

# Market Size, Trade, and Productivity

MARC J. MELITZ

*Princeton University, NBER, and CEPR*

and

GIANMARCO I. P. OTTAVIANO

*University of Bologna, FEEM and CEPR*

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We develop a monopolistically competitive model of trade with firm heterogeneity—in terms of productivity differences—and endogenous differences in the “toughness” of competition across markets—in terms of the number and average productivity of competing firms. We analyse how these features vary across markets of different size that are not perfectly integrated through trade; we then study the effects of different trade liberalization policies. In our model, market size and trade affect the toughness of competition, which then feeds back into the selection of heterogeneous producers and exporters in that market. Aggregate productivity and average mark-ups thus respond to both the size of a market and the extent of its integration through trade (larger, more integrated markets exhibit higher productivity and lower mark-ups). Our model remains highly tractable, even when extended to a general framework with multiple asymmetric countries integrated to different extents through asymmetric trade costs. We believe this provides a useful modelling framework that is particularly well suited to the analysis of trade and regional integration policy scenarios in an environment with heterogeneous firms and endogenous mark-ups.

## 1. INTRODUCTION

We develop a monopolistically competitive model of trade with heterogeneous firms and endogenous differences in the “toughness” of competition across countries. Firm heterogeneity—in the form of productivity differences—is introduced in a similar way to Melitz (2003): firms face some initial uncertainty concerning their future productivity when making a costly and irreversible investment decision prior to entry. However, we further incorporate endogenous mark-ups using the linear demand system with horizontal product differentiation developed by Ottaviano, Tabuchi and Thisse (2002). This generates an endogenous distribution of mark-ups across firms that responds to the toughness of competition in a market—the number and average productivity of competing firms in that market. We analyse how these features vary across markets of different size that are not perfectly integrated through trade and then study the effects of different trade liberalization policies.

In our model, market size and trade affect the toughness of competition in a market, which then feeds back into the selection of heterogeneous producers and exporters in that market. Aggregate productivity and average mark-ups thus respond to both the size of a market and the extent of its integration through trade (larger, more integrated markets exhibit higher productivity and lower mark-ups). Our model remains highly tractable, even when extended to a general framework with multiple asymmetric countries integrated to different extents through asymmetric trade costs. We believe this provides a useful modelling framework that is particularly well suited to the analysis of trade and regional integration policy scenarios in an environment with heterogeneous firms and endogenous mark-ups.

We first introduce a closed-economy version of our model. In a key distinction from Melitz (2003), market size induces important changes in the equilibrium distribution of firms and their performance measures. Bigger markets exhibit higher levels of product variety and host more productive firms that set lower mark-ups (hence lower prices). These firms are bigger (in terms of both output and sales) and earn higher profits (although average mark-ups are lower), but face a lower probability of survival at entry.<sup>1</sup> We discuss how our comparative statics results for the effects of market size on the distribution of firm-level performance measures accord well with the evidence for U.S. establishments across regions. We then present the open-economy version of the model. We focus on a two-country case but show in the Appendix how this set-up can be extended to multiple asymmetric countries. We show how costly trade does not completely integrate markets and thus does not obviate the effects of market size differences across trading partners: the bigger market still exhibits larger and more productive firms as well as more product variety, lower prices, and lower mark-ups.

Our model's predictions for the effects of bilateral trade liberalization are very similar to those emphasized in Melitz (2003): trade forces the least productive firms to exit and reallocates market shares towards more productive exporting firms (lower productivity firms only serve their domestic market).<sup>2</sup> Our model also explains other empirical patterns linking the extent of trade barriers to the distribution of productivity, prices, and mark-ups across firms. In an important departure from Melitz (2003), our model exhibits a link between bilateral trade liberalization and reductions in mark-ups, thus highlighting the potential pro-competitive effects often associated with episodes of trade liberalization. We then analyse the effects of asymmetric liberalization. We consider the case of unilateral liberalization in a two-country world and that of preferential liberalization in a three-country world. Although the liberalizing countries always gain from the pro-competitive effects of increased import competition in the short run, we show that these gains may be overturned in the long run due to shifts in the pattern of entry.

