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Optimal trade policy with monopolistic competition and heterogeneous firms

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Abstract

This paper derives optimal trade and domestic taxes for a small open economy containing a monopolistically competitive (MC) sector in which firms may have heterogeneous productivity levels. Analysis encompasses cases in which the domestic MC sector is able to expand or contract flexibly, or is constrained to be of fixed size. In the former case domestic protection can bring gains by increasing the number of product varieties on offer; these gains (and the corresponding rates of domestic subsidy or of import tariffs) are reduced by heterogeneity of foreign exporters some of whom may withdraw from the market. In the latter case gains from protection arise from terms-of-trade effects; since various margins of substitution are switched off, only the relative values of domestic taxes, import tariffs and export taxes matter. In general, policies work through both a terms-of-trade and a variety effect, and the paper shows how the relative importance of each depends on the structure of the economy.

Keywords: trade policy, monopolistic competition, heterogeneous firms, terms of trade, variety, productivity

JEL classification: F12, F13

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1. Introduction

What combination of domestic and trade taxes maximises welfare in an open economy? The classic answer to this turns on two sorts of reason for intervention; one is to manipulate the terms of trade and the other is to mitigate domestic distortions. The optimal tax and tariff structure depends on the extent to which policy can operate on each of these margins. We revisit this question in an economy in which some activity takes place in a sector with monopolistic competition and firms differing in their productivity. In particular we seek to understand the way in which the presence of heterogeneous firms changes standard arguments.

Our analytical framework has the following features. First, we model firms and the monopolistically competitive sector in what has become the standard manner (following Krugman 1980 and Melitz 2003). Each firm produces its own variety, demand for which is iso-elastic implying a constant price-cost mark-up; firms draw a productivity level, determining their decision of which markets (if any) to serve; the total number of firms is determined by free entry. Second, we look at a small open economy; this does not mean that all world prices are fixed but (following Demidova and Rodriguez-Clare 2009) that rest of world factor prices, numbers of firms, and relevant price indices and expenditure levels are constant. We look at policy pursued by a single country, holding policy elsewhere in the world constant.

Explicit formulae for optimal taxes and tariffs are derived in a relatively general model structure including the case in which firms have different productivity levels and fixed costs of market entry (heterogeneous firms, Melitz 2003) and the case of symmetric firms (Krugman 1980). The general equilibrium structure of the model encompasses different cases that are in the literature. The economy contains two sectors, one monopolistically competitive (MC) and the other perfectly competitive (PC). The economy's response to policy depends on the flexibility with which labour (the only sectorally mobile factor) can be shifted between sectors. Two polar cases are that the PC sector can release labour at constant wage (Krugman 1980, Venables 1982, Flam and Helpman 1987, Baldwin and Forslid 2010), or that the PC sector has fixed labour demand (of zero if the model is reduced to a one-sector economy, as in Demidova and Rodriguez-Clare 2009).

Results are derived using comparative static techniques, linearising the model and solving the ensuing equation systems to derive first order conditions for tax rates. This method enables us to derive optimal (and second best) taxes in a wide range of cases; it is conceptually simple and, we think, transparent, lending itself to relatively easy interpretation and to application to other issues. By comparing cases – MC with and without heterogeneous firms, alternative specifications of the general equilibrium model, and different combinations of admissible policy

instruments – we gain considerable insight into what drives results and why they differ across cases.

What are our findings? Welfare gains from policy derive from two opportunities that are not fully exploited by the market. One is the monopolistic competition (MC) distortion. In particular, the market under-supplies varieties because firms (that are not perfectly discriminating monopolists) are unable to capture the entire consumer surplus associated with a new variety.¹ The other is the possibility of improving the terms of trade (ToT). Some relative prices are fixed by the small open economy assumption, and others – such as the prices of firms’ export sales – are set efficiently, maximising the profit that can be extracted from foreign markets.² However, policy may, depending on the general equilibrium structure of the economy, bring about a change in the domestic wage, and this creates a ToT argument for policy intervention.

Both these mechanisms generate a case for subsidising domestic sales to the domestic market and, in some cases, for a positive tariff on imports. These policies have the effect of switching expenditure to the home MC industry leading, in general, to a price and quantity response. The quantity response increases the number of varieties that are offered, thereby reducing the MC distortion of under-supply of varieties. The price response raises wages in the domestic economy relative to foreign wages and thereby improves the ToT. We provide a decomposition which enables us to attribute the impact of tariffs to a precise combination of MC and ToT effects.

These arguments apply with both symmetric and heterogeneous firms. The latter creates no fundamentally new arguments for policy since this specification of technology is not itself associated with any market failure. However, the combination of a fixed cost of exporting and heterogeneous productivity levels means that foreign firms’ responses to policy become more elastic. In particular, they may react to domestic policy by changing the number of varieties sold in the domestic market. This reduces the value of using policy to change the number of domestic varieties, since more domestic varieties crowd-out some foreign varieties.

Related literature contains models which vary in (at least) four respects. Some papers look at the effects of changes in real trade barriers, others at tariffs; some look at unilateral changes, others bilateral; models vary in their general equilibrium structure; and they vary in whether they

¹ The MC distortion arises as price is greater than marginal cost and, for each variety, total benefit is greater than total cost. The ratios of benefit to cost are the same at the margin and for the totals, this giving the CES property that the market supports an outcome that is efficient, conditional on the level of employment in the sector (Dixit and Stiglitz, 1977). Dhingra and Morrow (2012) establish that this property also holds with heterogeneous firms.

² There is no strategic behaviour so ‘strategic trade policy’ arguments do not apply.

contain symmetric or heterogeneous firms. Since the objective of the present paper is to understand the welfare economics of monopolistic competition and firm heterogeneity (i.e. the inefficiencies present in the market equilibrium) we focus on tariff and other tax policy instruments that do not have their own real cost effect, and look at a single open economy (unilateral rather than multilateral policy). With this focus, we encompass several general equilibrium structures and both symmetric and heterogeneous firms.

Related work on tax and tariff policy under monopolistic competition includes an older literature from the 1980s. The identification of variety and a terms-of-trade reasons for active policies is addressed in work by Venables (1982, 1987), Flam and Helpman (1987) and Helpman and Krugman (1989), although without firm heterogeneity. The newer literature includes papers by Demidova and Rodriguez-Clare (2009) and Felbermayr, Jung and Larch (2013a). The former look at unilateral policy in a single sector economy and derive a policy result (taxing trade or subsidising domestic production) which we replicate and generalise. The latter extend the Demidova and Rodriguez-Clare model to large countries, and relate the optimal tariff to MC distortions and ToT effects.

Much of the recent literature looks at reductions in real trade barriers. Baldwin and Forslid (2010) study the effect of changes in real trade barriers in a model with an MC and a PC sector, and show that trade liberalisation will have an “anti-variety” effect, an effect that is present in our work. However, their finding that lower trade barriers raise welfare does not generally hold with tariffs rather than real barriers. The substantial new literature on the gains from trade also focuses on real, rather than revenue raising, trade barriers. Arkolakis et al. (2012) and following work points to the importance of trade elasticities in determining the welfare effects of trade. This is developed further in Melitz and Redding (2014) who study gains from trade and from bilateral liberalisation in a single sector economy, looking at both symmetric and heterogeneous firms. The two cases imply different trade elasticities which shape the gains from liberalisation and – in our work – shape optimal tax and tariff policy.

The remainder of the paper is organised as follows. Sections 2 and 3 set out the model in quite an extensive way, carrying a lot of variables and making few substitutions. Analysis is based on comparative statics, and we log-linearise the full system, without substituting out any variables. We think that this makes the structure of the model relatively transparent – and linear substitutions of the full system are readily undertaken by *Mathematica*. They generate explicit optimal (and constrained optimal) tax formulae which are the core of our results.

