark^{2}$	$\checkmark^{3}$	$\checkmark^{3}$	$\checkmark^{3}$
	x	x	x	x	x	$\checkmark^{1}$	x	x	x	x	x	x	x	x		$\checkmark^{3}$

Notes: Empty cells if no data available for one of the groups being tested
[1] Null rejected at significance level of 0.10
[2] Null rejected at significance level of 0.05
[3] Null rejected at significance level of 0.01

Figure 3.1: Statutory tax rates on corporate profit from 1979 - 2011

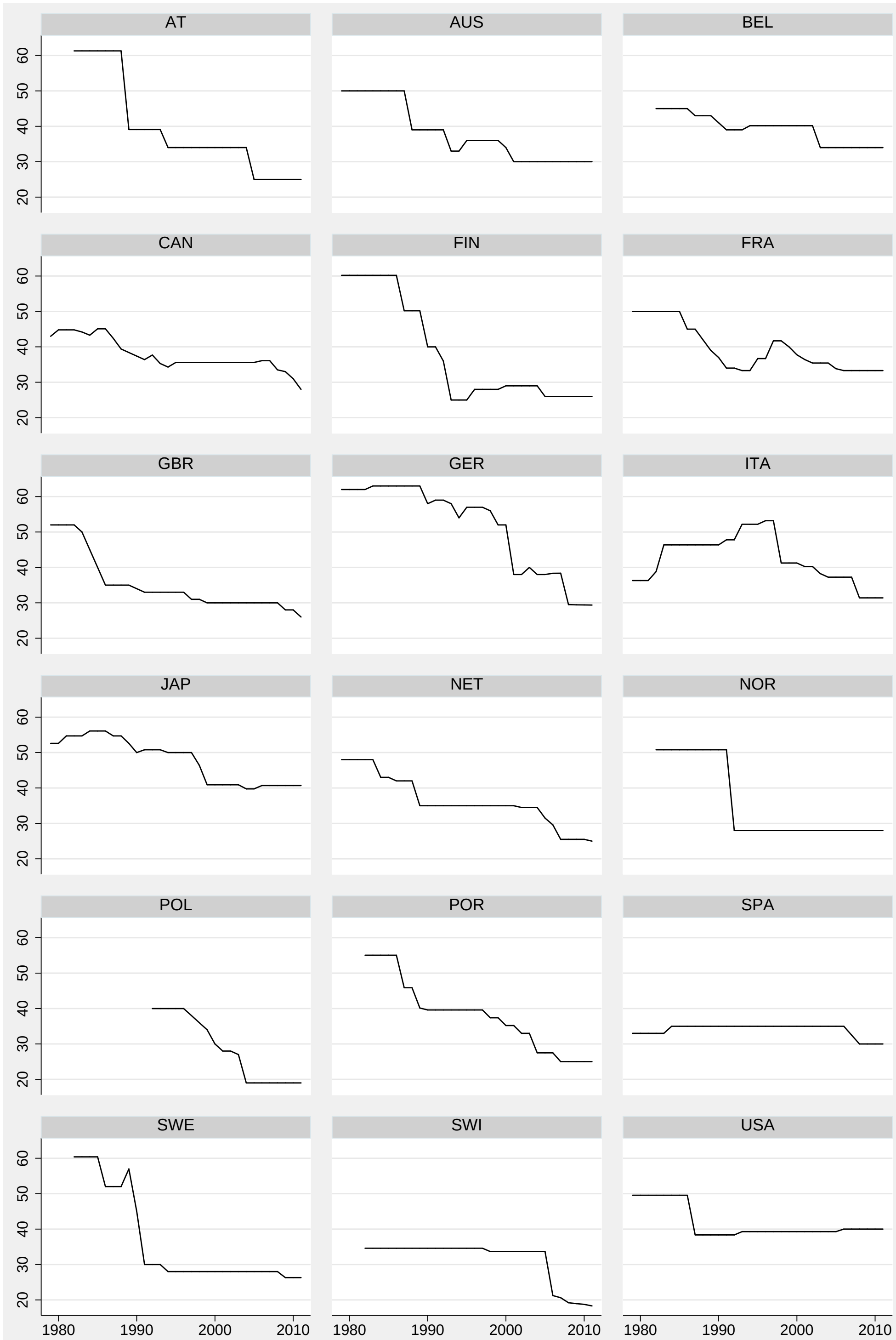


Figure 3.2: Effective Average Corporate Tax rates based on MTR. NOP is the ratio with net operating profit as denominator while GOP uses gross profit instead