The channels for all these welfare effects, stemming from both multilateral and unilateral liberalization, have all been previously identified in the early "new trade theory" literature emphasizing imperfect competition with representative firms. However, these contributions used very different modelling structures (monopolistic competition with product differentiation vs. oligopoly with a homogeneous good, free entry vs. a fixed number of firms) in order to isolate one particular welfare channel. The main contribution of our modelling approach is that it integrates all of these welfare channels into a single, unified (yet highly tractable) framework, while simultaneously incorporating the important selection and reallocation effects among heterogeneous firms that were previously emphasized. Krugman (1979) showed how trade can induce pro-competitive effects in a model with monopolistic competition and endogenous mark-ups while Markusen (1981) formalized and highlighted the pro-competitive effects from trade due to the reduction in market power of a domestic monopolist. This latter modelling framework was then extended by Venables (1985) and Horstmann and Markusen (1986) to the case of oligopoly with free entry (while maintaining the assumption of a homogeneous traded good). These papers emphasized, among other things, how free entry could generate welfare losses for a country unilaterally liberalizing imports—by "reallocating" firms towards the country's trading partners. Venables (1987) showed how this effect also can be generated in a model with monopolistic

1. This closed-economy version of our model is related to Asplund and Nocke (2006), which analyses firm dynamics in a closed economy. They obtain similar results linking higher firm churning rates with larger markets—and provide supporting empirical evidence. On the other hand, the increased tractability afforded by our model yields additional important comparative static predictions for this closed-economy case.

2. Microeconomic studies strongly confirm these selection effects of trade (both according to firm export status, and for the effects of trade liberalization). See, among others, Clerides, Lach and Tybout (1998), Bernard and Jensen (1999), Aw, Chung and Roberts (2000), Pavcnik (2002), Bernard, Jensen and Schott (2006), and the survey in Tybout (2002).

competition and product differentiation with exogenous mark-ups. Our model isolates this asymmetric effect of unilateral trade liberalization induced by entry by also considering a short-run response to liberalization, where the additional entry of firms is restricted. Of course, our model also features the now-standard welfare gains from additional product variety as well as the asymmetric welfare gains of trade induced by differences in country size and trade costs highlighted by Krugman (1980). Again, we emphasize that our contribution is not to highlight a new welfare channel but rather to show how all of these welfare channels can jointly be analysed within a single framework that additionally captures the welfare effects stemming from changes in average productivity based on the selection of heterogeneous firms into domestic and export markets.

Our paper is also related to a much more recent literature emphasizing heterogeneous firms and endogenous mark-ups, resulting in a non-degenerate distribution of mark-ups across firms. These models all generate the equilibrium property that more productive firms charge higher mark-ups. Bernard, Eaton, Jensen and Kortum (2003) also incorporate firm heterogeneity and endogenous mark-ups into an open-economy model. However, in their model, the distribution of mark-ups is invariant to country characteristics and to geographic barriers. Asplund and Nocke (2006) investigate the effect of market size on the entry and exit rates of heterogeneous firms. They analyse a stochastic dynamic model of a monopolistically competitive industry with linear demand and hence variable mark-ups. They consider, however, a closed economy, so they do not provide any results concerning the role of geography and partial trade liberalization. In this paper, we focus instead on the response of the mark-ups to country characteristics and to geographic barriers and their feedback effects on firm selection. Most importantly, we show how our model can be extended to an open-economy equilibrium with multiple countries, including the analysis of asymmetric trade liberalization scenarios.

The paper is organized in four additional sections after the introduction. The first presents and solves the closed-economy model. The second derives the two-country model and studies the effects of international market size differences. The third investigates the impacts of trade liberalization considering both bilateral and unilateral experiments. This includes a three-country version of the model that highlights the effects of preferential trade agreements. The last section concludes.

## 2. CLOSED ECONOMY

Consider an economy with  $L$  consumers, each supplying one unit of labour.