Results are presented and explained in sections 4 and 5. Section 4 looks at the two polar cases, first when the PC sector is such that the supply of labour to the MC sector is perfectly elastic,

and then when the PC sector has a fixed labour demand, a limiting case of which is no PC sector at all (Demidova and Rodriguez-Clare 2009). Section 5 places these in a general framework and shows that results are driven by a combination of MC distortion and ToT effects; we do a decomposition that separates these forces and establishes that the former drives results when labour supply is elastic (so quantity effects are large) and the latter when labour supply to the MC sector is inelastic (price effects dominate).

2. The model

We first outline the ingredients of the monopolistically competitive (MC) sector. We do this in a succinct manner since many fuller expositions are in the literature (e.g. Melitz and Redding 2015). Each firm in the sector produces a distinct variety of differentiated product. These products generate utility according to a sub-utility function with constant elasticity of substitution σ . E denotes total expenditure on MC products in the domestic economy and P is the price index (the unit expenditure function dual to the sub-utility function). The consumer price of a product is p , demand for the product is $p^{-\sigma}EP^{\sigma-1}$, and the value of its sales is $p^{1-\sigma}EP^{\sigma-1}$.

The marginal cost of a particular firm is W/φ where W is the price of labour, the only input, and φ is the firm's productivity. Firms mark-up price over marginal cost by factor $\sigma/(\sigma-1)$ so the producer price is $(W/\varphi)\sigma/(\sigma-1)$. The consumer price deviates from this according to ad valorem tax factor τ , so $p = \tau(W/\varphi)\sigma/(\sigma-1)$. The value, at consumer prices, of a firm's sales in one market is therefore $[\tau(W/\varphi)\sigma/(\sigma-1)]^{1-\sigma}EP^{\sigma-1}$. The firm captures fraction $1/\tau$ of this, so its revenue is $\tau^{-\sigma}[(W/\varphi)\sigma/(\sigma-1)]^{1-\sigma}EP^{\sigma-1}$. The remainder, fraction $1 - 1/\tau$, goes to government. The firm's operating profit, π , is fraction $1/\sigma$ of its revenue, so $\pi = \tau^{-\sigma}(W/\varphi)^{1-\sigma}\zeta EP^{\sigma-1}$ where $\zeta \equiv \sigma^{-\sigma}(\sigma-1)^{\sigma-1}$.

Entry decisions incur fixed costs that have to be weighed against expected operating profits. In order to produce at all, each home firm pays a fixed cost Wf_E to draw a productivity parameter φ from distribution G_H . If this exceeds cut-off value φ_D the firm will sell in the domestic market after incurring further fixed cost Wf_D , so its expected profits on domestic sales are given by the first term in equation (1) below, where τ_D is the domestic tax rate. Similarly, exporting incurs fixed cost Wf_X , is subject to tax τ_X , and faces foreign demand curve with fixed expenditure and

price index \bar{E}, \bar{P} (fixed by the small open economy assumption). A firm will export if productivity exceeds cut-off value φ_X . The firm's expected profits on export sales are the second term in (1), so the equation as a whole is the entry condition, giving zero expected profits.

$$\int_{\varphi_D} \left\{ EP^{\sigma-1} \zeta \tau_D^{-\sigma} \left(\frac{W}{\varphi} \right)^{1-\sigma} - Wf_D \right\} dG_H + \int_{\varphi_X} \left\{ \bar{E}\bar{P}^{\sigma-1} \zeta \tau_X^{-\sigma} \left(\frac{W}{\varphi} \right)^{1-\sigma} - Wf_X \right\} dG - Wf_E = 0. \quad (1)$$

The survival cut-offs are the lowest levels of productivity at which profits from an activity are non-negative. For domestic sales, φ_D satisfies

$$EP^{\sigma-1} \zeta \tau_D^{-\sigma} \left(\frac{W}{\varphi_D} \right)^{1-\sigma} = Wf_D, \quad \text{and we define} \quad \Phi_D \equiv \int_{\varphi_D} \varphi^{\sigma-1} dG_H \quad (2)$$

We call Φ_D the effective productivity index for home firms selling in the domestic market, as it aggregates productivity of active firms according to its impact on sales. Similarly, the export cut-off is φ_X :

$$\bar{E}\bar{P}^{\sigma-1} \zeta \tau_X^{-\sigma} \left(\frac{W}{\varphi_X} \right)^{1-\sigma} = Wf_X: \quad \Phi_X \equiv \int_{\varphi_X} \varphi^{\sigma-1} dG_H. \quad (3)$$

In addition to home firms, there are foreign firms some of which supply imports to the domestic market. The foreign wage is fixed at unity, the number of foreign firms is exogenous, and these firms have productivity distribution G_F (possibly different from G_H).³ They choose whether or not to supply the domestic market. The fixed cost they incur in supplying imports is f_M , so the importer cut-off is φ_M :

$$EP^{\sigma-1} \zeta \tau_M^{-\sigma} \left(\frac{1}{\varphi_M} \right)^{1-\sigma} = f_M: \quad \Phi_M \equiv \int_{\varphi_M} \varphi^{\sigma-1} dG_F. \quad (4)$$

It is convenient to have expressions for the total value of output sold by domestic firms in the domestic market, D , in the export market, X , and by foreign firms in the domestic market, M (all at consumer prices). The mass of domestic firms is denoted N and the mass of foreign firms \bar{N} so, integrating over firms' sales at consumer prices and using (2), (3), (4),

³ See Demidova (2008) for further development of the implications of different productivity distributions.

$$D \equiv N \int_{\varphi_D} EP^{\sigma-1} \zeta \sigma \left(\frac{\tau_D W}{\varphi} \right)^{1-\sigma} dG_H = EP^{\sigma-1} \zeta \sigma (\tau_D W)^{1-\sigma} N \Phi_D \quad (5)$$

$$X \equiv N \int_{\varphi_X} \bar{E} \bar{P}^{\sigma-1} \zeta \sigma \left(\frac{\tau_X W}{\varphi} \right)^{1-\sigma} dG_H = \bar{E} \bar{P}^{\sigma-1} \zeta \sigma (\tau_X W)^{1-\sigma} N \Phi_X \quad (6)$$

$$M \equiv \bar{N} \int_{\varphi_M} EP^{\sigma-1} \zeta \sigma \left(\frac{\tau_M}{\varphi} \right)^{1-\sigma} dG_F = EP^{\sigma-1} \zeta \sigma \tau_M^{1-\sigma} \bar{N} \Phi_M. \quad (7)$$

Notice that $E = D + M$, and hence the usual definition of the price index follows from (5) and (7),⁴

$$P^{1-\sigma} = \zeta \sigma \left[(\tau_D W)^{1-\sigma} N \Phi_D + \tau_M^{1-\sigma} \bar{N} \Phi_M \right]. \quad (8)$$

Government revenue, R , is earned from each of the tax instruments and, as noted above, is fraction $1 - 1/\tau$ of sales (at consumer prices) so:

$$R = D(1 - 1/\tau_D) + M(1 - 1/\tau_M) + X(1 - 1/\tau_X). \quad (9)$$

Employment in the home MC sector, L , is implicitly defined by the fact that, since firms break even (in expectation), the wage bill in the sector is equal to the value of sales at producer prices,

$$WL = D/\tau_D + X/\tau_X. \quad (10)$$

Turning from the MC sector to the general equilibrium of the economy as a whole, we assume that there is a fixed endowment of labour (set at unity) of which L is used in the MC sector and the remainder, $1 - L$, is employed in the PC sector. The PC sector (if it exists) is freely traded with price unity and concave production function $F(1 - L)$. The value of national output (at producer prices), Y , is therefore

$$Y = WL + F(1 - L). \quad (11)$$

Labour is employed in the PC sector to the point where the wage equals the marginal value product,

$$W = F'(1 - L). \quad (12)$$

Consumer income is the value of output plus government revenue, $Y + R$. Utility is Cobb-Douglas with expenditure share on the MC sector μ , giving utility U and MC expenditure E ,

⁴ The number of active firms in each market depends on the mass of firms and the productivity cut-offs, (2)-(4).

$$U = (Y + R)P^{-\mu}, \quad (13)$$

$$E = \mu(Y + R). \quad (14)$$

This completes description of the equilibrium; there are 14 equations in $N, E, P, \Phi_D, \Phi_X, \Phi_M, D, X, M, R, Y, L, W,$ and U .