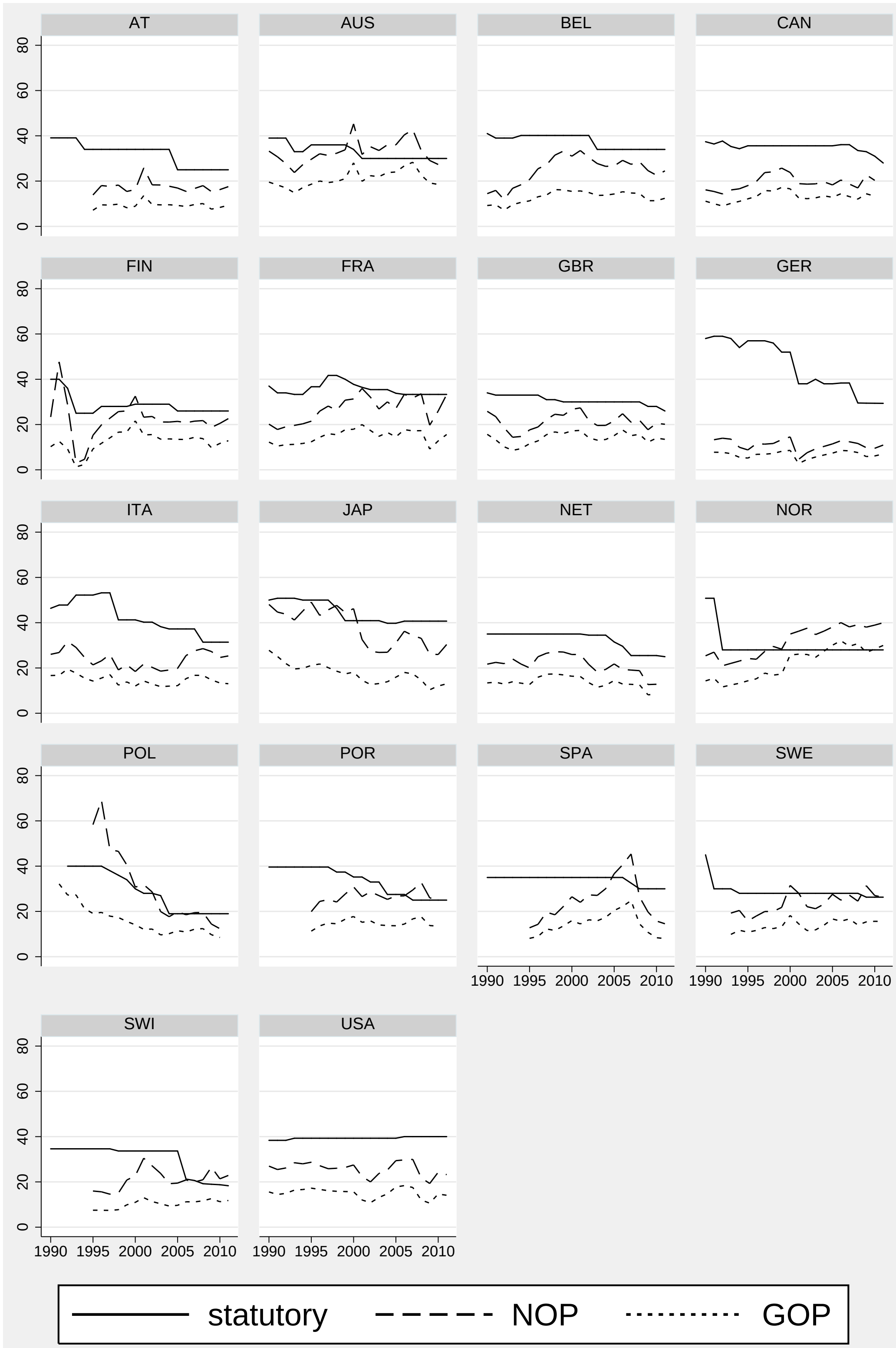


Figure 3.3: Time series plot for the different EATRs

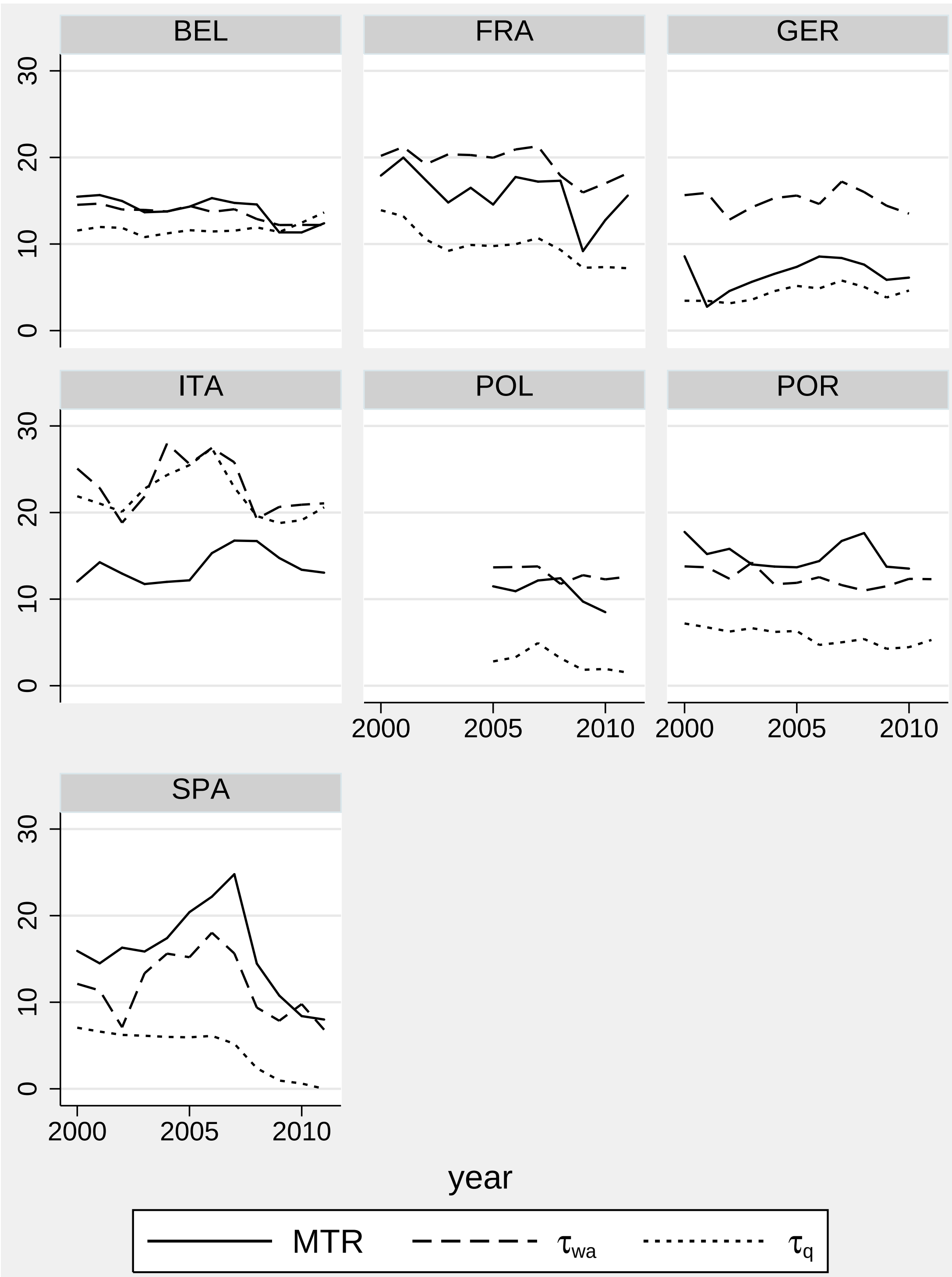


Figure 3.4: Effective Average Corporate Tax rates from BACH. The solid lines represent measure from weighted average values, while the slash line is for ratios obtained from quartile data

Figure 3.5: Effective average corporate tax rate of selected sectors. Estimates using weighted aggregated data.

