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Economic integration and the optimal corporate tax structure with heterogeneous firms*

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Abstract

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Keywords: corporate tax reform, tax base broadening, trade liberalization

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1 Introduction

Corporate tax reform has been a core issue on the agenda of most countries over the last decades. The corporate tax reforms that have been enacted have, in most cases, combined a strong reduction in the statutory rate of corporate taxation with a broadening of the corporate tax base that has been achieved by a reduction of depreciation allowances. Devereux et al. (2002) show that this pattern describes most of the corporate tax reforms that have taken place in the European Union (EU) and the G7 countries since the early 1980s. Klemm and van Parys (2009) demonstrate that similar trends can be observed among a sample of over 40 developing countries in Latin America, the Caribbean and Africa.

The worldwide fall in statutory corporate tax rates has been the subject of many theoretical and empirical studies. Meanwhile there is strong empirical evidence that this fall can be attributed to increasing international capital mobility and rising international tax competition for this scarce factor.[1] In contrast, the simultaneous increase in the corporate tax base has received only limited attention, and its motivation is also far less clear. This is true, in particular, against the backdrop of expert recommendations, which suggest to move to a system of corporate taxation that is fully neutral with respect to investment decisions.[2] If these proposals were followed, they would imply a *narrowing* of the corporate tax base instead of the tax base broadening that has been observed in actual policy.

In this paper we link the optimal choice of the corporate tax base, and hence the optimal structure of corporate taxation, to the rise in international trade and increasing economic integration. For this purpose we develop a model of a small open economy which trades different varieties of a good produced under conditions of monopolistic competition with a large rest of the world.[3] Our model allows for cost heterogeneity

[1]For empirical evidence linking the fall in capital tax rates to measures of increased 'openness' of economies, see e.g. Slemrod (2004) and Winner (2005). An empirical analysis of the strategic interaction between capital tax rates in the OECD countries is given in Devereux et al. (2008).

[2]Thus the Meade Committee (1978) suggested a move to one of different versions of cash-flow taxation. Recently, Auerbach et al. (2010) have reviewed these conclusions and have instead proposed a switch to a destination-based system of pure rent taxation in the corporate sector.

[3]Broda and Weinstein (2006) document the increase in the number of traded varieties for the

of firms both in the small open economy and in the large rest of the world. In our benchmark model we abstract from a government revenue constraint. In this setting we show that it is optimal for the government of a small open economy to effectively subsidize capital inputs by granting a tax allowance for the costs of capital in excess of its true value. Economic integration, measured either by a reduction in the unit costs of shipping goods abroad or by a reduction in the fixed costs of serving an export market, reduces the optimal allowance for capital expenditures and increases the corporate tax base. This is because rising exports or imports weaken the link between capital subsidies and domestic consumption in the small country, thus decreasing the incentive for the government to subsidize the use of capital in the monopolistically competitive sector.

Firm heterogeneity influences the optimal choice of the corporate tax base in two different ways. On the one hand, capital subsidies are a more powerful instrument in the presence of heterogeneous firms, because they strengthen the reallocation of resources towards the most productive firms, raising average productivity and average profits in the economy. On the other hand, low-cost firms use less capital and hence benefit relatively less from capital allowances than their higher-cost competitors. Therefore, firm heterogeneity generally has an ambiguous effect on the optimal choice of the corporate tax base. In a final step we plan to test the robustness of our conclusions by incorporating a government revenue constraint that enforces positive tax receipts from the corporation tax (still to be done).

Our analysis can be linked to different strands in the literature. A first set of papers analyzes the optimal corporate tax structure in open economies in the absence of firm heterogeneity. Haufler and Schjelderup (2000) show that profit shifting by multinational firms gives competing governments an incentive to reduce corporate taxes and increase the corporate tax base when revenue from the corporate tax must remain fixed. Fuest and Hemmelgarn (2005) also find that income shifting through thin capitalization leads to optimal tax rate cut cum base broadening reforms by competing governments. In their model, however, the broadening of the tax base tends to restore production efficiency, as real investment is subsidized in the absence of income shifting. Finally, Egger

example of the United States. In 1972 the U.S. imported 7,731 goods from 9.7 countries on average, whereas it imported 16,390 goods from 15.8 countries on average in 2001. This corresponds to an increase in the total number of imported varieties (new goods, or goods from new sources) of 250%.

and Raff (2007) analyze, both theoretically and empirically, tax competition via tax rates and tax bases for an internationally mobile monopolist.

More recently, several papers have analyzed the effects of trade and tax policies in open economies with heterogeneous firms. Demidova and Rodriguez-Clare (2009) compare the effects of import tariffs and export subsidies on aggregate productivity and welfare in a small open economy. Chor (2009) analyzes the effects of a production subsidy in an economy that competes for foreign direct investment. Closer to our setting, Baldwin and Okubo (2009) study the effects of tax rate and tax base policies on the location of internationally mobile firms. They show that a tax rate cut cum base broadening reform that keeps the effective tax rate constant for the marginal firm always increases tax revenues. None of these papers, however, endogenizes optimal government policies. In contrast, Pflüger and Südekum (2009) derive optimal equilibrium subsidies to market entry in an open economy model of policy competition. Davies and Eckel (2010) analyze tax rate competition for internationally mobile, heterogeneous firms, whereas Krautheim and Schmidt-Eisenlohr (2011) derive Nash equilibrium tax rates when the location of firms is fixed but profits can be shifted between countries. These papers, however, do not focus on the optimal determination of the corporate tax base. Finally, Finke et al. (2010) perform a microsimulation analysis to evaluate the impact of the German 2008 corporate tax reform, which followed a pattern of tax rate cut cum base broadening, on heterogeneous firms. They show that firms with low productivity benefitted least from the reform, because they were hit most by the reduction of depreciation allowances.

The present paper is organized as follows. Section 2 describes the basic model employed in our analysis. Section 3 derives the government's optimal tax base policy. Section 4 analyzes the roles of economic integration and of firm heterogeneity in shaping the optimal corporate tax base. Section 5 extends the analysis, using simulation methods, to simultaneously determine optimal tax rate and tax base policies when the government faces a fixed revenue objective (still to be done). Section 6 concludes.

2 The model

Our analysis is based on a two-country model of a small open economy (country H) and a large rest of the world (country F). Our focus lies on the analysis of tax policy in the small home country, whose government chooses an optimal corporate tax structure taking as given the degree of economic integration. The two countries produce and trade two goods, a homogeneous numeraire good Y and a differentiated good X. Following Melitz (2003), firms in the differentiated sector X are heterogeneous with respect to their unit production costs.

Consumers in the small country H hold a total endowment of K units of capital, which is mobile internationally. Capital is used in the production of both goods. In the numeraire sector Y, $1/r$ units of capital are used to produce one unit of output. International trade in the numeraire good then fixes the return to capital at the rate r.[4] In the differentiated sector X, producing a new variety requires one unit of a fixed production factor, which we label 'entrepreneurial services'. In each country there is an exogenous number of potential entrants ('entrepreneurs') N^e, who are capable of producing the differentiated varieties in the X sector. We normalize $N^e = 1$. Each entrepreneur receives a residual profit that accrues in the country where production takes place, whereas the return to internationally mobile capital accrues in the country where the capital owner resides.

Similarly, there are N^{e*} potentially active heterogeneous firms in the foreign country. Since the home country H is small, policy changes in H do not affect the mass of active firms in F (cf. Flam and Helpman, 1987).[5] Active firms in each country can sell their output domestically and they can also choose to export, subject to both fixed costs of serving an export market and per unit (iceberg) transportation costs.

[4] As capital is internationally mobile, the two countries can effectively trade capital against good Y, implying that our model does not define in which country the numeraire good is produced. This, however, is immaterial for all of our results.

[5] This definition of small has been applied to the heterogenous firms literature by Demidova and Rodriguez-Clare (2009) among others.

2.1 Government

The government of country H imposes a corporation tax in the profit-making differentiated sector X. Taxable profits are subject to the corporate tax rate $t \in (0,1)$. The base of the corporation tax is given by the firm's revenue less a fixed share δ of total capital outlays. The deduction parameter δ is the crucial equilibrium choice variable in our analysis.