The analysis of policy in our general case requires that both the MC and the PC sector are active (although the PC sector becomes inactive in one of the special cases we study). To ensure this, we assume that f_E is small enough for the expected profits of a domestic firm to be positive if $N = 0$, implying that the MC industry is present in the domestic economy; and large enough that expected profits are less than or equal to zero if the entire labour force is employed in the MC sector.⁵ We show in Appendix 1 that expected profits are monotonically decreasing with N , this giving an interior equilibrium. Profits decline with N for two reasons. One is that the wage may increase as the PC sector contracts (equation 12). The other is domestic market crowding; entry of domestic firms increases supply to the domestic market and thereby reduces the price index (equation 8) and $EP^{\sigma-1}$, hence reducing profits. Market crowding is offset by displacement of imports, occurring as lower values of $EP^{\sigma-1}$ increase the importer cut-off, φ_M (equation 4). However, this displacement occurs progressively (because importers are heterogeneous), so increasing N is sure to reduce $EP^{\sigma-1}$ and hence the expected profits of domestic firms.

Our primary task is to investigate the effect of changes in tax instruments, and we do this by log differentiation of the equilibrium. Expressions so derived contain proportionate changes (denoted \wedge) in the tax instruments and endogenous variables, together with some further variables capturing relative values of endogenous variables. We define these as follows.

The share of domestic firms' sales in the domestic MC market (at consumer prices), s_D :

$$s_D \equiv \frac{D}{D + M} = \frac{D}{E}. \quad (15)$$

The share of export sales in MC production (at producer prices), s_X :

$$s_X \equiv \frac{X / \tau_X}{WL}. \quad (16)$$

Government revenue as a share of total consumer income,

⁵ Expected profits are the left hand side of equation (1). The thought experiment here is to evaluate profits given the number of domestic firms, N , and with other variables in equilibrium, i.e. satisfying equations (2) – (14)

$$r \equiv \frac{R}{Y+R} = \frac{\mu R}{E} = \mu \left\{ \frac{(\tau_D - 1)}{\tau_D} s_D + \frac{(\tau_M - 1)}{\tau_M} (1 - s_D) + \frac{(\tau_X - 1)}{\tau_X} \left(\frac{\tau_X}{\tau_D} \right) \left(\frac{s_D s_X}{1 - s_X} \right) \right\} \quad (17)$$

(where (10), (14), (15) and (16) have been used to derive the final expression).

Finally, we define the share of the MC sector in total income, s_Y ,

$$s_Y \equiv WL / Y. \quad (18)$$

Given the share of MC spending in income, μ , the shares s_D, s_X, s_Y are not independent. Using (10), (14), (15) and (16) the equation linking them is,

$$s_D = s_Y (1 - s_X) (1 - r) \tau_D / \mu. \quad (19)$$

3. Comparative statics

Differentiation of the equilibrium conditions (1) – (14) is straightforward, if lengthy. Changes satisfying the zero profit condition, equation (1), are

$$0 = (1 - s_X) \left\{ \hat{E} + (\sigma - 1) \hat{P} - \sigma (\hat{W} + \hat{\tau}_D) \right\} - s_X \sigma (\hat{W} + \hat{\tau}_X). \quad (1')$$

Equations (2) – (4) define the effective productivity indices, Φ_j . Henceforth, we assume that productivity is Pareto distributed, i.e. $G_i(\varphi) = 1 - (\varphi_{\min} / \varphi)^{k_i}$, $i = H, F$. Setting $\varphi_{\min} = 1$ gives $\Phi_j = k_i \varphi_j^{\sigma - k_i - 1} / (k_i - \sigma + 1)$ for $i = H, j = D, X$ and for $i = F, j = M$. We define the parameter $\lambda_i \equiv \sigma k_i / (\sigma - 1)$ and make the standard assumption that $k_i \geq \sigma_i - 1$ so that $\lambda_i \geq \sigma$.

The change in Φ_i is then $\hat{\Phi}_i = (\lambda_i - \sigma)(1 - \sigma) \hat{\varphi}_i / \sigma$. Total differentials of (2) – (4) are:

$$(1 - \sigma) \hat{\varphi}_D = \hat{E} + (\sigma - 1) \hat{P} - \sigma (\hat{W} + \hat{\tau}_D), \quad \rightarrow \quad \hat{\Phi}_D = \frac{\lambda_H - \sigma}{\sigma} \left\{ \hat{E} + (\sigma - 1) \hat{P} - \sigma (\hat{W} + \hat{\tau}_D) \right\}, \quad (2')$$

$$(1 - \sigma) \hat{\varphi}_X = -\sigma (\hat{W} + \hat{\tau}_X), \quad \rightarrow \quad \hat{\Phi}_X = (\sigma - \lambda_H) (\hat{W} + \hat{\tau}_X), \quad (3')$$

$$(1 - \sigma) \hat{\varphi}_M = \hat{E} + (\sigma - 1) \hat{P} - \sigma \hat{\tau}_M, \quad \rightarrow \quad \hat{\Phi}_M = \frac{\lambda_F - \sigma}{\sigma} \left\{ \hat{E} + (\sigma - 1) \hat{P} - \sigma \hat{\tau}_M \right\}. \quad (4')$$

Changes in the values of sales (domestic, export and imports) satisfy;

$$\hat{D} = \hat{E} + (\sigma - 1) \hat{P} + (1 - \sigma) (\hat{W} + \hat{\tau}_D) + \hat{N} + \hat{\Phi}_D, \quad (5')$$

$$\hat{X} = (1 - \sigma) (\hat{W} + \hat{\tau}_X) + \hat{N} + \hat{\Phi}_X, \quad (6')$$

$$\hat{M} = \hat{E} + (\sigma - 1)\hat{P} + (1 - \sigma)\hat{\tau}_M + \hat{\Phi}_M. \quad (7')$$

The price index (8) changes according to:

$$\hat{P} = s_D \left[\hat{W} + \hat{\tau}_D + \frac{\hat{N} + \hat{\Phi}_D}{1 - \sigma} \right] + (1 - s_D) \left[\hat{\tau}_M + \frac{\hat{\Phi}_M}{1 - \sigma} \right] \quad (8')$$

The change in government revenue is dR and, since R can equal zero, we use dR/E not dR/R .

$$\frac{dR}{E} = \left(\frac{\hat{D}(\tau_D - 1) + \hat{\tau}_D}{\tau_D} \right) s_D + \left(\frac{\hat{M}(\tau_M - 1) + \hat{\tau}_M}{\tau_M} \right) (1 - s_D) + \left(\frac{\hat{X}(\tau_X - 1) + \hat{\tau}_X}{\tau_D} \right) \left(\frac{s_D s_X}{1 - s_X} \right). \quad (9')$$

From (10), employment in the MC sector changes according to⁶

$$\hat{L} + \hat{W} = (1 - s_X)(\hat{D} - \hat{\tau}_D) + s_X(\hat{X} - \hat{\tau}_X). \quad (10')$$

Turning to the general equilibrium, the change in the value of output satisfies

$$\hat{Y} = s_Y \hat{W}. \quad (11')$$

Changes in employment in the MC sector may draw labour from the PC sector, perhaps at an increasing wage. Denoting the elasticity of labour supply from the PC sector with respect to the wage by η ⁷,

$$\hat{W} = \hat{L} / \eta. \quad (12')$$

The change in utility is:

$$\hat{U} = (1 - r)\hat{Y} + r\hat{R} - \mu\hat{P} = (1 - r)s_Y\hat{W} + \mu dR/E - \mu\hat{P}, \quad (13')$$

where the second equation comes from (11') and (17), $r = \mu R/E$. The final equation is the change in expenditure on MC products, \hat{E} . This comes from the change in the value of production plus tax revenue and is given by

$$\hat{E} = (1 - r)\hat{Y} + r\hat{R} = (1 - r)s_Y\hat{W} + \mu dR/E. \quad (14')$$

⁶ With the Pareto distribution and equal price cost mark-ups in both markets, employment is proportional to the number of firms, so $\hat{L} = \hat{N}$, as can be seen from (5') and (6'), using (1'), (2') and (3').