### 2.1. Preferences and demand

Preferences are defined over a continuum of differentiated varieties indexed by  $i \in \Omega$ , and a homogenous good chosen as numeraire. All consumers share the same utility function given by

$$U = q_0^c + \alpha \int_{i \in \Omega} q_i^c di - \frac{1}{2} \gamma \int_{i \in \Omega} (q_i^c)^2 di - \frac{1}{2} \eta \left( \int_{i \in \Omega} q_i^c di \right)^2, \quad (1)$$

where  $q_0^c$  and  $q_i^c$  represent the individual consumption levels of the numeraire good and each variety  $i$ . The demand parameters  $\alpha$ ,  $\eta$ , and  $\gamma$  are all positive. The parameters  $\alpha$  and  $\eta$  index the substitution pattern between the differentiated varieties and the numeraire: increases in  $\alpha$  and decreases in  $\eta$  both shift out the demand for the differentiated varieties relative to the numeraire. The parameter  $\gamma$  indexes the degree of product differentiation between the varieties. In the limit when  $\gamma = 0$ , consumers only care about their consumption level over all varieties,  $Q^c = \int_{i \in \Omega} q_i^c di$ . The varieties are then perfect substitutes. The degree of product differentiation

increases with  $\gamma$  as consumers give increasing weight to the distribution of consumption levels across varieties.

The marginal utilities for all goods are bounded, and a consumer may thus not have positive demand for any particular good. We assume that consumers have positive demands for the numeraire good ( $q_0^c > 0$ ). The inverse demand for each variety  $i$  is then given by

$$p_i = \alpha - \gamma q_i^c - \eta Q^c, \quad (2)$$

whenever  $q_i^c > 0$ . Let  $\Omega^* \subset \Omega$  be the subset of varieties that are consumed ( $q_i^c > 0$ ). Equation (2) can then be inverted to yield the linear market demand system for these varieties:

$$q_i \equiv Lq_i^c = \frac{\alpha L}{\eta N + \gamma} - \frac{L}{\gamma} p_i + \frac{\eta N}{\eta N + \gamma} \frac{L}{\gamma} \bar{p}, \quad \forall i \in \Omega^*, \quad (3)$$

where  $N$  is the measure of consumed varieties in  $\Omega^*$  and  $\bar{p} = (1/N) \int_{i \in \Omega^*} p_i di$  is their average price. The set  $\Omega^*$  is the largest subset of  $\Omega$  that satisfies

$$p_i \leq \frac{1}{\eta N + \gamma} (\gamma \alpha + \eta N \bar{p}) \equiv p_{\max}, \quad (4)$$

where the R.H.S. price bound  $p_{\max}$  represents the price at which demand for a variety is driven to 0. Note that (2) implies  $p_{\max} \leq \alpha$ . In contrast to the case of Constant Elasticity of Substitution (CES) demand, the price elasticity of demand,  $\varepsilon_i \equiv |(\partial q_i / \partial p_i)(p_i / q_i)| = [(p_{\max} / p_i) - 1]^{-1}$ , is not uniquely determined by the level of product differentiation  $\gamma$ . Given the latter, lower average prices  $\bar{p}$  or a larger number of competing varieties  $N$  induce a decrease in the price bound  $p_{\max}$  and an increase in the price elasticity of demand  $\varepsilon_i$  at any given  $p_i$ . We characterize this as a “tougher” competitive environment.<sup>3</sup>

Welfare can be evaluated using the indirect utility function associated with (1):

$$U = I^c + \frac{1}{2} \left( \eta + \frac{\gamma}{N} \right)^{-1} (\alpha - \bar{p})^2 + \frac{1}{2} \frac{N}{\gamma} \sigma_p^2, \quad (5)$$

where  $I^c$  is the consumer's income and  $\sigma_p^2 = (1/N) \int_{i \in \Omega^*} (p_i - \bar{p})^2 di$  represents the variance of prices. To ensure positive demand levels for the numeraire, we assume that  $I^c > \int_{i \in \Omega^*} p_i q_i^c di = \bar{p} Q^c - N \sigma_p^2 / \gamma$ . Welfare naturally rises with decreases in average prices  $\bar{p}$ . It also rises with increases in the variance of prices  $\sigma_p^2$  (holding the mean price  $\bar{p}$  constant), as consumers then re-optimize their purchases by shifting expenditures towards lower priced varieties as well as the numeraire good. Finally, the demand system exhibits “love of variety”: holding the distribution of prices constant (namely holding the mean  $\bar{p}$  and variance  $\sigma_p^2$  of prices constant), welfare rises with increases in product variety  $N$ .