With respect to the disposal of government revenue we consider two different cases. In our benchmark case, all revenue from the corporation tax is redistributed to the consumers in country H as a lump-sum payment. If corporate tax revenue is negative, then the government budget can be balanced with a lump-sum tax. In this case we can thus simply set the tax rate t at an exogenous, positive level and focus on the optimal choice of the depreciation parameter δ. The advantage of this case is its analytical tractability. In a second step, a government revenue target will be introduced. In this setting we analyze optimal simultaneous adjustments of the corporate tax rate and the tax base in the process of economic integration, while keeping total revenues from the corporation tax constant. In this case, however, the model can no longer be solved analytically and we have to resort to numerical simulations.

2.2 Consumers

Consumers in H are homogeneous and value the two private goods X and Y. In our basic model, there is no public good (or alternatively there is one that enters the utility function in an additively separable fashion which is financed by a lump sum tax)

and the utility function of consumers is

$$U \equiv \mu \ln X + Y^D, \qquad X \equiv \left[\int_{i \in \Omega} q\left(j\right)^{\alpha} dj \right]^{\frac{1}{\alpha}} \tag{1}$$

In (1), Y^D is the quantity consumed of the numéraire good and X is the Dixit-Stiglitz composite of all varieties in the monopolistically competitive sector that are available to home consumers. The set of these varieties is given by Ω, elements of which can include home and foreign-produced varieties.

Varieties are consumed in quantity $q(j)$, where j is the index for the firm producing the variety. Varieties are substitutes and the elasticity of substitution between any two varieties is given by $\varepsilon \equiv 1/(1-\alpha) > 1$, where $\alpha \in (0,1)$.

Utility maximization requires that the ratio of marginal utilities for the two private goods equals their relative price. From the utility function (1) this implies $\mu/X = p_X$ and thus fixes the expenditures for the differentiated good X at μ.[6] This yields isoelastic demand functions for each variety

$$q(j) = \left[\frac{P}{p(j)}\right]^{\varepsilon} \frac{\mu}{P}, \tag{2}$$

where the price index for good X is

$$P = \left[\int_{i\in\Omega} p(j)^{-(\varepsilon-1)}\, dj\right]^{-\frac{1}{\varepsilon-1}}. \tag{3}$$

2.3 Firms

Profit maximization: Firms in the X sector differ with respect to their unit production cost $a(j)$, which is exogenously assigned to them. The distribution of these productivities is given by $G(.)$.[7]

When entering a market, each active firm must pay a uniform overhead cost, which equals rF. In addition, if it chooses to service the export market, it must pay an additional fixed cost F_x.

Since firms differ only with respect to their unit costs $a(j)$, we can replace the firm index j with the firm-specific costs a.

[6]This simplifying result of the quasi-linear preference structure has been exploited by Chor (2009), Cole and Davies (forthcoming), and others.

[7]Some heterogeneous firm models to have entrepreneurs draw from this distribution of productivities at a cost. Melitz (2003) is one such model. The advantage to this is that potential entrepreneurs continue to take draws until the expected profit of doing so is zero, implying that in equilibrium, total firm profits sum to zero as a result of free entry into the set of potential entrants. This, however, adds complications to the model impeding tractability. Since our quasi-linear preferences remove some of the burden that positive equilibrium profits create, we use this alternative approach. Nevertheless, as discussed by Cole (forthcoming) and Jørgensen and Schröder (2008) the two approaches yield generally comparable results.

The capital demand for a firm with input coefficient a for sale in the domestic market (subscript d) and in the export market (subscript x) is then given by

$$k_d(a) \equiv aq(a) + F, \qquad k_x(a) \equiv (1+\tau)aq_x(a) + F_x, \tag{4}$$

Similarly, we can express the revenues of a firm with variable unit costs a in the two markets by

$$\rho_d(a) \equiv p(a)\,q(a), \qquad \rho_x(a) \equiv p_x(a)\,q_x(a). \tag{5}$$

Incorporating the parameters of the corporate tax system, the after-tax profits of a firm with costs a in market $i \in \{d, x\}$ are given by

$$\begin{aligned} \pi_i(a) &= \underbrace{\rho_i(a) - rk_i(a)}_{\text{gross profits}} - t\underbrace{[\rho_i(a) - \delta rk_i(a)]}_{\text{taxable profit base}} \\ &= (1-t)\left[\rho_i(a) - r\Delta(t,\delta)\,k_i(a)\right] \end{aligned} \tag{6}$$

where

$$\Delta(t,\delta) \equiv 1 + \frac{t}{1-t}(1-\delta). \tag{7}$$

is the tax factor with which the net costs of capital rk_i are multiplied. Eq. (6) allows a simple representation of after-tax profits by regarding the corporate tax as a proportional tax on the difference between revenues ρ_i and the total after-tax capital cost $r\Delta k_i$. In the special case where capital costs can be fully deducted from the corporate tax base ($\delta = 1$) the tax factor for the capital cost is $\Delta = 1$ and the corporate tax is a tax on pure profits only. When the tax deductibility of inputs is incomplete ($\delta < 1$) the tax factor is $\Delta > 1$ and the corporate tax includes a partial taxation of capital inputs. Conversely, if $\delta > 1$ and hence $\Delta < 1$ the corporation tax implies a subsidy for capital inputs. Throughout our analysis we restrict our attention to values of the tax variables that result in $\Delta > 0$. If this were not true, the after-tax cost of capital would become negative, implying that the capital market would not be in equilibrium.

In what follows it will prove convenient to introduce

$$\pi_i^G \equiv \rho_i(a) - r\Delta(t,\delta)\,k_i(a) \qquad \forall\, i \in \{d, x\}, \tag{8}$$

where π_i^G are the profits of a firm in market i before deducting the corporate tax rate t but incorporating the taxation of capital inputs by the tax factor Δ. For brevity, though somewhat loosely, we will generally refer to this term as 'gross profits' in the following.

Total capital demand of a firm serving both the domestic and the export market is $k(a) \equiv k_d(a) + k_x(a)$, its total sales revenue is $\rho(a) \equiv \rho_d(a) + \rho_x(a)$ and its overall profits are $\pi(a) \equiv \pi_d(a) + \pi_x(a)$.

Substituting (4) and (5) into (6) and optimizing yields profit maximizing prices and quantities for each firm in the domestic market as

$$p(a) = \frac{a\Delta r}{\alpha}, \qquad q(a) = \left[\frac{\alpha}{\Delta r a}\right]^{\varepsilon} P^{\varepsilon-1}\mu. \tag{9}$$

This shows that more productive firms (firms with a lower a) charge lower prices and sell larger quantities. Also an increase in the gross-of tax costs per unit of capital, $r\Delta$, raises prices and reduces quantities. For future discussion, note the this reduction in output is greater for high-productivity firms (i.e. those with low values of a).

Similarly, firm-specific prices and quantities in the export market are given by

$$p_x(a) = \frac{(1+\tau)\Delta r a}{\alpha}, \qquad q_x(a) = \left[\frac{\alpha}{\Delta r(1+\tau)a}\right]^{\varepsilon} (P^*)^{\varepsilon-1}\mu^*, \tag{10}$$

where P^* is the aggregate price index in country F and μ^* is country F's expenditure share for good X. These parameters are fixed from the perspective of the small home country. Note also that, as a result of transport costs, export prices are higher, and export quantities are lower, for any given level of a than in the domestic market.

These choices give maximized after-tax profits in the domestic market equal to

$$\pi_d(a) = (1-t)\left\{(1-\alpha)\left(\frac{\alpha P}{\Delta r a}\right)^{\varepsilon-1}\mu - \Delta r F\right\}, \tag{11}$$

indicating that more productive firms earn larger profits. Moreover, since $\varepsilon > 1$, profits are unambiguously falling in the (gross) costs of capital $r\Delta$.

Similarly, for a firm that also chooses to exports, the additional after-tax profits from doing so equal

$$\pi_x(a) = (1-t)\left\{(1-\alpha)\left[\frac{\alpha P^*}{(1+\tau)\Delta r a}\right]^{\varepsilon-1}\mu^* - \Delta r F_x\right\}. \tag{12}$$

Finally, we assume that the foreign firms in the monopolistically competitive sector face the same distribution of costs. Ignoring taxes in the foreign country, the maximized after-tax profits of a foreign firm that also chooses to export to the home country are given by

$$\pi_x^* = (1-\alpha)\left[\frac{\alpha P}{(1+\tau^*)\,ra}\right]^{\varepsilon-1}\mu - rF_x^*, \tag{13}$$

where all foreign variables are denoted by an asterisk.