⁷ $\eta \equiv -F'/LF''$. This elasticity is, in general, not constant. For example, if the PC production function is iso-elastic, $F(1 - L) = (1 - L)^\alpha$, then $\eta = (1 - L) / \{(1 - \alpha)L\}$.

Thus, totally differentiating the system there are exogenous changes in three tax instruments, and 14 equations giving changes in the endogenous variables. Our principal interest is to obtain the coefficients giving the effect of changes in each of the tax rates, $\hat{\tau}_D, \hat{\tau}_X, \hat{\tau}_M$, on utility, \hat{U} . These coefficients will in general contain parameters $\sigma, \mu, \lambda_H, \lambda_F$; endogenous variables r, s_D, s_X, s_Y ; and tax instruments, τ_D, τ_X, τ_M . Setting these coefficients equal to zero gives the first order conditions for optimal policy and, solving for tax rates, we obtain explicit solutions for optimal policies. This is conceptually straightforward but is cumbersome, even for the linearised system of proportional changes; we use *Mathematica*.

We derive results both for heterogeneous firms, and for a case which we term symmetric firms. The difference is that in the symmetric case there are no firm selection effects, i.e. the number of firms (and varieties) supplying each market varies only with N , the number of active domestic firms. Formally, $\hat{\phi}_i = \hat{\Phi}_i = 0$, so that productivity cut-offs are fixed. The Krugman-Dixit-Stiglitz model, in which all active firms supply all markets, is an example of this.⁸ In our model selection effects are switched off if $\lambda_H = \lambda_F = \sigma$ (equations 2' – 4'). It turns out that optimal tax and tariff rates in the symmetric case differ from those in the heterogeneous case only in that λ_H, λ_F are replaced by σ . The point can be illustrated by inspection of the elasticity of imports w.r.t. a tariff which, using (7') and (4'), is

$$\frac{d \ln M}{d \ln \tau_M} = (1 - \sigma) + \frac{\lambda_F - \sigma}{\sigma} (-\sigma) = 1 - \lambda_F.$$

Following Chaney (2008), the first element $(1 - \sigma)$ shows the intensive margin – the effect of a tariff on imports from the existing (foreign) firms – and the second element is the extensive margin, capturing the effects of changing cut-off levels for the selection into imports.⁹ With symmetric firms there is no selection effect so the import elasticity is given by the intensive margin. With heterogeneous firms, both intensive and extensive margin matter, and the combined elasticity is $(1 - \lambda_F)$. Similar reasoning applies for export elasticities. Since we allow for the possibility that $\lambda_H \neq \lambda_F$, our setup is general enough for firms in one country to symmetric and elsewhere heterogeneous.

⁸ Melitz and Redding (2014) compare gains from trade with homogenous and heterogeneous firms in a similar way, pointing out that the case with 'symmetric' firms does not require that all firms are identical. The key point is that there is no endogenous selection effect.

⁹ Head and Mayer (2015) show how the extensive margin can be decomposed into a selection effect and a composition effect, and Felbermayr et al (2013b) use the same framework to show how the effects of a tariff may differ from the effect of a real trade cost. Our expressions are consistent with Felbermayr et al.

4. Optimal policies

We start by presenting results for two special cases, first with a perfectly elastic supply of labour to the MC sector ($\eta = \infty$, section 4.1) and then perfectly inelastic supply ($\eta = 0$, section 4.2). In both sections we look at policy with symmetric firms (case A) and heterogeneous firms (case B). We present optimal tax formulae when all three tax instruments are optimised (denoting values τ^{**}) and where just one instrument is optimised (τ^*) with other instruments not used (i.e. set at unity). We call the former first-best policies and the latter second-best. We omit expressions that are excessively complex (e.g. reporting τ_X^* for the special cases in section 4 but not the general case in section 5).¹⁰

In each section we tabulate results and draw out intuition. For intuition, we concentrate on effects of the import tariff. In section 4.1 we are able to develop intuition by some simple arguments which show how policy equates marginal benefits and costs. For other cases intuition is more complex and a crucial issue becomes understanding the different roles of MC distortions and ToT effects. Our discussion of this is contained in section 5.

4.1 Perfectly elastic labour supply to the MC sector

A frequent assumption in the literature on trade under imperfect competition is that there is a PC sector that produces a good that has fixed world price with constant returns to labour alone. This fixes the wage in the economy, meaning that the MC sector faces a perfectly elastic labour supply curve. In terms of the model, $\eta = \infty$, $\hat{W} = 0$, and \hat{L} adjusts freely. Table 1 presents results.

The first row of Table 1 gives optimal policy for the case of symmetric firms. The optimum is achieved by a subsidy on domestic sales of home firms, $\tau_D^{**} < 1$, with the import tariff and export tax set at unity. The effect of the subsidy is to expand home's MC sector, bringing in new varieties thereby mitigating the MC distortion. The optimal import tariff is zero, $\tau_M^{**} = 1$, since the economy is importing goods at constant price. The optimal export tax is also zero. The economy can vary its export terms of trade, raising their price by an export tax; however, domestic firms have already chosen the price that maximises profit extracted from the foreign market, and any deviation from this is welfare reducing.

Turning to cases in which only one instrument is used, the optimal value of τ_D^* is as above. If the tariff is the only instrument, then it should be positive, $\tau_M^* > 1$. While this distorts the

¹⁰ These more complex expressions are available on request from the authors.

domestic price of imports away from the marginal cost at which they are supplied to the economy, it is a second best policy to expand the domestic MC sector, bringing in domestic varieties and mitigating the MC distortion.

The economic intuition underlying this can be developed by establishing the marginal benefits and costs of the quantity changes, and noting that optimal policy equates the ratios of marginal benefit to marginal cost across affected quantities. The first quantity change from an import tariff is a reduction in imports of MC products. Their marginal cost to the economy is their price, and their marginal benefit is price times the factor τ_M , as the tariff raises the marginal value.¹¹ The second quantity change is that, as the tariff shrinks imports of MC products, so it expands domestic production. From inspection of equation (1') a change in τ_M with wage constant means that $\hat{E} + (\sigma - 1)\hat{P} = 0$; constancy of $EP^{\sigma-1}$ means that sales per firm are unchanged, so the quantity change is met entirely by a change in the mass of domestic firms, N . As always in a Dixit-Stiglitz model, entry of a new variety brings consumer surplus, and the ratio of utility to expenditure is $\sigma/(\sigma - 1)$.¹² Since firms break even expenditure on each product equals (expected) costs, so the ratio of benefit to cost for a marginal change in the number of varieties is $\sigma/(\sigma - 1)$. Equating these marginal benefit to cost ratios for the change in imports and the change in domestic production gives the tariff formula $\tau_M^* = \sigma/(\sigma - 1)$.