## 2.2. Production and firm behaviour

Labour is the only factor of production and is inelastically supplied in a competitive market. The numeraire good is produced under constant returns to scale at unit cost; its market is also competitive. These assumptions imply a unit wage. Entry in the differentiated product sector is costly as each firm incurs product development and production start-up costs. Subsequent production exhibits constant returns to scale at marginal cost  $c$  (equal to unit labour requirement).<sup>4</sup>

3. We also note that, given this competitive environment (given  $N$  and  $\bar{p}$ ), the price elasticity  $\varepsilon_i$  monotonically increases with the price  $p_i$  along the demand curve.

4. For simplicity, we do not model any overhead production costs. This would significantly degrade the tractability of our model without adding any new insights. In our model with bounded marginal utility, high-cost firms will not survive, even without such fixed costs.

Research and development yield uncertain outcomes for  $c$ , and firms learn about this cost level only after making the irreversible investment  $f_E$  required for entry. We model this as a draw from a common (and known) distribution  $G(c)$  with support on  $[0, c_M]$ . Since the entry cost is sunk, firms that can cover their marginal cost survive and produce. All other firms exit the industry. Surviving firms maximize their profits using the residual demand function (3). In so doing, given the continuum of competitors, a firm takes the average price level  $\bar{p}$  and number of firms  $N$  as given. This is the monopolistic competition outcome.

The profit maximizing price  $p(c)$  and output level  $q(c)$  of a firm with cost  $c$  must then satisfy

$$q(c) = \frac{L}{\gamma} [p(c) - c]. \tag{6}$$

The profit maximizing price  $p(c)$  may be above the price bound  $p_{\max}$  from (4), in which case the firm exits. Let  $c_D$  reference the cost of the firm who is just indifferent about remaining in the industry. This firm earns zero profit as its price is driven down to its marginal cost,  $p(c_D) = c_D = p_{\max}$ , and its demand level  $q(c_D)$  is driven to 0. We assume that  $c_M$  is high enough to be above  $c_D$ , so that some firms with cost draws between these two levels exit. All firms with cost  $c < c_D$  earn positive profits (gross of the entry cost) and remain in the industry. The threshold cost  $c_D$  summarizes the effects of both the average price and number of firms on the performance measures of all firms. Let  $r(c) = p(c)q(c)$ ,  $\pi(c) = r(c) - q(c)c$ ,  $\mu(c) = p(c) - c$  denote the revenue, profit, and (absolute) mark-up of a firm with cost  $c$ . All these performance measures can then be written as functions of  $c$  and  $c_D$  only:

$$p(c) = \frac{1}{2}(c_D + c), \tag{7}$$

$$\mu(c) = \frac{1}{2}(c_D - c), \tag{8}$$

$$q(c) = \frac{L}{2\gamma}(c_D - c), \tag{9}$$

$$r(c) = \frac{L}{4\gamma}[(c_D)^2 - c^2], \tag{10}$$

$$\pi(c) = \frac{L}{4\gamma}(c_D - c)^2. \tag{11}$$

As expected, lower cost firms set lower prices and earn higher revenues and profits than firms with higher costs. However, lower cost firms do not pass on all of the cost differential to consumers in the form of lower prices: they also set higher mark-ups (in both absolute and relative terms) than firms with higher costs.

### 2.3. Free entry equilibrium

Prior to entry, the expected firm profit is  $\int_0^{c_D} \pi(c)dG(c) - f_E$ . If this profit were negative, no firms would enter the industry. As long as some firms produce, the expected profit is driven to 0 by the unrestricted entry of new firms. Using (11), this yields the equilibrium free entry condition

$$\int_0^{c_D} \pi(c)dG(c) = \frac{L}{4\gamma} \int_0^{c_D} (c_D - c)^2 dG(c) = f_E, \tag{12}$$

which determines the cost cut-off  $c_D$ . This cut-off, in turn, determines the number of surviving firms, since  $c_D = p(c_D)$  must also be equal to the zero demand price threshold in (4):

$$c_D = \frac{1}{\eta N + \gamma} (\gamma \alpha + \eta N \bar{p}).$$

This yields the zero cut-off profit condition

$$N = \frac{2\gamma}{\eta} \frac{\alpha - c_D}{c_D - \bar{c}}, \quad (13)$$

where  $\bar{c} = [\int_0^{c_D} c dG(c)] / G(c_D)$  is the average cost of surviving firms.<sup>5</sup> The number of entrants is then given by  $N_E = N / G(c_D)$ .