Market entry decisions: The home country's firms will only be active in the domestic market if $\pi_d(a) > 0$ holds. Setting $\pi_d(a) = 0$ in equation (11) determines a cutoff productivity (or a maximum cost threshold) given by

$$a_d \equiv \alpha P\,(\Delta r)^{-\frac{\varepsilon}{\varepsilon-1}}\left(\frac{\mu}{\varepsilon F}\right)^{\frac{1}{\varepsilon-1}}. \tag{14}$$

Only firms with unit costs $a \leq a_d$ will choose to be active in the domestic market. An increase in the costs of capital Δr reduces the cutoff value a_d, implying that fewer firms will enter the domestic market (a result that holds even when accounting for the general equilibrium impact on P).

With the exogenous mass of firms normalized to $N^e = 1$, the number of domestic firms operating in the domestic market is then given by $N = G(a_d)$, the value of the cumulative distribution function at the cutoff level of costs.

Similarly, domestic firms choose to export if $\pi_x(a) \geq 0$ in (12). This yields a maximum cost threshold a_x for exporting:

$$a_x \equiv \frac{\alpha P^*}{1+\tau}\,(\Delta r)^{-\frac{\varepsilon}{\varepsilon-1}}\left(\frac{\mu^*}{\varepsilon F_x}\right)^{\frac{1}{\varepsilon-1}}. \tag{15}$$

All firms with unit costs $a \leq a_x$ will choose to export. Since any firm choosing the export must pay F as well as F_x, any firm choosing to export will also serve the domestic market, however, not all firms selling in the domestic market will be able to cover the additional costs of exporting. This implies that $a_d > a_x$.

Finally, foreign firms choose to export if $\pi_x^*(a) > 0$ holds in (13). This yields a cutoff cost level for foreign producers equal to

$$a_x^* \equiv \frac{\alpha P}{1+\tau^*}\,(\Delta^* r)^{-\frac{\varepsilon}{\varepsilon-1}}\left(\frac{\mu^*}{\varepsilon F_x^*}\right)^{\frac{1}{\varepsilon-1}}. \tag{16}$$

The foreign export cutoff a_x^*, and hence the number of foreign exporters $M^* = G(a_x^*)$, are only affected through the domestic price index P. The total number of active firms in the rest of the world, N^*, is exogenous in our model. Note that by the foreign equivalent of (14), this implies that P^* is fixed.

2.4 Equilibrium

The cutoff levels in (14) and (16) include the domestic price level P, which is endogenous. To derive a first expression for P, we define the harmonic means of marginal costs of domestic producers and of foreign exporters:

$$\tilde{a}_d(a_d) \equiv \left[\int_0^{a_d} a^{-(\varepsilon-1)} dG(a)\right]^{-\frac{1}{\varepsilon-1}}, \qquad \tilde{a}_x(a_x) \equiv \left[\int_0^{a_x} a^{-(\varepsilon-1)} dG(a)\right]^{-\frac{1}{\varepsilon-1}}. \tag{17}$$

We can then apply the mark-up pricing rules in (9) and (10) to these harmonic means to get

$$P^{-(\varepsilon-1)} = \left(\frac{\Delta r \tilde{a}_d}{\alpha}\right)^{-(\varepsilon-1)} + \left[\frac{\Delta^* r(1+\tau^*)\tilde{a}_x}{\alpha}\right]^{-(\varepsilon-1)}. \tag{18}$$

Capital market clearing is derived as follows. In the home country, the total demand for capital in the Y and X sectors is given by

$$K_Y = Y^S, \quad K_X \equiv \int_0^N k(j)\, dj,$$

where Y^S stands for the production of good Y. Any discrepancy between country H's capital endowment K and its total capital demand $K_Y + K_X$ is met by international trade in capital.

The income of consumers in country H is composed of three sources: the return to the fixed capital endowment K, the net profits of domestic firms, and tax revenues R, which are redistributed to consumers as a lump sum. Hence

$$I \equiv rK + (1-t)\left[\int_0^{a_d} \pi(a)\, dG(a)\right] + R,$$

where we have aggregated the profits earned by domestic firms in the home and in the foreign market, $\pi = \pi_d + \pi_x$.[8] Tax revenues R are determined as the difference between the firms' gross value added and their net profits. Using π_i^G from (8), this gives

$$\begin{aligned} R &= \int_0^{a_d} [\rho(q) - rk(q)]dG(a) - (1-t)\int_0^{a_d} \pi^G(q)dG(a) \\ &= t\int_0^{a_d} \pi^G(q)dG(a) + (\Delta - 1)r\int_0^{a_d} k(q)dG(a). \end{aligned} \tag{19}$$

[8] We assume $a_d > a_x$. Hence aggregating over the total profits of all firms with cost levels up to a_d includes the exporting profits of all firms that serve both markets.

Intuitively, tax revenue can be decomposed into a profit tax on the base π^G and a tax on capital inputs levied at the rate $(\Delta - 1)$. The first of these terms just cancels against the reduction in profit income that is caused by the corporation tax. Hence we can consolidate the expression for the income of the representative consumer as

$$I = rK + \int_0^{a_d} \pi^G(q)dG(a) + (\Delta - 1)r \int_0^{a_d} k(q)dG(a). \tag{20}$$

Finally, consumption of the numéraire good Y is equal to total income minus the expenditures on good X. Consumer utility maximization [eq. (1)] yields $PX = \mu$ so that

$$Y^D = I - \mu. \tag{21}$$

3 The optimal tax structure

The home government chooses its capital tax structure so as to maximize the utility of the representative consumer (1). Substituting in (21) and the individual's income from (20) yields the indirect utility function

$$V = \int_0^{a_d} \pi^G(q)dG(a) + (\Delta - 1)\, r \int_0^{a_d} k(q)dG(a) - \mu \ln P + C, \tag{22}$$

where $C \equiv rK - \mu + \mu \ln \mu$ is a constant.

Since we allow for lump-sum redistribution of tax revenues in our model, only the choice of δ, and hence Δ, has allocative effects. We can thus simply set t at some positive level in our benchmark analysis and focus on the optimal choice of Δ.

The first-order condition of (22) with respect to Δ is

$$\frac{\partial}{\partial \Delta} \int_0^{a_d} \pi^G dG + r \int_0^{a_d} k\,(q)\, dG + (\Delta - 1)\, r \frac{\partial}{\partial \Delta} \int_0^{a_d} k\,(q)\, dG - \frac{\mu}{P} \frac{\partial P}{\partial \Delta} = 0.$$

It is shown in Appendix A that this can be simplified to

$$\frac{\mu}{P} \frac{\partial P}{\partial \Delta} \left[\int_0^{a_d} \frac{\partial p}{\partial P} \frac{Pq}{\mu} dG - 1 \right] + (\Delta - 1)\, r \frac{\partial}{\partial \Delta} \int_0^{a_d} k\,(q)\, dG = 0. \tag{23}$$

Appendix A further shows that the first term in (23) is strictly negative. A rise in Δ raises the input costs of all firms and this is passed on via mark-up pricing into the price level (18). Note that, due to the markup, the price level rises by more than the cost of capital. Other things equal, this increase in the price level raises producer profits. The positive effect on the income of the representative consumer is insufficient, however, to compensate the consumer for the loss in purchasing power that results from the increase in P. Intuitively this is because imperfect competition aggravates the tax-induced increase in the price of good X and exacerbates the gap between marginal cost for the firm and marginal benefit for the consumer.