Continuing in part A of table 1, the final row gives the optimal export tax, when other instruments are not used; it should be used to subsidise exports (its maximum value is unity, occurring if $s_X = 1$). This is second best policy shaped by the interaction of two forces. The subsidy attracts entry of domestic firms (an increase in N) which increases the number of varieties offered in the domestic market, partially correcting the MC distortion; but, since this policy involves subsidising foreign consumers (ToT loss) it is an inefficient instrument, so the subsidy is relatively small (going to zero if $s_X = 1$).

¹¹ Equivalently, marginal benefit is price times $1 + (\tau_M - 1)$, where the second term is tariff revenue earned.

¹² The sub-utility for single variety is written generally as $v(x)$, where x is sales of the variety and v is a concave function; quantity times marginal value is $xv'(x)$. The ratio of utility to expenditure is therefore $v(x)/xv'(x)$. For the CES case $v(x) = x^{(\sigma-1)/\sigma}$ so $v/xv' = \sigma/(\sigma - 1)$. Venables (1982) looks at trade policy in this more general case.

Table 1: Optimal policy with perfectly elastic labour supply.

A: Symmetric firms.

All taxes optimally set:

$\tau_D^{**} = \frac{\sigma-1}{\sigma} < 1$	$\tau_M^{**} = 1$	$\tau_X^{**} = 1$
<i>Fixed</i>	<i>Optimised</i>	
$\tau_M = \tau_X = 1$	$\tau_D^* = \frac{\sigma-1}{\sigma} < 1$	
$\tau_D = \tau_X = 1$	$\tau_M^* = \frac{\sigma}{\sigma-1} > 1$	
$\tau_D = \tau_M = 1$	$\tau_X^* = 1 - \frac{(1-s_X)[\sigma(1-s_D) + (1-\mu)s_D]}{(\sigma-1+\mu)[\sigma s_D + \sigma s_X(1-s_D) - s_D(1-s_X)] - \sigma\mu s_X} < 1$	

B: Heterogeneous firms: $\lambda_F, \lambda_H > \sigma$

All taxes optimally set:

$\tau_D^{**} = \frac{\sigma-1}{\sigma} < 1$	$\tau_M^{**} = \left(\frac{\sigma-1}{\sigma}\right)\left(\frac{\lambda_F}{\lambda_F-1}\right) \leq 1$	$\tau_X^* = 1$
<i>Fixed</i>	<i>Optimised</i>	
$\tau_M = \tau_X = 1,$	$\tau_D^* = \left(\frac{\sigma-1}{\sigma}\right)\left\{1 + \frac{(1-s_D)(\lambda_F-\sigma)(\sigma-1+\mu)}{(\sigma-1)[(1-s_D)\lambda_F(\sigma-1+\mu) + \sigma(1-\mu)]}\right\} < 1$	
$\tau_D = \tau_X = 1$	$\tau_M^* = \left(\frac{\lambda_F}{\lambda_F-1}\right) > 1$	
$\tau_D = \tau_M = 1$	$\tau_X^* = 1 - \frac{(1-s_X)[\sigma(1-s_D) + (1-\mu)s_D]}{(\sigma-1+\mu)[\lambda_H s_D + \lambda_F s_X(1-s_D) - s_D(1-s_X)] - \sigma\mu s_X} < 1$	

The lower panel of Table 1 gives policy with heterogeneous firms, case B. The key difference is that expanding the domestic MC sector now reduces the number of foreign firms that select to supply imports ($\hat{\Phi}_M < 0$, equation 4') so welfare gains from drawing in domestic varieties are offset by loss of imported varieties. First-best optimal policy is therefore the domestic subsidy $\tau_D^{**} < 1$ as before, combined with an import subsidy, $\tau_M^{**} < 1$. The size of this depends on the magnitudes of the expenditure elasticities with respect to tax rates, with the import subsidy less than the subsidy to domestic firms, and collapsing down to the symmetric case when $\lambda_F = \sigma$.

Notice that the expression for τ_M^{**} does not contain λ_H so it is heterogeneity of foreign firms, not of domestic firms, that makes the case for the import subsidy.

If τ_D is the only instrument used then it should be a subsidy, although at a lower rate (i.e. τ_D^* closer to unity) than in the symmetric case because of the loss of imported varieties. The import tariff alone mirrors that in the symmetric case, but with σ replaced by λ_F . Intuition for this comes from extending the line of reasoning that we used in the symmetric case. The marginal cost of imports is their price. Their marginal benefit is price times a term that includes the tariff and a term arising as the change in imports now includes a change in variety. We can derive this from (4'), giving $\hat{\Phi}_M = (\sigma - \lambda_F)\hat{\tau}_M$, and from (7'), $\hat{M} = (1 - \sigma)\hat{\tau}_M + \hat{\Phi}_M = (1 - \lambda_F)\hat{\tau}_M$.¹³ The ratio of these, $\hat{\Phi}_M / \hat{M} = (\sigma - \lambda_F)/(1 - \lambda_F)$, is the proportion of the change in imports coming from a change in the number of varieties supplied. This proportion carries a benefit *premium* of $\sigma/(\sigma - 1) - 1 = 1/(\sigma - 1)$, so the ratio of marginal benefit to marginal cost for a change in imports that incorporates adjustment at the extensive margin is $\tau_M + \frac{\sigma - \lambda_F}{1 - \lambda_F} \frac{1}{\sigma - 1}$. The marginal

benefit cost ratio on domestically produced MC goods is $\sigma/(\sigma - 1)$ as before, and equating these expressions gives the optimal tariff, $\tau_M^* = \lambda_F/(\lambda_F - 1)$. This argument makes clear the forces at work. The argument for policy is simply the MC distortion, but the number of MC varieties on offer now changes at two margins, N and Φ_M .

The final row of the table is the export tax with heterogeneous firms. As in the symmetric case, the export subsidy is determined by tension between ToT loss and variety gain. It collapses to the symmetric case if $\lambda_F = \lambda_H = \sigma$ and is a smaller subsidy if $\lambda_F, \lambda_H > \sigma$. This is because changes in both the import and export cut-offs reduce the impact of the export subsidy on the number of varieties sold in the domestic market; some import varieties are crowded out, and some of the quantity response of the domestic industry is more firms exporting (rather than an increase in N). It is noteworthy that this is the only result reported Table 1 in which λ_H appears, i.e. where heterogeneity of domestic firms has any bearing on policy. The reason can be seen by inspection of (1') - (4'); the productivity cut-offs φ_D and φ_X are unaffected by either τ_M or τ_D (see footnote (13), again), while both these cut-offs are affected by τ_X .

¹³ With $\eta = \infty$ and $\hat{W} = 0$, (1') implies that a change in $\hat{\tau}_M$ leaves $\hat{E} + (\sigma - 1)\hat{P} = 0$.

4.2 Inelastic labour supply to MC sector

We now look at situations in which the general equilibrium structure of the economy is such that the supply of labour to the MC sector is perfectly inelastic, including the one sector economy studied by Demidova and Rodriguez-Clare (2009, henceforth DRC). While tax formulae derived in this case are similar (in several cases identical) to those in the previous section, they are driven by quite different mechanisms. Essentially, when labour supply is elastic quantity changes interact with the MC distortion, but when it is fixed quantity effects are absent and price effects (the ToT) drive results. The distinction is key to understanding the role of policy – and welfare economics more generally – in this class of models.

It turns out that there are two assumptions involved in going from a general setting to the results of DRC. One is that $\eta = 0$ so that the supply of labour to the MC sector is perfectly inelastic. The other is that $\mu = 1$, so domestic consumers only purchase the MC good. Table 2 presents results in three stages; first, the infinitely elastic labour supply case ($\eta = \infty$, $\mu \in [0,1]$, repeating the first rows of each section of Table 1); secondly, $\eta = 0$, $\mu \in [0,1]$; and finally $\eta = 0$, $\mu = 1$, the DRC case.