Given a production technology referenced by  $G(c)$ , average productivity will be higher (lower  $\bar{c}$ ) when sunk costs are lower, when varieties are closer substitutes (lower  $\gamma$ ), and in bigger markets (more consumers  $L$ ). In all these cases, firm exit rates are also higher (the pre-entry probability of survival  $G(c_D)$  is lower). The demand parameters  $\alpha$  and  $\eta$  that index the overall level of demand for the differentiated varieties (relative to the numeraire) do not affect the selection of firms and industry productivity—they only affect the equilibrium number of firms. Competition is “tougher” in larger markets as more firms compete and average prices  $\bar{p} = (c_D + \bar{c}) / 2$  are lower. A firm with cost  $c$  responds to this tougher competition by setting a lower mark-up (relative to the mark-up it would set in a smaller market—see (8)).

#### 2.4. Parametrization of technology

All the results derived so far hold for any distribution of cost draws  $G(c)$ . However, in order to simplify some of the ensuing analysis, we use a specific parametrization for this distribution. In particular, we assume that productivity draws  $1/c$  follow a Pareto distribution with lower productivity bound  $1/c_M$  and shape parameter  $k \geq 1$ .<sup>6</sup> This implies a distribution of cost draws  $c$  given by

$$G(c) = \left( \frac{c}{c_M} \right)^k, \quad c \in [0, c_M]. \quad (14)$$

The shape parameter  $k$  indexes the dispersion of cost draws. When  $k = 1$ , the cost distribution is uniform on  $[0, c_M]$ . As  $k$  increases, the relative number of high-cost firms increases, and the cost distribution is more concentrated at these higher cost levels. As  $k$  goes to infinity, the distribution becomes degenerate at  $c_M$ . Any truncation of the cost distribution from above will retain the same distribution function and shape parameter  $k$ . The productivity distribution of surviving firms will therefore also be Pareto with shape  $k$ , and the truncated cost distribution will be given by  $G_D(c) = (c/c_D)^k$ ,  $c \in [0, c_D]$ .

Given this parametrization, the cut-off cost level  $c_D$  determined by (12) is then

$$c_D = \left[ \frac{2(k+1)(k+2)\gamma (c_M)^k f_E}{L} \right]^{1/(k+2)}, \quad (15)$$

5. Given (7), it is readily verified that  $\bar{p} = (c_D + \bar{c}) / 2$ .

6. Del Gatto, Mion and Ottaviano (2006) estimate the distribution of total factor productivity using firm-level data for a panel of 11 EU countries and 18 manufacturing sectors. They find that the Pareto distribution provides a very good fit for firm productivity across sectors and countries. The average  $k$  is estimated to be close to 2. Combes, Duranton, Gobillon, Puga and Roux (2007) extend our model and consider general cost/productivity distributions. They show how our main comparative static results do not depend on our choice of parametrization.

where we assume that  $c_M > \sqrt{[2(k+1)(k+2)\gamma f_E]/L}$  in order to ensure that  $c_D < c_M$  as was previously anticipated. The number of surviving firms, determined by (13), is then

$$N = \frac{2(k+1)\gamma}{\eta} \frac{\alpha - c_D}{c_D}. \quad (16)$$

This parametrization also yields simple derivations for the averages of all the firm-level performance measures described in (7)–(11):<sup>7</sup>

$$\begin{aligned} \bar{c} &= \frac{k}{k+1} c_D, & \bar{q} &= \frac{L}{2\gamma} \frac{1}{k+1} c_D = \frac{(k+2)(c_M)^k}{(c_D)^{k+1}} f_E, \\ \bar{p} &= \frac{2k+1}{2k+2} c_D, & \bar{r} &= \frac{L}{2\gamma} \frac{1}{k+2} (c_D)^2 = \frac{(k+1)(c_M)^k}{(c_D)^k} f_E, \\ \bar{\mu} &= \frac{1}{2} \frac{1}{k+1} c_D, & \bar{\pi} &= f_E \frac{(c_M)^k}{(c_D)^k}. \end{aligned}$$