In an interior optimum for Δ, the second effect in (23) must therefore be positive. The aggregate change in the demand for capital in this term is unambiguously negative. Intuitively an increase in the cost of one unit of capital, $r\Delta$, reduces the cutoff levels of costs a_d and a_x at which firms can profitable enter the domestic and the foreign market [see eqs. (14) and (15)]. Hence the mass of active firms falls in the domestic market and in the exporting market. At the same time, all firms that remain active reduce their output, lowering their variable demand for capital [see eqs.(4) and (9)–(10)]. It is shown in the appendix that these negative effects on the demand for capital cannot be overcompensated by the rise in the price level, and thus firm profitability, that accompanies the increase in Δ. It thus follows that in an interior optimum $(\Delta - 1)$ must be unambiguously negative. This is summarized in:

Proposition 1 *The optimal policy in the small open economy is to set* $\Delta < 1$*, implying that the tax allowance for capital inputs exceeds their true costs (*$\delta > 1$*). It is thus optimal to choose a tax base for the corporation tax that is narrower than the tax base under a pure profit tax.*

Proof: See Appendix A.

Proposition 1 states that the optimal policy for the small country in the absence of a tax revenue objective is to grant a capital subsidy to all active domestic firms. This reduces the price level of good X and increases consumption, thus offsetting the initial distortion arising from monopolistic competition in this sector. As in homogeneous firms models the capital subsidy increases the variable capital demand, and hence output, for all active firms. In addition, the subsidization of capital for home producers leads to additional entry of domestic firms into both the home and the foreign markets, whereas the number of foreign exporters to the home market falls.

To provide a more detailed analysis of the first-order condition (23), we now introduce the assumption that the unit costs of firms follow the Pareto distribution[9]

$$G(a) = \left(\frac{a}{a_0}\right)^{\theta}, \qquad 0 < a \leq a_0, \quad \theta > \varepsilon - 1, \tag{24}$$

where a_0 is the highest possible cost level that can be drawn and an increase in θ implies that more firms draw high cost levels approaching a_0.

In a first step we derive a compact first-order condition for Δ based on the Pareto distribution. This is done in Appendix B and the resulting optimality condition is given by

$$\frac{1}{\Delta}\left[\frac{\theta-(\varepsilon-1)}{\varepsilon\theta}+\alpha-\Delta\right]\left[\Gamma(\Delta)+\frac{\varepsilon\theta}{\varepsilon-1}\chi(\Delta)\right]+\chi(\Delta)=\frac{1}{\varepsilon-1}-\frac{1}{\theta}, \tag{25}$$

where

$$\chi(\Delta) \equiv \frac{F_x G(a_x)}{F G(a_d)} = \left(\frac{1}{1+\tau}\right)^{\theta} \frac{N^* \left[\Delta^{-\left(\varepsilon\frac{\theta}{\varepsilon-1}-1\right)} + \left(\frac{1}{1+\tau^*}\right)^{\theta}\left(\frac{F}{F_x^*}\right)^{\frac{\theta}{\varepsilon-1}-1}\right]}{\left(\frac{F_x}{F^*}\right)^{\frac{\theta}{\varepsilon-1}-1}\left(1-\frac{\varepsilon-1}{\theta}\right)\left(\frac{\mu}{\varepsilon F^*}\right)} \tag{26}$$

gives the aggregated fixed costs incurred by exporting firms, relative to the aggregated fixed costs of all domestic firms, and

$$\Gamma\left(\Delta; \tau^*, F/F_x^*\right) \equiv \left[1+\frac{\left(\frac{\varepsilon\theta}{\varepsilon-1}-1\right)\Delta^{\varepsilon\frac{\theta}{\varepsilon-1}-1}\left(\frac{1}{1+\tau^*}\right)^{\theta}\left(\frac{F}{F_x^*}\right)^{\frac{\theta}{\varepsilon-1}-1}}{1+\Delta^{\varepsilon\frac{\theta}{\varepsilon-1}-1}\left(\frac{1}{1+\tau^*}\right)^{\theta}\left(\frac{F}{F_x^*}\right)^{\frac{\theta}{\varepsilon-1}-1}}\right] \tag{27}$$

is a measure of the relative fixed costs incurred by domestic vis-a-vis foreign firms for serving the domestic market.

As a prerequisite for the ensuing analysis, we can state the following properties of $\chi(\Delta)$ and $\Gamma(\Delta)$ for special cases where either the import or the export channel of trade in good X is shut down. In our setting this will arise when either the fixed costs of foreign firms to export into the domestic market or the fixed costs of domestic firms to export to the foreign market become prohibitively high, implying $F_x^* \to \infty$,

[9] This distribution is frequently used in the related literature on firm heterogeneity (e.g. Baldwin and Okubo, 2009; Krautheim and Schmidt-Eisenlohr, 2011), as the Pareto distribution is analytically convenient and it is also a good approximation of empirically observed cost distributions.

respectively $F_x \to \infty$. In these cases we get:

$$\begin{array}{lll} \text{(no exports of } X\text{)} & \lim_{F_x \to \infty} & \chi(\Delta) = 0 \\ \text{(no imports of } X\text{)} & \lim_{F_x^* \to \infty} & \Gamma(\Delta) = 1 \\ \text{(autarky in } X\text{)} & \lim_{F_x \to \infty} & \chi(\Delta) = 0 \quad \text{and} \quad \lim_{F_x^* \to \infty} \Gamma(\Delta) = 1. \end{array} \tag{28}$$

A natural starting point to interpret (25) is therefore the case of autarky. Using (28) to simplify (25) yields, after some manipulations

$$\Delta^{aut} = \alpha \equiv \frac{(\varepsilon - 1)}{\varepsilon} \tag{29}$$

This special case of the more general result in Proposition 1 shows that, for the case of autarky, the optimal capital subsidy is higher (i.e., Δ is lower), when there is weaker competition between different varieties of the differentiated good (i.e., the lower is ε). Weak competition between different varieties implies a high mark-up $1/\alpha$ that each producer charges on its marginal cost. As eq. (9) shows the optimal capital subsidy in (29) leads to output prices that equal before-tax input prices for each variety of good X, as the capital subsidy exactly offsets the effects of monopolistic market power. Hence, for the case of autarky, the rule (29) guarantees a first-best allocation in our model.

4 Trade liberalization and firm heterogeneity

In the following we analyze the optimal adjustment in the capital subsidy Δ when the home and the foreign country become more closely integrated. As a first step in this analysis, we consider the discrete switch from a situation without any trade in good X to the opening up of either imports or exports. The results for this case are summarized in:

Proposition 2 *Consider a closed economy that opens up for imports, exports, or both. Starting from the autarky solution $\Delta = \alpha$, the optimal policy response to the opening of trade is to reduce the capital subsidies and broaden the tax base to $\Delta > \alpha$.*

Proof: See Appendix C.

To give an intuitive understanding of Proposition 2, recall first that the main motivation to grant capital subsidies by means of generous depreciation allowances is to increase domestic consumption of good X and thus counteract the distortion arising from imperfect competition in that sector. However, the capital subsidy can only be targeted at producers. Clearly the link between domestic production and domestic consumption of good X is closest under autarky. When part of domestic production is exported, the case for subsidizing capital is weakened, other things being equal, because part of the production subsidy now benefits foreign consumers. In addition, as is well known in heterogenous firms models, there is also a selection effect brought about by heterogeneity. By offering a capital subsidy, the home government encourages additional firms to export even though their productivity is insufficient for that to be profitable in the absence of the subsidy. Since the only gain to the home country from having these firms export is the profits they earn, the net impact of these firms' exporting on home income is negative. Therefore opening for exports would lead home to reduce its capital subsidy (i.e. raise Δ) to minimize this loss.

Turning to the import side, heterogeneity again plays a key role. First, recall that since foreign firms are not eligible for the capital subsidy, the subsidy distorts international trade and drives out some foreign exporters. Since exporters are more productive than the average firm, this means that low-cost imports are being replaced by the entry of high cost domestic firms. Thus, the subsidy undermines the welfare improving selection effect discussed by Melitz (2003) and others. In addition, recall from eq. (9) that more productive firms are more responsive to changes in Δ than less productive firms. When the country opens for imports, the added competition from relatively productive foreign firms drives out low productivity home firms. This increases the average responsiveness of home firms to Δ. Since the same average quantity increase can now be achieved by a higher (although still less than one) value of Δ, the optimal capital subsidy declines with imports. Thus, although the decoupling of production from domestic consumption would certainly occur in a model of homogenous firms, there are additional impacts arising from heterogeneity that would not be found.