The first row of each block of Table 2 gives results for $\eta = 0$, $\mu \in [0,1]$ in which optimal policy requires setting all three of the instruments at the values indicated. In the second row the size of the domestic MC sector is fixed by inelastic labour supply. This has the consequence that, since domestic MC production cannot change, the only margin is its distribution between domestic and export sales. Hence, policy is achieved by the ratio τ_D/τ_X taking the value indicated (the separate values of τ_D and τ_X being immaterial), together with $\tau_M = \tau_M^{**}$.¹⁴

In the third row of each block the consumer demand margin is also removed, by assuming that consumption consists solely of the MC good, $\mu = 1$. This means that the only tax instrument that matters is the combination $\tau_D/\tau_X\tau_M$. Export taxes and import tariffs have identical effects, a statement of Lerner symmetry in what is now a very simple economy. Varying any one of τ_D, τ_X, τ_M has the same real effect, changing exports and imports together. With heterogeneous firms (final row), this gives the result derived by DRC in a single sector economy. We note that it does not require that the economy contains a single sector, or that trade in the MC good be balanced (the PC sector could still exist, simply taking a fixed amount of labour to produce and

¹⁴ Table 2 does not report cases where an instrument is constrained to equal unity.

export a fixed amount of output). But it does require that margins of substitution between the MC sector and the PC sector – on both the supply and demand side – are switched off.

Table 2: Inelastic labour supply and Lerner symmetry

A: Symmetric firms.

$\eta = \infty, \mu \in [0,1] :$	$\tau_D^{**} = \frac{\sigma - 1}{\sigma}$	$\tau_M^{**} = 1$	$\tau_X^{**} = 1$
$\eta = 0, \mu \in [0,1] :$	$\left(\frac{\tau_D}{\tau_X}\right)^{**} = \frac{\sigma - 1}{\sigma}$	$\tau_M^{**} = 1$	
$\eta = 0, \mu = 1 :$	$\left(\frac{\tau_D}{\tau_M \tau_X}\right)^{**} = \frac{\sigma - 1}{\sigma}$		

B: Heterogeneous firms. $\lambda_F, \lambda_H > \sigma$

$\eta = \infty, \mu \in [0,1] :$	$\tau_D^{**} = \frac{\sigma - 1}{\sigma}$	$\tau_M^{**} = \left(\frac{\sigma - 1}{\sigma}\right) \left(\frac{\lambda_F}{\lambda_F - 1}\right)$	$\tau_X^{**} = 1$
$\eta = 0, \mu \in [0,1] :$	$\left(\frac{\tau_D}{\tau_X}\right)^{**} = \frac{\sigma - 1}{\sigma}$	$\tau_M^{**} = \left(\frac{\sigma - 1}{\sigma}\right) \left(\frac{\lambda_F}{\lambda_F - 1}\right)$	
$\eta = 0, \mu = 1 :$	$\left(\frac{\tau_D}{\tau_M \tau_X}\right)^{**} = \frac{\lambda_F - 1}{\lambda_F}$		

Despite the similarities in the tax and tariff formulae in Tables 1 and 2, the mechanisms driving policy are completely different in the two cases. Consider first symmetric firms with $\eta = 0, \mu = 1$. Policy cannot be operating through the domestic MC distortion (as it does in Table 1), since the size of the MC sector, number of varieties offered, and output of each firm are completely fixed and constant. Instead, it is a ToT effect.¹⁵ This now comes into play because the opportunity cost of labour in the MC sector is no longer set by its employment in the price-taking PC sector. In the heterogeneous firms case numbers of firms supplying the domestic market do change, due to the selection effects for domestic and foreign producers. To understand this fully, the following section provides a formal decomposition of the welfare effect of a tariff into parts driven by ToT and MC distortion forces.

¹⁵ We have verified this by computing results with separate notation for home and domestic elasticities of substitution, σ_H, σ_F . When $\eta = 0$ it is σ_F not σ_H in these expressions.

5. The general case: decomposition and optimal policies

Our focus up to this point has been on deriving optimal tariff and tax formulae for two special cases, and we now switch attention to identifying the relative importance of the different forces that make the case for policy. In section 5.1 we focus on the case of an import tariff with heterogeneous firms, and decompose the welfare effect of the tariff into ToT and MC distortion effects. The decomposition helps us understand the optimal policies for the general case, presented in section 5.2.

5.1 Decomposition of the tariff effect

With the appropriate substitutions, the expression for welfare change, (13'), can be written in terms of the change in the wage, the change in numbers of varieties sold in the domestic market (productivity weighted), and the change in import quantities. The change in import quantities is captured by the change in imports at producer prices, given by $\tilde{M} \equiv \hat{M} - \hat{\tau}_M$, i.e., at given foreign producer prices and netting out the price change due to the import tariff. We focus on the import tariff, so the substitutions are undertaken with $\tau_D = \tau_X = 1$ and $\hat{\tau}_D = \hat{\tau}_X = 0$. Making these substitutions (see Appendix 2 for the details), we get

$$\hat{U} = [(1-r)s_Y - \mu s_D] \hat{W} + \left[\frac{\mu s_D (\hat{N} + \hat{\Phi}_D) + \mu (1-s_D) \hat{\Phi}_M}{\sigma - 1} \right] + \mu (1-s_D) \left[1 - \frac{1}{\tau_M} \right] \tilde{M}. \quad (20)$$

This can be interpreted more directly if we use the definitions of the share variables μ , r , s_D and s_Y to give,

$$\hat{U} = \frac{X}{Y+R} \hat{W} + \frac{1}{\sigma-1} \left[\frac{D}{Y+R} (\hat{N} + \hat{\Phi}_D) + \frac{M}{Y+R} \hat{\Phi}_M \right] + \frac{M}{Y+R} \left[1 - \frac{1}{\tau_M} \right] \tilde{M}. \quad (21)$$

The first term on the right hand side is the ToT effect. It is the change in the wage (the price of domestic goods relative to foreign goods), times an expression which is proportional to exports (with $\tau_D = \tau_X = 1$).¹⁶ The second term is the variety (MC distortion) effect. The expression in square brackets gives changes in the number of varieties sold in the domestic market weighted by market shares in consumption; as noted above, entry of a new variety carries a premium, $1/(\sigma - 1)$. The final term is a standard expression giving change in the quantity of a variable

¹⁶ Import prices are fixed, by the small open economy assumption. If domestic taxes differ from unity, the coefficient for the wage change becomes slightly more complicated, as it must account for the difference between domestic consumer and producer prices.

times a tax wedge; thus, if the import tariff is positive, $\tau_M > 1$, a reduction in the quantity of imports will reduce welfare.¹⁷

Expression (20) applies across all our general equilibrium structures. For the context of the special case in Table 2 we evaluate it with $\eta = 0$, $\mu = 1$. If the MC sector is the entire economy then $s_y = 1$ and if labour supply to the MC sector is fixed, $\hat{N} = 0$. Changes $\hat{W}, \hat{\Phi}_D, \hat{\Phi}_M, \tilde{M}$ come from differentiation of the system with respect to τ_M and are generated from *Mathematica* (and reported in appendix 2) to give

$$\hat{U} = \frac{(1-s_D)s_D\hat{\tau}_M\tau_M(\lambda_H-1)}{s_D\tau_M(\lambda_F+\lambda_H-1)+(1-s_D)\lambda_F}. \quad (22)$$

$$\left\{ \left[\frac{\lambda_F}{\tau_M(\lambda_H-1)} \right] + \frac{1}{\sigma-1} \left[\frac{\lambda_F(\lambda_H-\sigma)}{(\lambda_H-1)\tau_M} - (\lambda_F-\sigma) \right] - \lambda_F \left[1 - \frac{1}{\tau_M} \right] \right\}.$$

At the optimum τ_M is set at the value that makes this expression equal to zero; we know that this is $\tau_M^{**} = \lambda_F / (\lambda_F - 1)$ (Table 2B with $\tau_D = \tau_X = 1$) giving,

$$\hat{U} = \frac{(1-s_D)s_D\hat{\tau}_M(\lambda_H-1)}{\lambda_F+s_D\lambda_H-1} \left\{ \left[\frac{\lambda_F-1}{\lambda_H-1} \right] + \left[\frac{\lambda_H-\lambda_F}{\lambda_H-1} \right] - 1 \right\} = 0. \quad (23)$$

In both (22) and (23) the three terms in the curly brackets (multiplied by the common factor) correspond to the terms in the general expression, (20 or 21), giving the welfare impact of the ToT effect, variety (MC) effect, and tariff distortion respectively.