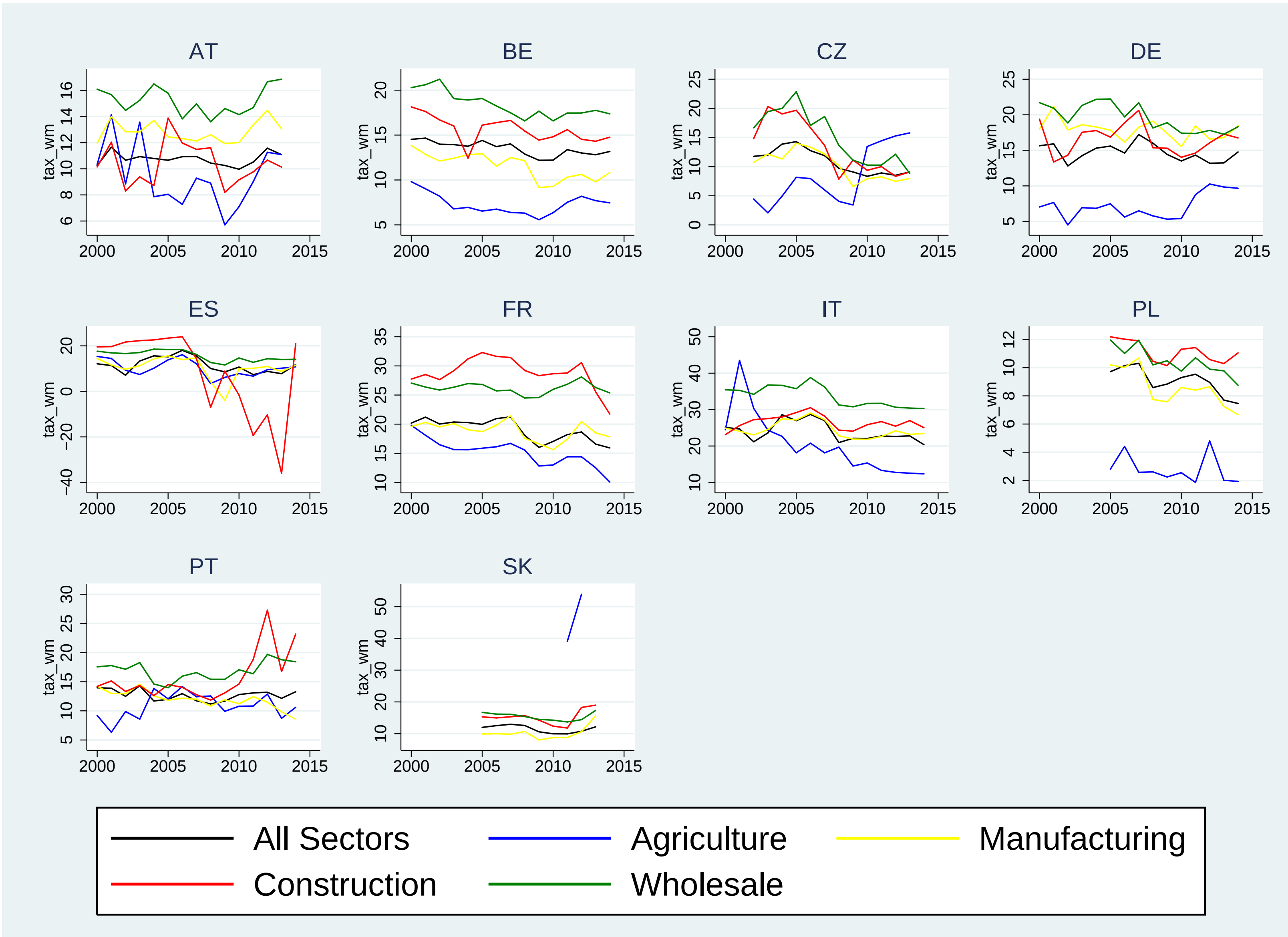


Figure 3.6: Effective average corporate tax rate of selected sectors. Estimates using data of the median firm