So far, we have only dealt with a discrete switch from autarky to a situation with trade in the differentiated good. Our next result shows that similar results apply for continuous changes in economic integration, starting from an initial equilibrium with trade in good X. There are two different measures of economic integration in our model, the per-unit trade costs (τ, τ^*), and the fixed costs of serving an export market (F_x, F_x^*). The results in the following proposition hold for both of these different measures of trade costs.

Proposition 3 *(a) Consider a situation where the home country imports good X, but does not export it. Then either a small reduction in the trade costs τ^* or a reduction in the fixed exporting costs F_x^* faced by foreign firms leads the home country's government to raise Δ and thus to broaden the tax base.*

(b) Consider a situation with bilateral trade in good X. Then either a small reduction in the trade costs τ or a reduction in the fixed exporting costs F_x faced by domestic exporters leads the home country's government to raise Δ and thus to broaden the tax base.

Proof: See Appendix D.

The fundamental effects behind Proposition 3 are the same as those discussed above (Proposition 2). An increase in either exports or imports of the differentiated good, caused by a reduction in unit trade costs or in the fixed costs of serving an export market, will weaken the link between domestic production and domestic consumption and therefore reduces the incentive for the home government to subsidize domestic capital inputs. This implies a continuous broadening of the corporate tax base as economic integration proceeds.

What are the effects of firm heterogeneity on the optimal level of the capital subsidy? This issue can be addressed with the help of the parameter θ in the exponent of the Pareto distribution function (24). The higher is θ the more firms have unit costs approaching the upper bound a_0, and hence the smaller is the degree of heterogeneity between firms.[10] Thus we implicitly differentiate the first-order condition (25) with respect to θ. To simplify we focus on the case without exports, which implies $\chi = 0$

[10] This can be easily checked by calculating the variance of the stochastic cost variable as a function of θ. In the extreme, as $\theta \to \infty$, all firms have the cost level a_0 and hence the model approaches the case of homogeneous firms.

from (28). Using this assumption, equation (25) can be rewritten as

$$F \equiv \frac{\Gamma(\theta)}{\Delta}\rho - \left(\frac{1}{\varepsilon-1} - \frac{1}{\theta}\right) = 0, \qquad \rho \equiv \frac{1}{\varepsilon} - \frac{(\varepsilon-1)}{\varepsilon\theta} + \alpha - \Delta > 0, \tag{30}$$

where $\rho > 0$ follows from $\Delta > 0$, $\Gamma > 0$ and $\theta > \varepsilon - 1$. We then get from the implicit function theorem and assuming an interior maximum for Δ:

$$\text{sign}\left(\frac{\partial\Delta}{\partial\theta}\right) = \text{sign}\left(\frac{\partial F}{\partial\theta}\right).$$

Differentiating F gives, using Γ in (27)

$$\frac{\partial F}{\partial\theta} = (\Delta - \alpha)\frac{1}{\theta^2} + \frac{\rho}{\Delta}\left[\frac{\varepsilon}{\varepsilon-1}\frac{\gamma}{(1+\gamma)} + \left(\frac{\varepsilon\theta}{\varepsilon-1} - 1\right)\frac{1}{(1+\gamma)^2}\frac{\partial\gamma}{\partial\theta}\right], \tag{31}$$

where

$$\gamma \equiv \Delta^{\frac{\varepsilon\theta}{\varepsilon-1}-1}\left(\frac{1}{1+\tau^*}\right)^{\theta}\left(\frac{F}{F_x^*}\right)^{\frac{\theta}{\varepsilon-1}-1}. \tag{32}$$

The first term in (31) is positive from Proposition 2. The first part of the bracketed second term is also positive, since $\rho > 0$ from (30). The second term in the squared bracket is negative, however, since $\partial\gamma/\partial\theta$ follows from (32). This reflects counteracting forces of increased firm heterogeneity on the optimal capital subsidy (to be continued).

5 Introducing a revenue constraint

So far, our analysis has not enforced positive revenues from taxing the profits of firms in the differentiated sector. With a binding constraint that tax revenues of $\overline{G}$ must be collected from the corporation tax, the government's maximization problem becomes

$$\max_{\Delta,t} U = \ln X + Y + \lambda\left[\int \left[t\pi^G + (\Delta - 1)\, rk\,(q)\right] - \bar{G}\right],$$

where λ is the endogenous shadow price of tax revenues. Thus the government now chooses t and Δ simultaneously, where the two variables are linked through the government's revenue constraint. We expect that this case can only be solved numerically (still to be done). Note that when doing so, heterogeneity plays a crucial role, otherwise free entry will drive profits (and the tax base) to zero.

6 Conclusion

Over the past thirty years, there has been a simultaneous increase in openness to trade and a broadening of the tax base even as corporate tax rates fall. The goal of this paper has been to link the two in a model of imperfectly competitive, heterogenous firms. We begin by showing that, as a result of imperfect competition, a government has an incentive to offer capital subsidies as a method of increasing output. When trade barriers to exporting falls, so too does the desired capital allowance. This is due two to results. First, there is a decoupling of production and domestic consumption. Since it does not benefit home to subsidize foreign consumption, this lowers the desired capital subsidy. This result would occur in a model of homogenous firms. There are other effects, however, that would not. On the exporting side, capital subsidization permits low productivity firms to begin exporting. Since this is a net loss to home income, opening to exports again reduces the desired subsidy.

When opening for imports, the reduction in the optimal subsidy is linked to heterogeneity in two ways. First, subsidization leads to entry of high cost domestic firms at the expense of lower cost foreign importers. This counteracts the selection effect of trade liberalization that has been the focus of the trade literature on heterogeneous firms. Second, because trade drives low productivity firms from the market, it increases the responsiveness of the average home firm to the subsidy, meaning that the desired movement in output can be achieved with a smaller capital allowance and a lower corporate tax rate.

While there are undoubtedly several factors that have fed into the observed changes in corporate tax structures, we hope that our analysis adds additional insight into the issue.

Appendix

Appendix A: Proof of Proposition 1

We start from the first-order condition for Δ, which is repeated here for convenience.

$$\frac{\partial}{\partial \Delta}\int_0^{a_d} \pi^G dG + r\int_0^{a_d} k(q)\, dG + (\Delta - 1)\, r\frac{\partial}{\partial \Delta}\int_0^{a_d} k(q)\, dG - \frac{\mu}{P}\frac{\partial P}{\partial \Delta} = 0. \tag{A.1}$$

Differentiating the maximized profit function for a single firm with respect to Δ and collecting terms gives

$$\frac{\partial \pi_d^G}{\partial \Delta} = \left(\frac{\partial q}{\partial \Delta} + \frac{\partial q}{\partial P}\frac{\partial P}{\partial \Delta}\right)\left[\frac{\partial p}{\partial q}q + p - r\Delta\frac{\partial k_d}{\partial q}\right] + \frac{\partial p}{\partial P}\frac{\partial P}{\partial \Delta}q - rk(q)\,. \tag{A.2}$$

The first term in (A.2) is zero from the optimal output choice of firms. Summing over all firms the third term in (A.2) cancels against the second term in (A.1). Combining the second term in (A.2) with the last term in (A.1) gives eq. (23).

To show that the first term in (23) is negative, note first that $\partial P/\partial \Delta > 0$ from (18). Next, differentiating the inverse demand function and using $\alpha = (\varepsilon - 1)/\varepsilon$ gives

$$\frac{\partial p(\cdot)}{\partial P} = \alpha\left(\frac{\mu}{qP}\right)^{\frac{1}{\varepsilon}}.$$

Thus,

$$\int_0^{a_d}\frac{\partial p}{\partial P}\frac{Pq(\Delta, P(\Delta))}{\mu}dG(a) = \alpha\left(\frac{P}{\mu}\right)^{\alpha}\int_0^{a_d} q^{\alpha} dG(a) = \alpha\left(\frac{PX}{\mu}\right)^{\alpha} = \alpha, \tag{A.3}$$

where the second equality follows from changing variables and the last equality follows from $\mu = PX$. Since $\alpha < 1$ the squared bracket in the first term of (23) must be negative.