As with the cost average  $\bar{c}$ , the average for a performance measure  $z(c)$  is given by  $\bar{z} = [\int_0^{c_D} z(c) dG(c)] / G(c_D)$ . Although  $\bar{c}$  is computed as the unweighted average of firm cost, it provides an index to a much broader set of inverse productivity measures. The average of firm productivity  $1/c$ —whether unweighted, weighted by revenue  $r(c)$ , or weighted by output  $q(c)$ —is proportional to  $1/\bar{c}$  (and hence to  $1/c_D$ ). In the Appendix, we further show how the variances of all the firm performance measures can be written as simple functions of the variance of the cost draws. Since the cut-off level completely summarizes the distribution of prices as well as all the other performance measures, it also uniquely determines welfare from (5):

$$U = 1 + \frac{1}{2\eta} (\alpha - c_D) \left( \alpha - \frac{k+1}{k+2} c_D \right). \quad (17)$$

Welfare increases with decreases in the cut-off  $c_D$ , as the latter induces increases in product variety  $N$  as well as decreases in the average price  $\bar{p}$  (these effects dominate the negative impact of the lower price variance).<sup>8</sup>

We previously mentioned that bigger markets induced tougher selection (lower cut-off  $c_D$ ), leading to higher average productivity (lower  $\bar{c}$ ) and lower average prices. In addition, under our assumed parametrization of cost draws, average firm size (both in terms of output and sales) and profits are higher in larger markets: the direct market size effect outweighs its indirect effect through lower prices and mark-ups. Similarly, average mark-ups are lower as the direct effect of increased competition on firm-level mark-ups ( $\mu(c)$  shifts down) outweighs the selection effect on firms with lower cost (and relatively higher mark-ups). We also note that average profits and sales increase by the same proportion when market size increases. Thus, average industry profitability  $\bar{\pi}/\bar{r}$  does not vary with market size. Finally, we note that our technology parametrization also allows us to unambiguously sign the effects of market size on the dispersion of the firm performance measures: the variance of cost, prices, and mark-ups are lower in bigger markets (the selection effect decreases the support of these distributions for any distribution  $G(c)$ ); on the

7. All derivations are based on the assumption that consumers have positive demands for the numeraire good. Consumers derive all of their income from their labour: there are no redistributed firm profits as industry profits (net of the entry costs) are 0. We therefore need to ensure that each consumer spends less than this unit income on the differentiated varieties. Spending per consumer on the varieties is  $N\bar{r}/L = (\alpha - c_D)c_D(k+1)/[\eta(k+2)]$ . A sufficient condition for this to be less than 1 is  $\alpha < 2\sqrt{\eta(k+2)/(k+1)}$ .

8. This welfare measure reflects the reduced consumption of the numeraire to account for the labour resources used to cover the entry costs.



other hand, the variance of firm size (in terms of either output or revenue) is larger in bigger markets due to the direct magnifying effect of market size on these variables.

These comparative statics for the effects of market size on the mean and variance of firm performance measures accord well with the empirical evidence for U.S. establishments/plants (across regions) reported by Syverson (2004, forthcoming) and Campbell and Hopenhayn (2005). These studies focus on sectors (retail, concrete, cement) where U.S. regional markets are relatively closed—and focus on the effects of U.S. market size (across regions) on the distribution of U.S. establishments. Campbell and Hopenhayn (2005) report that retail establishments in larger markets exhibit higher sales and employment and find weaker evidence that these distributions are more disperse. Syverson (2004, forthcoming) focuses on sectors where physical output can be measured along with sales (and hence prices recovered). He finds similar evidence of larger average plant size in larger markets along with higher average plant productivity. He finds further support for the tougher selection effect in the larger markets: the distribution of productivity is less disperse, with a higher lower bound for the productivity distribution. These effects also show up in the distribution of plant level prices: average prices are lower in bigger markets, while the dispersion is reduced.