A few observations are due. First, there is a positive ToT effect, since $\lambda_H, \lambda_F > 1$. Although individual firms take into account the slope of foreign demand curves for their varieties, they do not internalise the fact that changes in output change the wage, and it is this that creates the ToT effect. Second, the variety (MC distortion) effect makes an ambiguous contribution to utility change. An increase in the tariff raises the number of domestic varieties and reduces the number of foreign varieties offered in the home economy. The magnitude of these effects depend on λ_H and λ_F respectively, with positive net effect λ if the domestic response is relatively more elastic,

¹⁷ Flam and Helpman (1987) discuss a similar decomposition in a model with monopolistic competition but without firm heterogeneity. Hence, the variety effect only comes through the number of firms, N , in their model. Venables (1982) adds an (ad hoc) assumption about the possible changes in imported varieties when domestic market conditions changes, and thus also includes the possible crowding out of foreign varieties.

$\lambda_H > \lambda_F$. The final term is the negative effect of the tariff distortion. The optimal tariff is set such that $\hat{U} / \hat{\tau}_M = 0$, i.e. τ_M takes whatever value makes terms in the curly brackets sum to zero.

Hence, for the single-sector economy, the main message from this decomposition is that, while some MC distortion effects are present if $\lambda_H \neq \lambda_F$, the case for the tariff is driven principally by the fact that it improves the ToT. As the tariff cuts imports, so the wage has to rise in order to cut exports in line.

Equations (22) and (23) above explore the decomposition with $\eta = 0$, $\mu = 1$. However, the decomposition (20) is more general and can be written as

$$\hat{U} = (\text{ToT} + \text{MC}) \left\{ \frac{\text{ToT}}{\text{ToT} + \text{MC}} + \frac{\text{MC}}{\text{ToT} + \text{MC}} - 1 \right\} = 0, \quad (24)$$

(evaluated at the optimum, so terms in curly bracket sum to zero; MC denotes the MC distortion). Details are given in Appendix 2. Our primary interest is the shares of the ToT and MC effects in driving results. In the general case, with $\eta \in [0, \infty)$ and $\mu \in [0, 1]$, the share of the ToT effect is (evaluating expressions in (20) for the general case, see Appendix 2),

$$\frac{\text{ToT}}{\text{ToT} + \text{MC}} = \frac{(\sigma - 1 + \mu)s_x s_D (\lambda_F - 1)}{(\sigma - 1 + \mu)s_D [\eta(1 - s_x) + s_x (\lambda_H - 1)] - (\lambda_F - \sigma)(1 - \mu)}. \quad (25)$$

Evidently, if $\eta = 0$, $\mu = 1$ this collapses to the first term in the curly brackets in (23) and the preceding discussion applies. As $\eta \rightarrow \infty$ so the share of the ToT effect goes to zero, as in the case of section 4.1 in which the optimal tariff is driven entirely by the MC variety effect.

More generally, the share of the ToT effect is strictly decreasing in both η and μ .¹⁸

5.2 Optimal policies in the general case

We turn finally to presenting optimal policies for the general case (Table 3). We limit discussion to a few observations. First, if all three tax instruments are set optimally, then tax and tariff rates are the same in Tables 1, 2, and 3.¹⁹ This is true both with symmetric and heterogeneous firms. One way of thinking about this is that the first-best optimum ensures that marginal benefit equals marginal costs everywhere in the economy, so the general equilibrium assumptions have nothing to add in terms of first-best optima. However, although the first-best optimal policies are the

¹⁸ These are the derivatives holding the share variables, s_x , s_D constant. The limiting statements (concerning η at zero and infinity) hold providing these shares are positive.

¹⁹ Although in the one-sector economy, only relative taxes matter, as shown in section 4.2.

same the underlying mechanisms differ, in line with the discussion above. In the general case, policies will have both a ToT and an MC variety effect. But since the optimal policies are the same for the two cases, so is a convex combination of them.

Second, when only one policy instrument is in use, it is interesting to observe that for domestic subsidies, τ_D^* , the optimal level does not depend on the elasticity of labour supply, η . With symmetric firms it is the same in all cases; with heterogeneous firms, the expression is the same as long as $\mu < 1$ ²⁰. This may seem surprising, but it follows from the fact that τ_D^* is set to adjust two relative prices: between domestic goods and imports, and between domestic goods and the PC good. For both of these margins, it is $\tau_D W$ that matters; hence, the wage rate does not have an independent effects on the margins and the optimal subsidy is thus not be affected by the labour supply elasticity. It does, however, depend on μ , and it is easy to see that as μ increases, τ_D^* goes towards $(\lambda_F - 1)/\lambda_F$ i.e. the value in Table 2.

Optimal values of each of the trade policy instruments do however depend on η (we report import tariffs only, the export tax formula being complicated). This is because trade taxes and the wage rate do not have identical effects on the two relative prices discussed above; hence, the optimal trade taxes (or subsidies) vary with the labour supply elasticity. For both the symmetric and heterogeneous firms case, the second-best optimal tariff is increasing in η and approaches the levels in Table 1 as $\eta \rightarrow \infty$. Furthermore, with $\mu = 1$ the optimal tariffs are as in Table 2.

In the general case, an import tariff will have both a variety (MC distortion) and a ToT effect; the relative importance of the two follow from (25). Hence, the variety (MC distortion) effect is relatively more important in determining the optimal tariff the more elastic the labour supply and the higher the share of MC goods in domestic consumption.

Finally, the role of firm heterogeneity comes through by comparing sections A and B of Table 3. Selection effects for importers ($\lambda_F > \sigma$) leads to a lower optimal tariff through the variety effect, as discussed in the previous cases. The effect of selection at home ($\lambda_H > \sigma$) is similar to the wage effect: higher wages imply that fewer firms export (the extensive margin) and this dampens the wage effect and increases the variety effect in the domestic market.

²⁰ This is seen from inspection the expression, or by comparing Table 1 and 3.

Table 3: Optimal policy in the general model

A: Symmetric firms.