It remains to show that

$$\frac{\partial}{\partial \Delta}\int_0^{a_i} k_i(q)\, dG = \frac{\partial a_i}{\partial \Delta}k_i(a_i)\, g(a_i) + \int_0^{a_i}\frac{\partial k_i(q(\Delta))}{\partial \Delta}dG \quad < 0 \quad \forall i \in \{d, x\} \tag{A.4}$$

For $i = x$ this must always be fulfilled since $\partial a_x/\partial \Delta < 0$ from (15) and $\partial k_x/\partial \Delta < 0$ from (10) and (4). For $i = d$ it is equally true that $\partial a_d/\partial \Delta < 0$ from (14) and $\partial k_d/\partial \Delta < 0$ from (9) and (4). However, there is a counteracting effect from the increase in the price level ($\partial P/\partial\Delta > 0$) on k_d. To see that the net effect is negative, and thus $\Delta < 1$, we verify $\frac{\partial}{\partial\Delta}\int_0^{a_d} aq\left(\Delta, P\left(\Delta\right)\right) + FdG < 0$. Using $q\left(\Delta, P\left(\Delta\right)\right)$,

$$\int_0^{a_d} aq\left(\Delta, P\left(\Delta\right)\right)dG = P^{\varepsilon-1}\frac{\mu\alpha}{\Delta r}\left[\int_0^{a_d}\left(\frac{\Delta ra}{\alpha}\right)^{-(\varepsilon-1)}dG\right]. \tag{A.5}$$

The effect of Δ on P is via the domestic producers and via the mass of foreign exporters (whose prices are independent of Δ), i.e. the foreign export cutoff. We define an auxiliary variable

$$\begin{aligned} p_M\left(\Delta\right) &\equiv \int_0^{M^*(P(\Delta))} p^*\left(j\right)^{-(\varepsilon-1)}dj = M^*\int_0^{a_x^*} p^*\left(a\right)^{-(\varepsilon-1)}\frac{g^*\left(a\right)}{G\left(a_x^*\right)}da \\ p_M\left(\Delta\right) &= \int_0^{a_x^*} p^*\left(a\right)^{-(\varepsilon-1)}dG^*\left(a\right), \end{aligned} \tag{A.6}$$

which is increasing in Δ :

$$\frac{\partial p_M}{\partial\Delta} = \underbrace{\frac{\partial a_x^*}{\partial P}}_{>0}\underbrace{\frac{\partial P}{\partial\Delta}}_{>0} p^*\left(a_x^*\right)^{-(\varepsilon-1)} g\left(a_x^*\right) \quad > 0. \tag{A.7}$$

With this notation,

$$\begin{aligned} P^{-(\varepsilon-1)} &= \int_0^N p\left(j\right)^{-(\varepsilon-1)}dj + \int_0^{M^*} p^*\left(j\right)^{-(\varepsilon-1)}dj \\ P^{-(\varepsilon-1)} &= \int_0^{a_d}\left(\frac{\Delta ra}{\alpha}\right)^{-(\varepsilon-1)}dG + p_M\left(\Delta\right). \end{aligned} \tag{A.8}$$

This allows us to write

$$\begin{aligned} \int_0^{a_d} aq\left(\cdot\right)dG &= P^{\varepsilon-1}\frac{\mu\alpha}{\Delta r}\left[P^{-(\varepsilon-1)} - p_M\left(\Delta\right)\right] \\ \int_0^{a_d} aq\left(\cdot\right)dG &= \frac{\mu\alpha}{\Delta r}\left[1 - P\left(\Delta\right)^{\varepsilon-1}p_M\left(\Delta\right)\right]. \end{aligned} \tag{A.9}$$

Thus, $\frac{\partial}{\partial\Delta}\int_0^{a_d} aq\left(\cdot\right)dG < 0$ as $P^{\varepsilon-1}p_M$ is increasing in Δ. This completes the proof. □

Appendix B: Derivation of equation (25)

In a first step we derive the solution for the three cutoff variables a_d, a_x and a_x^* and the price index P under the Pareto distribution. Noting that the derivative of the Pareto distribution function (24) (i.e., the density function) is

$$G'(a) \equiv g(a) = \frac{\theta a^{(\theta-1)}}{a_0^\theta}, \tag{B.1}$$

we obtain

$$(\alpha P)^{\theta} = \frac{\left(1-\frac{\varepsilon-1}{\theta}\right) a_0^{\theta} r^{\varepsilon\frac{\theta}{\varepsilon-1}-1} \left(\frac{\varepsilon}{\mu}\right)^{\frac{\theta}{\varepsilon-1}-1}}{\left(\frac{1}{\Delta}\right)^{\varepsilon\frac{\theta}{\varepsilon-1}-1} \left(\frac{1}{F}\right)^{\frac{\theta}{\varepsilon-1}-1} + \left(\frac{1}{\Delta^*}\right)^{\varepsilon\frac{\theta}{\varepsilon-1}-1} \left(\frac{1}{1+\tau^*}\right)^{\theta} \left(\frac{1}{F_x^*}\right)^{\frac{\theta}{\varepsilon-1}-1}} \tag{B.2}$$

$$\left(\frac{a_d}{a_0}\right)^{\theta} = \frac{\left(1-\frac{\varepsilon-1}{\theta}\right)\left(\frac{\mu}{\varepsilon r}\right)}{\Delta F\left\{1+\left(\frac{\Delta}{\Delta^*}\right)^{\varepsilon\frac{\theta}{\varepsilon-1}-1}\left(\frac{1}{1+\tau^*}\right)^{\theta}\left(\frac{F}{F_x^*}\right)^{\frac{\theta}{\varepsilon-1}-1}\right\}} \tag{B.3}$$

$$\left(\frac{a_x^*}{a_0}\right)^{\theta} = \frac{\left(1-\frac{\varepsilon-1}{\theta}\right)\left(\frac{\mu}{\varepsilon r}\right)}{\Delta^* F_x^*\left[1+(1+\tau^*)^{\theta}\left(\frac{F_x^*}{F}\right)^{\frac{\theta}{\varepsilon-1}-1}\left(\frac{\Delta^*}{\Delta}\right)^{\varepsilon\frac{\theta}{\varepsilon-1}-1}\right]} \tag{B.4}$$

$$\left(\frac{a_x}{a_0}\right)^{\theta} = \left(\frac{1}{1+\tau}\right)^{\theta}\left(\frac{F^*}{F_x}\right)^{\frac{\theta}{\varepsilon-1}}\left(\frac{\Delta^*}{\Delta}\right)^{\varepsilon\frac{\theta}{\varepsilon-1}} N^* \tag{B.5}$$

with the comparative static properties with respect to Δ:

$$\frac{\partial P}{\partial \Delta} > 0, \quad \frac{\partial a_d}{\partial \Delta} < 0, \quad \frac{\partial a_x^*}{\partial \Delta} > 0, \quad \frac{\partial a_x}{\partial \Delta} < 0, \tag{B.6}$$

which follow from (B.2)–(B.5) and $\theta > \varepsilon - 1$, $\varepsilon > 1$.

Next we rewrite the indirect utility function (22) in a more compact form. From the definition of (8) the first and the second term in (22) can be combined, cancelling the Δ terms. Further normalizing $r \equiv 1$ gives

$$\tilde{V} = \int_0^{a_d} (\rho_d - k_d)\, dG + \int_0^{a_x} (\rho_x - k_x)\, dG - \mu \ln P, \tag{B.7}$$

where $\tilde{V} \equiv V - C$. We define

$$\bar{a}_d \equiv \left[\int_0^{a_d} a^{-(\varepsilon-1)} \frac{dG}{G(a_d)}\right]^{-\frac{1}{\varepsilon-1}}, \qquad \bar{a}_x \equiv \left[\int_0^{a_x} a^{-(\varepsilon-1)} \frac{dG}{G(a_x)}\right]^{-\frac{1}{\varepsilon-1}}.$$

Under the Pareto distribution, $\bar{a}_d$ and $\bar{a}_x$ are linear in the respective cutoffs:

$$\bar{a}_d = \left[\frac{\theta-(\varepsilon-1)}{\theta}\right]^{\frac{1}{\varepsilon-1}} \equiv \bar{\theta}^{\frac{1}{\varepsilon-1}}\, a_d, \qquad \bar{a}_x = \bar{\theta}^{\frac{1}{\varepsilon-1}} a_x \tag{B.8}$$