### 2.5. A short-run equilibrium

In the following sections, we introduce an open-economy version of our model and analyse the consequences of various trade liberalization scenarios. The asymmetric liberalization scenarios induce a well-known relocation of firms (entrants in our model) across countries. We will then want to separate these “long-run” effects from the direct “short-run” effects of liberalization on competition and selection across markets. Towards this goal, we introduce a short-run version of our model. For now, we describe its main features and equilibrium characteristics in the closed economy.

Up to this point, we have considered a long-run scenario where entry and exit decisions were endogenously determined. In contrast, the short run is characterized by a fixed number and distribution of incumbents. In this time frame, these incumbents decide whether they should operate and produce—or shut down. If so, they can restart production without incurring the entry cost again. No entry is possible in the short run.

Let  $\bar{N}$  denote the fixed number of incumbents and  $\bar{G}(c)$  their cost distribution with support  $[0, \bar{c}_M]$ . We maintain our Pareto parametrization assumption for productivity  $1/c$ , implying  $\bar{G}(c) = (c/\bar{c}_M)^k$ . As was the case in the long run, only firms earning non-negative profits produce. This leads to the same determination of the cost cut-off  $c_D$ . Firms with cost  $c > c_D$  shut down and the remaining  $N = \bar{N}\bar{G}(c_D) = \bar{N}(c_D/\bar{c}_M)^k$  firms produce. If the least productive firm with cost  $\bar{c}_M$  earns non-negative profits, then  $c_D = \bar{c}_M$  and all firms produce in the short run. Otherwise, the cut-off  $c_D$  is determined by the zero cut-off profit condition (13):

$$N = \frac{2\gamma}{\eta} \frac{\alpha - c_D}{c_D - \bar{c}} = \frac{2(k+1)\gamma}{\eta} \frac{\alpha - c_D}{c_D}, \quad \text{whenever } c_D < \bar{c}_M,$$

since the average cost of producing firms is still  $\bar{c} = [k/(k+1)]c_D$  as in the long-run equilibrium. Using the new condition for the number of firms  $N = \bar{N}(c_D/\bar{c}_M)^k$ , the zero cut-off profit condition yields

$$\frac{(c_D)^{k+1}}{\alpha - c_D} = \frac{2(k+1)\gamma(\bar{c}_M)^k}{\eta\bar{N}}, \quad \text{whenever } c_D < \bar{c}_M,$$

which uniquely identifies the short-run cut-off  $c_D$  and the number of producing firms  $N$ .



In this short-run equilibrium, changes in market size do not induce any changes in the distribution of producing firms ( $c_D$  remains constant), nor in the distribution of prices and mark-ups (see (7) and (8)). All firms adjust their output levels in proportion to the market size change.<sup>9</sup> Only entry in the long run induces inter-firm reallocations (and the associated change in the cut-off  $c_D$ ).

### 3. OPEN ECONOMY

In the previous section we used a closed-economy model to assess the effects of market size on various performance measures at the industry level. This closed-economy model could be immediately applied to a set of open economies that are perfectly integrated through trade. In this case, the transition from autarky to free trade is equivalent to an increase in market size—which would induce increases in average productivity and product variety, and decreases in average mark-ups. However, the closed-economy scenario cannot be readily extended to the case of goods that are not freely traded. Furthermore, although trade is costly, it nevertheless connects markets in ways that preclude the analysis of each market in isolation. To understand these inter-market linkages, we now extend our model to a two-country setting. In the Appendix, we show how our framework can be extended to an arbitrary number of countries and trade cost patterns (including arbitrary asymmetric costs).

Consider two countries,  $H$  and  $F$ , with  $L^H$  and  $L^F$  consumers in each country. Consumers in both countries share the same preferences, leading to the inverse demand function (2). The two markets are segmented, although firms can produce in one market and sell in the other, incurring a per-unit trade cost.<sup>10</sup> Specifically, the delivered cost of a unit with cost  $c$  to country  $l$  ( $l = H, F$ ) is  $\tau^l c$  where  $\tau^l > 1$ . Thus, we allow countries to differ along two dimensions: market size  $L^l$  and barriers to imports  $\tau^l$ .