All taxes optimally set:

$\tau_D^{**} = \frac{\sigma-1}{\sigma} < 1$	$\tau_M^{**} = 1$	$\tau_X^{**} = 1$
<i>Fixed</i>	<i>Optimised</i>	
$\tau_M = \tau_X = 1,$	$\tau_D^* = \frac{\sigma-1}{\sigma} < 1.$	
$\tau_D = \tau_X = 1,$	$\tau_M^* = \frac{\sigma}{\sigma-1} \left\{ 1 - \frac{1-\mu}{\sigma(1-\mu) + (\sigma-1+\mu)s_D[(1-s_X)\eta + s_X(\sigma-1)]} \right\} > 1.$	

B: Heterogeneous firms: $\lambda_F, \lambda_H > \sigma$

All taxes optimally set:

$\tau_D^{**} = \frac{\sigma-1}{\sigma} < 1,$	$\tau_M^{**} = \left(\frac{\sigma-1}{\sigma} \right) \left(\frac{\lambda_F}{\lambda_F-1} \right) \leq 1,$	$\tau_X^{**} = 1$
<i>Fixed</i>	<i>Optimised</i>	
$\tau_M = \tau_X = 1,$	$\tau_D^* = \left(\frac{\sigma-1}{\sigma} \right) \left\{ 1 + \frac{(1-s_D)(\lambda_F-\sigma)(\sigma-1+\mu)}{(\sigma-1)[(1-s_D)\lambda_F(\sigma-1+\mu) + \sigma(1-\mu)]} \right\} < 1$	
$\tau_D = \tau_X = 1,$	$\tau_M^* = \frac{\lambda_F}{\lambda_F-1} \left\{ 1 - \frac{1-\mu}{\sigma(1-\mu) + (\sigma-1+\mu)s_D[(1-s_X)\eta + s_X(\lambda_H-1)]} \right\}$	

6. Concluding comments

The CES model of monopolistic competition, with or without heterogeneous firms, is the workhorse model of trade theory. The structure is simple enough to yield explicit formula for optimal policies, yet also complicated enough for the algebra involved in deriving these for the general case to explode. This has given rise to a literature of special cases and incomplete general understanding. The present paper has derived the optimal tax and tariff formulae in a model that encompasses these special cases and thereby draws out the underlying arguments for policy.

The main messages are that there are potential gains from using policy to support the home MC sector, either through a subsidy to firms' domestic sales, an import tariff, or an export subsidy. The gains are driven by a combination of two effects, one through quantities, the other through prices. The quantity effect arises from the interaction of trade policy with the MC distortion; supporting the domestic industry increases the range of products on offer with beneficial variety

effects. The price effect arises through the general equilibrium of the model; if labour supply to the MC sector is inelastic then supporting the MC sector raises wages and this brings a ToT improvement. The presence of heterogeneous productivity levels tempers results since the number of foreign varieties sold in the domestic market is endogenous and foreign reactions become more price elastic. However, this heterogeneity creates no qualitatively new arguments for or against policy interventions.

Our results coincide with the results from Demidova and Rodriguez-Clare (2009) and Felbermayr et al (2013a) for the one-sector economy; however, by decomposing the welfare effects, we highlight the mechanisms and draw out similarities with the older literature on homogeneous firms, e.g. Flam and Helpman (1987) and Venables (1982 and 1987). With more than one sector, there is a trade-off between terms-of-trade effects and variety effects, and we demonstrate how the general equilibrium conditions affect this trade-off. In general, the more flexible the labour market is, the more will the variety effect dominate. Furthermore, our results show that although firm heterogeneity does not give qualitatively new arguments for policy interventions, the size of the optimal taxes or subsidies are affected. And by distinguishing between domestic and foreign selection effects, the importance of foreign firms' selection effects for product variety in the home market becomes clear in our results.

Appendix 1.

We assume that f_E is small enough for the expected profits of a domestic firm to be positive if $N = 0$, and large enough that expected profits are less than or equal to zero if the entire labour force is employed in the MC sector. There is a unique value of N at which a domestic entrant expects to break even if expected profits are monotonically declining with N . We establish this relationship using the comparative statics of section 3, with one extension. The left hand side of equation (1) is expected profits, which we now denote π . We take N as exogenous, all tax rates constant and equal to unity, and use (2') – (14') to investigate how π changes with N . From *Mathematica*,

$$\hat{\pi} = -\sigma \hat{N} \left[\frac{s_Y [\lambda_H s_D + \lambda_F (1 - s_D)] + \mu s_D [s_D (1 - \lambda_H) - s_Y] + \eta \mu s_D^2}{\lambda_H \{s_Y [\lambda_H s_D + \lambda_F (1 - s_D)] + \mu s_D [s_D (1 - \lambda_H) - s_Y]\} + \eta s_Y \{\lambda_F (1 - s_D) + \lambda_H s_D\}} \right]$$

For the analyses of section 4.1 and 4.2 respectively,

$$\hat{\pi} = -\sigma \hat{N} \left[\frac{\mu s_D^2}{s_Y \{\lambda_F (1 - s_D) + \lambda_H s_D\}} \right] < 0 \quad \text{and} \quad \hat{\pi} = -\frac{\sigma \hat{N}}{\lambda_H} < 0.$$

Appendix 2. Decomposition of the welfare effects of an import tariff.

Substituting (8'), (9') and (11') in (13') together with $\tau_D = \tau_X = 1$ and $\tilde{M} \equiv \hat{M} - \hat{\tau}_M$ gives (20),

$$\hat{U} = [(1 - r)s_Y - \mu s_D] \hat{W} + \left[\frac{\mu s_D (\hat{N} + \hat{\Phi}_D) + \mu (1 - s_D) \hat{\Phi}_M}{\sigma - 1} \right] + \mu (1 - s_D) \left[1 - \frac{1}{\tau_M} \right] \tilde{M}.$$

Using $\mu s_D = D / (Y + R)$, $\mu (1 - s_D) = M / (Y + R)$, and $[(1 - r)s_Y - \mu s_D] = X / (Y + R)^{21}$, gives equation (21) of the text.

For the case of Table 2.B *Mathematica* gives:

$$\hat{W} = \lambda_F s_D \tau_M \hat{\tau}_M / \Delta, \quad \hat{\Phi}_D = \lambda_F (\lambda_H - \sigma) (1 - s_D) \hat{\tau}_M / \Delta, \quad \hat{\Phi}_M = (1 - \lambda_H) (\lambda_F - \sigma) s_D \tau_M \hat{\tau}_M / \Delta, \\ \tilde{M} = \lambda_F (\lambda_H - 1) s_D \tau_M \hat{\tau}_M / \Delta, \quad \text{with} \quad \Delta \equiv s_D \tau_M (\lambda_F + \lambda_H - 1) + (1 - s_D) \lambda_F.$$

Using these expressions in (20) gives (22).

²¹ More generally, we have $[(1 - r)s_Y - \mu s_D] = \frac{1}{Y + R} \left[\frac{X}{\tau_X} - D \left(\frac{\tau_D - 1}{\tau_D} \right) \right]$; hence, domestic tax wedges will

have to be taken into account, if $\tau_D, \tau_X \neq 1$.

In general, the welfare change can be expressed as $\hat{U} = ToT + MC + tariff\ distortion$, where ToT is the terms-of-trade effects, MC is the variety effect, and tariff distortion is the effect of the tariff wedge. With the optimal tariff in place the *tariff distortion* is set such that $\hat{U} = ToT + MC + tariff\ distortion = 0$, giving (24) of the text. The expressions for ToT and MC are found by using *Mathematica* to evaluate terms in (20) (for changes in the tariff evaluated at the second-best optimal tariff in the bottom row of Table 3B). The first and second terms in equation (20) are:

$$ToT = \frac{\mu(\sigma - 1 + \mu)(1 - s_D)s_X s_D(\lambda_F - 1)\hat{\tau}_M}{(\sigma - 1 + \mu)\{s_D[(1 - s_X)(\eta + 1) + s_X \lambda_H] + (1 - s_D)\lambda_F\} - \sigma\mu},$$

$$MC = \frac{\mu(1 - s_D)\{(\sigma - 1 + \mu)[\eta(1 - s_X) + s_X(\lambda_H - \lambda_F)]s_D - (\lambda_F - \sigma)(1 - \mu)\}\hat{\tau}_M}{(\sigma - 1 + \mu)\{s_D[(1 - s_X)(\eta + 1) + s_X \lambda_H] + (1 - s_D)\lambda_F\} - \sigma\mu}.$$

By inspection, ToT is positive (both the numerator and denominator are positive) while MC may be positive or negative (the special case with $\eta = 0$, $\mu = 1$, analysed in section 4.2 and 5.1, shows this clearly). Expression (25) follows.

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