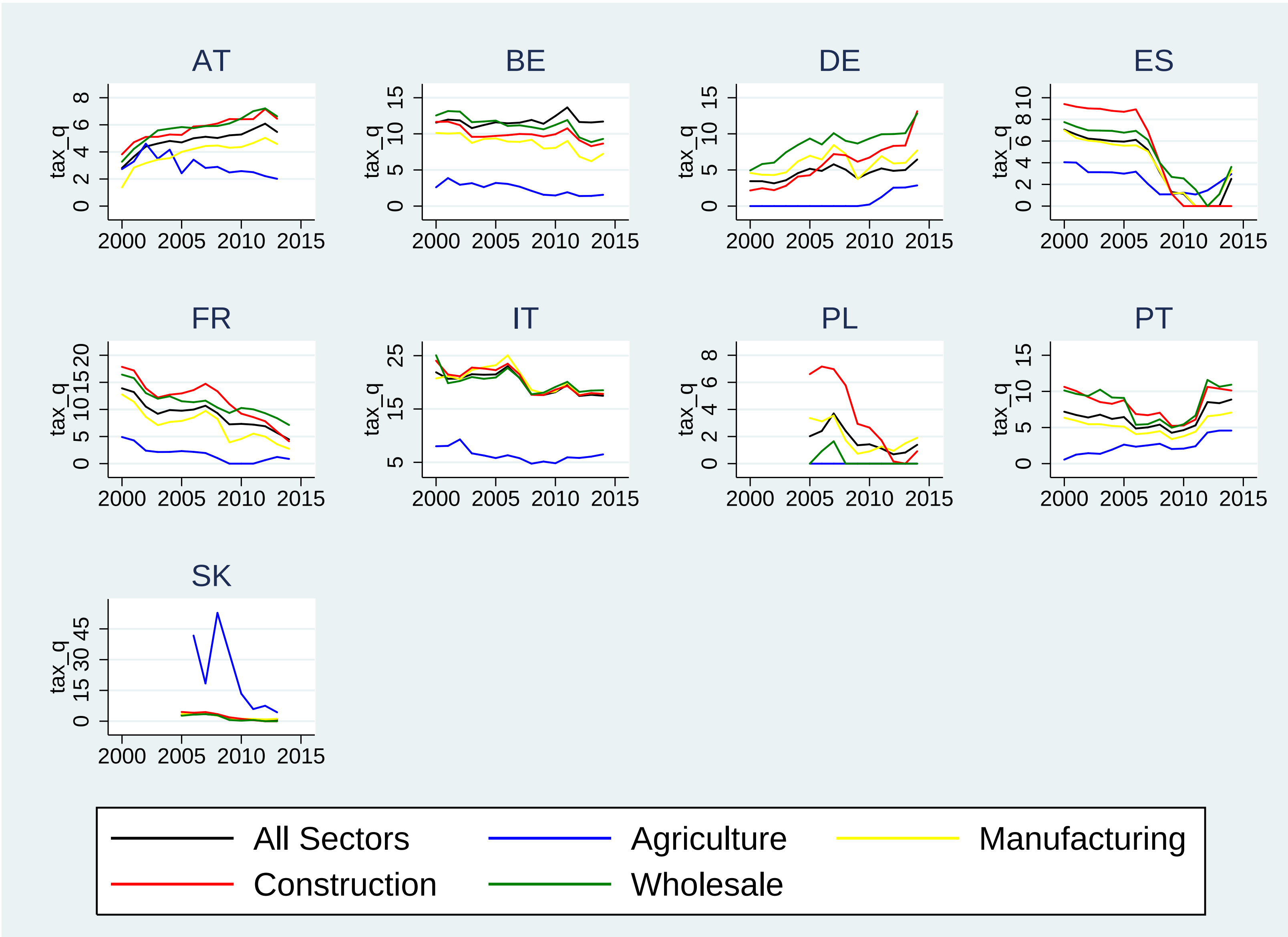
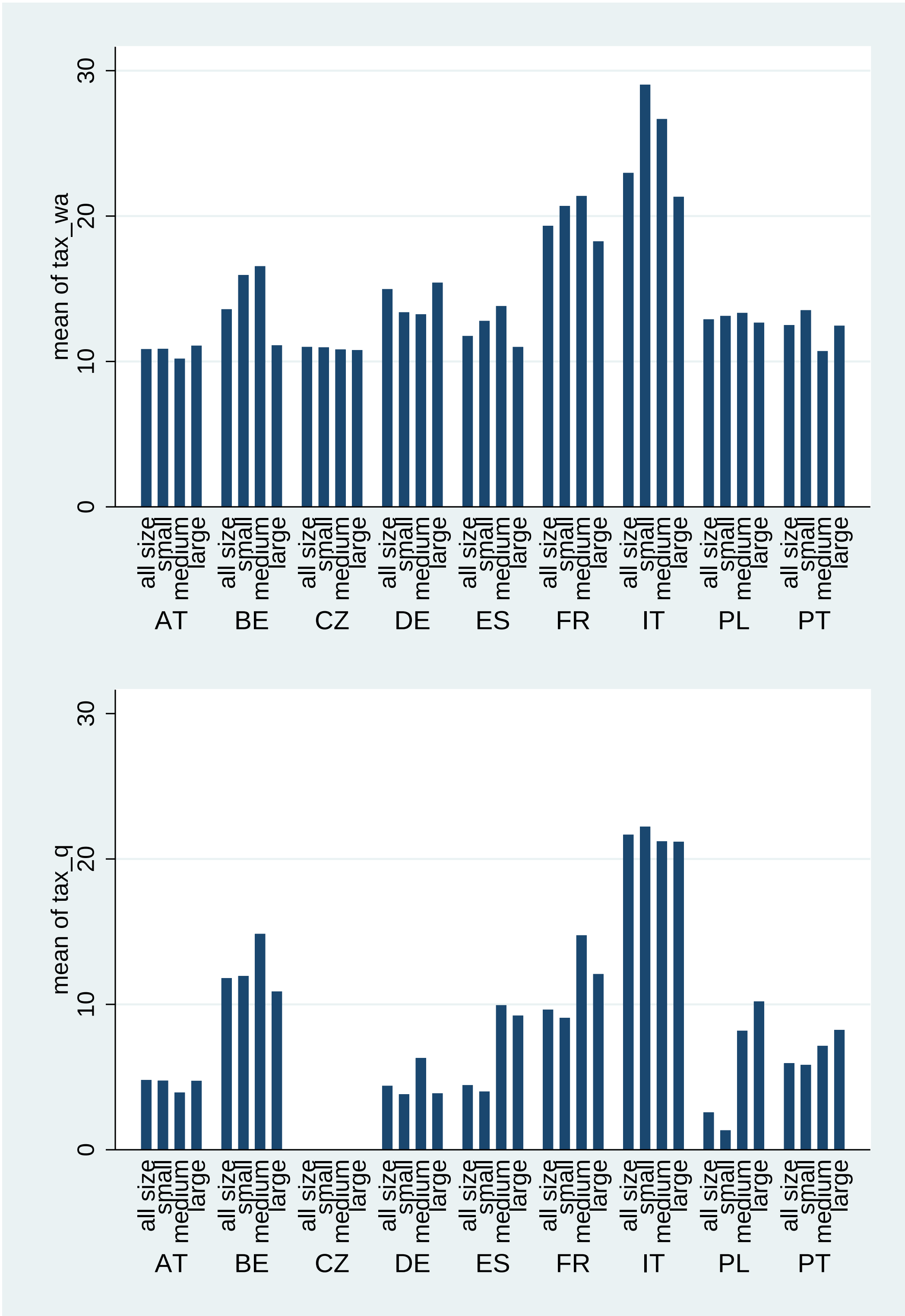


Figure 3.7: Mean across time for τ_{wa}^{a} and τ_{q}^{a}, subdivided by countries and firm sizes



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