Moreover, inserting optimal price and quantity choices of firms under the Pareto distribution gives

$$\int_0^{a_d} (\rho_d - k_d)\, dG = \left\{\left(1-\frac{\alpha}{\Delta}\right)\left[\frac{P}{p(\bar{a}_d)}\right]^{\varepsilon-1} \mu - F_d\right\} G(a_d), \tag{B.9}$$

$$\int_0^{a_x} (\rho_x - k_x)\, dG = \left\{\left(1-\frac{\alpha}{\Delta}\right)\left[\frac{P^*}{p(\bar{a}_x)}\right]^{\varepsilon-1} \mu - F_x\right\} G(a_x). \tag{B.10}$$

Using (B.2) and (B.3) together with (B.8) in (B.9) gives

$$\int_0^{a_d} (\rho_d - k_d)\, dG = \left[(\Delta - \alpha)\frac{\varepsilon}{\bar{\bar{\theta}}} - 1\right] F_d G(a_d) \tag{B.11}$$

and similarly for the exporting profits, using (B.5) and (B.8) and setting $\Delta^* = 1$

$$\int_0^{a_x} (\rho_x - k_x)\, dG = \left[(\Delta - \alpha)\frac{\varepsilon}{\bar{\bar{\theta}}} - 1\right] F_x G(a_x) \tag{B.12}$$

From (B.11)–(B.12) and (B.2) we obtain the indirect utility function

$$\tilde{V}_1 = \left[(\Delta - \alpha)\frac{\varepsilon}{\bar{\bar{\theta}}} - 1\right]\left[F_d G(a_d) + F_x G(a_x)\right] + \frac{\mu}{\theta}\ln\left[\left(\frac{1}{\Delta}\right)^{\frac{\varepsilon\theta}{\varepsilon-1}-1} + \left(\frac{1}{1+\tau^*}\right)^{\theta}\left(\frac{F_d}{F_x^*}\right)^{\frac{\theta}{\varepsilon-1}-1}\right] \tag{B.13}$$

where $\tilde{V}_1$ is a monotonous transformation of $\tilde{V}$, with $\tilde{V}_1 \equiv \tilde{V} + \ln\left[\frac{a_0 \bar{\theta}^{\frac{1}{\theta}}\left(\frac{\varepsilon F}{\mu}\right)^{\frac{1}{\varepsilon-1}-\frac{1}{\theta}}}{\alpha}\right]^{\mu}$.

The optimality condition derived from (B.13) is given by

$$\begin{aligned}
&\frac{\varepsilon}{\bar{\bar{\theta}}}\left[F_d G(a_d) + F_x G(a_x)\right] + \left[(\Delta - \alpha)\frac{\varepsilon}{\bar{\bar{\theta}}} - 1\right]\left[F_d g(a_d)\frac{\partial a_d}{\partial \Delta} + F_x g(a_x)\frac{\partial a_d}{\partial \Delta}\right] \\
= &\left(\varepsilon\frac{\theta}{\varepsilon-1} - 1\right)\frac{\mu}{\theta}\frac{\Delta^{-\varepsilon\frac{\theta}{\varepsilon-1}}}{\left(\frac{1}{\Delta}\right)^{\varepsilon\frac{\theta}{\varepsilon-1}-1} + \left(\frac{1}{1+\tau^*}\right)^{\theta}\left(\frac{F}{F_x^*}\right)^{\frac{\theta}{\varepsilon-1}-1}}
\end{aligned} \tag{B.14}$$

The right-hand side of this expression can be simplified using

$$\left(\frac{1}{\Delta}\right)^{\varepsilon\frac{\theta}{\varepsilon-1}-1} + \left(\frac{1}{1+\tau^*}\right)^{\theta}\left(\frac{F_d}{F_x^*}\right)^{\frac{\theta}{\varepsilon-1}-1} = \frac{\left(\frac{\bar{\theta}\mu}{\varepsilon F}\right)}{\Delta^{\varepsilon\frac{\theta}{\varepsilon-1}} G(a_d)}. \tag{B.15}$$

Further we use the properties of the Pareto distribution

$$g(a_d) = \theta\frac{a_d^{\theta-1}}{a_0^{\theta}} = \frac{\theta}{a_d}G(a_d), \qquad g(a_x) = \frac{\theta}{a_x}G(a_x). \tag{B.16}$$

Using (B.15), (B.16), in (B.14) and substituting $\bar{\theta} = [\theta - (\varepsilon - 1)]/\theta$ the first-order condition becomes

$$\left[1 + \frac{F_x G(a_x)}{F G(a_d)}\right] + \left[(\Delta - \alpha) - \frac{\bar{\theta}}{\varepsilon}\right]\left[\frac{\theta}{a_d}\frac{\partial a_d}{\partial \Delta} + \frac{F_x G(a_x)}{F G(a_d)}\frac{\theta}{a_x}\frac{\partial a_x}{\partial \Delta}\right] = \frac{\varepsilon}{\varepsilon - 1} - \frac{1}{\theta} \tag{B.17}$$

The next step is to calculate the derivatives $\partial a_d/\partial\Delta$ and $\partial a_x/\partial\Delta$ in (B.17). Consider first $\partial a_d/\partial\Delta$. We define

$$a_d = \left[\frac{\frac{\bar{\theta}\mu}{\varepsilon\Delta F}}{1 + \Delta^{\varepsilon\frac{\theta}{\varepsilon-1}-1}\left(\frac{1}{1+\tau^*}\right)^{\theta}\left(\frac{F}{F_x^*}\right)^{\frac{\theta}{\varepsilon-1}-1}}\right]^{\frac{1}{\theta}} a_0 \equiv \left[\frac{\zeta}{\nu}\right]^{\frac{1}{\theta}} a_0 \tag{B.18}$$

The derivative of a_d with respect to Δ is

$$\frac{\partial a_d}{\partial \Delta} = \frac{a_d}{\theta}\left[\frac{\partial \zeta/\partial \Delta}{\zeta} - \frac{\partial \nu/\partial \Delta}{\nu}\right],$$

where

$$\frac{\partial \zeta/\partial \Delta}{\zeta} = -\frac{1}{\Delta},$$

$$\frac{\partial \nu/\partial \Delta}{\nu} = \frac{\left(\varepsilon\frac{\theta}{\varepsilon-1} - 1\right)}{\Delta} \frac{\Delta^{\varepsilon\frac{\theta}{\varepsilon-1}-1}\left(\frac{1}{1+\tau^*}\right)^{\theta}\left(\frac{F}{F_x^*}\right)^{\frac{\theta}{\varepsilon-1}-1}}{1+\Delta^{\varepsilon\frac{\theta}{\varepsilon-1}-1}\left(\frac{1}{1+\tau^*}\right)^{\theta}\left(\frac{F}{F_x^*}\right)^{\frac{\theta}{\varepsilon-1}-1}}$$

This yields

$$\frac{1}{a_d}\frac{\partial a_d}{\partial \Delta} = -\frac{\Gamma(\Delta)}{\Delta\theta} \tag{B.19}$$

where Γ is defined in (27) in the main text.

Differentiating $\partial a_x/\partial \Delta$ is straightforward. Using (B.5) gives

$$\frac{1}{a_x}\frac{\partial a_x}{\partial \Delta} = -\frac{\varepsilon}{\varepsilon-1}\frac{1}{\Delta}. \tag{B.20}$$

Substituting (B.19)–(B.20) in (B.17) gives

$$\left[1+\frac{F_x G(a_x)}{F G(a_d)}\right] - \frac{1}{\Delta}\left[(\Delta-\alpha) - \frac{\bar{\theta}}{\varepsilon}\right]\left[\Gamma(\Delta) + \varepsilon\frac{\theta}{\varepsilon-1}\frac{F_x G(a_x)}{F G(a_d)}\right] = \frac{\varepsilon}{\varepsilon-1} - \frac{1}{\theta} \tag{B.21}$$

The final step is to incorporate $G(a_x)$ and $G(a_d)$ under the Pareto distribution:

$$G(a_x) = \left(\frac{a_x}{a_0}\right)^{\theta} = \left(\frac{1}{1+\tau}\right)^{\theta}\Delta^{-\varepsilon\frac{\theta}{\varepsilon-1}}\left(\frac{F^*}{F_x}\right)^{\frac{\theta}{\varepsilon-1}} N^* \tag{B.22}$$

$$G(a_d) = \left(\frac{a_d}{\bar{a}}\right)^{\theta} \equiv \frac{\left(\frac{\bar{\theta}\mu}{\varepsilon}\right)}{\Delta F\left[1+\Delta^{\varepsilon\frac{\theta}{\varepsilon-1}-1}\left(\frac{1}{1+\tau^*}\right)^{\theta}\left(\frac{F}{F_x^*}\right)^{\frac{\theta}{\varepsilon-1}-1}\right]} \tag{B.23}$$

Using this in (B.21) gives equation (25) in the main text. Moreover, using the definition of ν in (B.18) we can rewrite $G(a_d)$ as $G(a_d) = (\bar{\theta}\mu)/(\varepsilon\Delta F\nu)$. Using this and the definition of ν in (B.18) yields (26) in the main text.

Appendix C: Proof of Proposition 2

Consider first the opening up of imports. As long as the export channel remains closed ($F_x \to \infty$), $\chi = 0$ holds from (28) and the optimality condition is:

$$\left(1 - \underbrace{\frac{1}{\varepsilon}\frac{\varepsilon-1}{\theta}}_{<1}\right)\frac{1}{\Delta} = 1 + \left(\frac{1}{\varepsilon-1} - \frac{1}{\theta}\right)\frac{1}{\Gamma(\Delta)}. \tag{C.1}$$

In autarky, $\Gamma = 1$. Opening up for imports, Γ rises to a level $\Gamma > 1$ when $F_x^* < \infty$. Hence the RHS of (C.1) is now smaller. For the LHS to also fall, Δ must increase. The fact that $\Delta = \alpha$ under autarky completes the proof for this case.

Consider next the case where the small country exports good X, but there are no imports. Hence $\Gamma = 1$ from (28). The first-order condition (25) then simplifies to:

$$\left\{1 - \varepsilon\frac{\theta}{\varepsilon - 1}\left[1 - \frac{1}{\Delta}\left(1 - \frac{1}{\varepsilon}\frac{\varepsilon - 1}{\theta}\right)\right]\right\}\chi\left(\Delta\right) + \frac{1}{\Delta}\left(1 - \frac{1}{\varepsilon}\frac{\varepsilon - 1}{\theta}\right) = \frac{\varepsilon}{\varepsilon - 1} - \frac{1}{\theta}. \quad \text{(C.2)}$$

Note first that the LHS of (C.2) is strictly increasing in χ, i.e. $1 - \varepsilon\frac{\theta}{\varepsilon-1}\left[1 - \frac{1}{\Delta}\left(1 - \frac{1}{\varepsilon}\frac{\varepsilon-1}{\theta}\right)\right] > 0$. To see this, suppose to the contrary that $\frac{\partial LHS}{\partial \chi} \leq 0$. This implies

$$\begin{aligned} 1 - \varepsilon\frac{\theta}{\varepsilon - 1}\left[1 - \frac{1}{\Delta}\left(1 - \frac{1}{\varepsilon}\frac{\varepsilon - 1}{\theta}\right)\right] &\leq 0 \\ (\varepsilon - 1) - \varepsilon\theta &\geq \left[(\varepsilon - 1) - \varepsilon\theta\right]\Delta. \end{aligned}$$

$(\varepsilon - 1) - \varepsilon\theta < 0$, since assuming to the contrary that $(\varepsilon - 1) - \varepsilon\theta \geq 0$ implies $\varepsilon - 1 > \frac{\varepsilon-1}{\varepsilon} \geq \theta$, a contradiction. Thus, supposing $\frac{\partial LHS}{\partial \chi} \leq 0$ implies $1 \leq \Delta$, a contradiction (recall Prop. 1). Thus, the LHS is strictly increasing in χ. In autarky, $\chi = 0$, and $\Delta = \alpha$. Allowing firms to export, χ jumps up to some $\chi > 0$, so the LHS is now higher. Thus, as $\frac{\partial LHS}{\partial \Delta} < 0$, Δ must increase to restore optimality.

The case where the economy simultaneously open up for imports and exports combines the arguments made above. This completes the proof. $\square$

Appendix D: Proof of Proposition 3

As a preliminary step, group the different measures of economic integration into two (non-exclusive) sets, $i = \{\tau, \tau^*, F_x, F_x^*\}$ and $j = \{\tau^*, F_x^*\}$. Differentiating χ in (26) and Γ in (27) with respect to these different measures of economic integration gives

$$\frac{\partial \chi}{\partial i} < 0, \quad \frac{\partial \Gamma}{\partial i} = 0, \quad \frac{\partial \Gamma}{\partial j} < 0. \quad \text{(D.1)}$$

Moreover, differentiating χ and Γ with respect to Δ gives

$$\frac{\partial \chi}{\partial \Delta} < 0, \qquad \frac{\partial \Gamma}{\partial \Delta} > 0 \quad \text{(D.2)}$$

We start with part (a) of the Proposition, where there are no exports ($\chi = 0$), but there are imports ($\Gamma > 1$).

The first-order-condition in this case is

$$\frac{1}{\Delta}\underbrace{\left(1-\frac{\alpha}{\theta}\right)}_{>0} = 1 + \underbrace{\left[\frac{1}{\varepsilon-1}-\frac{1}{\theta}\right]}_{>0}\frac{1}{\Gamma(\Delta)}, \tag{D.3}$$

where the signing of terms uses $1-\alpha/\theta > 0$ and $\theta > (\varepsilon-1)/\varepsilon$.

Next, define:

$$\bar{\Omega} = \frac{1}{\Delta}\underbrace{\left(1-\frac{\alpha}{\theta}\right)}_{>0} - 1 - \underbrace{\left[\frac{1}{\varepsilon-1}-\frac{1}{\theta}\right]}_{>0}\frac{1}{\Gamma(\Delta)} = 0 \tag{D.4}$$

Starting from an interior optimum Δ^* in the initial equilibrium, it must be true that $\partial\bar{\Omega}/\partial\Delta < 0$ for $\Delta > \Delta^*$. Moreover, for $j = \{\tau^*, F_x^*\}$

$$\frac{\partial\bar{\Omega}}{\partial j} = \underbrace{\frac{\partial\bar{\Omega}}{\partial\Gamma}}_{>0}\underbrace{\frac{\partial\Gamma}{\partial j}}_{<0} < 0. \tag{D.5}$$

Thus, by the implicit function theorem:

$$\frac{\partial\Delta}{\partial j} = -\frac{\partial\bar{\Omega}/\partial j}{\partial\Omega/\partial\Delta} = -\frac{(<0)}{(<0)} < 0,$$

demonstrating that a decrease in $j = \{\tau^*, F_x^*\}$ raises Δ.

Turning to part (b) of the proposition, the optimality condition without any restrictions on trade is:

$$\Omega \equiv \underbrace{\left\{1-\varepsilon\frac{\theta}{\varepsilon-1}\tilde{\alpha}(\Delta)\right\}}_{>0}\chi(\Delta) - \tilde{\alpha}(\Delta)\Gamma(\Delta) - \left(\frac{1}{\varepsilon-1}-\frac{1}{\theta}\right) = 0 \tag{D.6}$$

where we define

$$\tilde{\alpha}(\Delta) \equiv 1 - \frac{1}{\Delta}\left(1-\frac{1}{\varepsilon}\frac{\varepsilon-1}{\theta}\right), \quad \tilde{\alpha}(\Delta)' > 0. \tag{D.7}$$

Again, given that the initial equilibrium represented a maximum, it must be true that $\partial\Omega/\partial\Delta < 0$ for $\Delta > \Delta^*$. Hence base broadening is an optimal response to trade liberalization if and only if $\partial\Omega/\partial i < 0$, where $i = \{\tau, \tau^*, F_x, F_x^*\}$. Differentiating Ω gives

$$\frac{\partial\Omega}{\partial i} = \underbrace{\left\{1-\varepsilon\frac{\theta}{\varepsilon-1}\tilde{\alpha}(\Delta)\right\}}_{>0}\underbrace{\frac{\partial\chi}{\partial i}}_{<0} < 0, \tag{D.8}$$

which proves part (b) of the Proposition. □

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