Let  $p_{\max}^l$  denote the price threshold for positive demand in market  $l$ . Then (4) implies

$$p^l = \frac{1}{\eta N^l + \gamma} (\gamma \alpha + \eta N^l \bar{p}^l), \quad l = H, F, \quad (18)$$

where  $N^l$  is the total number of firms selling in country  $l$  (the total number of domestic firms and foreign exporters) and  $\bar{p}^l$  is the average price (across both local and exporting firms) in country  $l$ . Let  $p_D^l(c)$  and  $q_D^l(c)$  represent the domestic levels of the profit maximizing price and quantity sold for a firm producing in country  $l$  with cost  $c$ . Such a firm may also decide to produce some output  $q_X^l(c)$  that it exports at a delivered price  $p_X^l(c)$ .

Since the markets are segmented and firms produce under constant returns to scale, they independently maximize the profits earned from domestic and exports sales. Let  $\pi_D^l(c) = [p_D^l(c) - c]q_D^l(c)$  and  $\pi_X^l(c) = [p_X^l(c) - \tau^h c]q_X^l(c)$  denote the maximized value of these profits as a function of the firm's marginal cost  $c$  (where  $h \neq l$ ).<sup>11</sup> Analogously to (6), the profit maximizing prices and output levels must satisfy:  $q_D^l(c) = (L^l/\gamma)[p_D^l(c) - c]$  and  $q_X^l(c) = (L^h/\gamma)[p_X^l(c) - \tau^h c]$ . As was the case in the closed economy, only firms earning non-negative profits in a market (domestic or export) will choose to sell in that market. This leads to similar

9. When market size changes, the residual inverse demand curve rotates around the same price bound  $p_{\max}$ . With linear demand curves, the marginal revenue curve rotates in such a way that the profit maximizing price for any given marginal cost remains unchanged.

10. We later show how our equilibrium conditions rule out any profitable arbitrage opportunities. For simplicity, we do not model any fixed export costs. This would significantly degrade the tractability of our model without adding any new insights. In our model with bounded marginal utility, per-unit costs alone are enough to induce selection into export markets.

11. Throughout this analysis, all derivations involving  $l$  and  $h$  hold for  $l = H, F$ , and  $h \neq l$ .

cost cut-off rules for firms selling in either market. Let  $c_D^l$  denote the upper bound cost for firms selling in their domestic market, and let  $c_X^l$  denote the upper bound cost for exporters from  $l$  to  $h$ . These cut-offs must then satisfy

$$\begin{aligned} c_D^l &= \sup\{c : \pi_D^l(c) > 0\} = p_{\max}^l, \\ c_X^l &= \sup\{c : \pi_X^l(c) > 0\} = \frac{p_{\max}^h}{\tau^h}. \end{aligned} \quad (19)$$

This implies  $c_X^h = c_D^l/\tau^l$ : trade barriers make it harder for exporters to break even relative to domestic producers.

As was the case in the closed economy, the cut-offs summarize all the effects of market conditions relevant for firm performance. In particular, the optimal prices and output levels can be written as functions of the cut-offs:

$$\begin{aligned} p_D^l(c) &= \frac{1}{2}(c_D^l + c), \quad q_D^l(c) = \frac{L^l}{2\gamma}(c_D^l - c), \\ p_X^l(c) &= \frac{\tau^h}{2}(c_X^l + c), \quad q_X^l(c) = \frac{L^h}{2\gamma}\tau^h(c_X^l - c), \end{aligned} \quad (20)$$

which yield the following maximized profit levels:

$$\begin{aligned} \pi_D^l(c) &= \frac{L^l}{4\gamma}(c_D^l - c)^2, \\ \pi_X^l(c) &= \frac{L^h}{4\gamma}(\tau^h)^2(c_X^l - c)^2. \end{aligned} \quad (21)$$

### 3.1. Free entry condition

Entry is unrestricted in both countries. Firms choose a production location prior to entry and paying the sunk entry cost. In order to focus our analysis on the effects of market size and trade costs differences, we assume that countries share the same technology—referenced by the entry cost  $f_E$  and cost distribution  $G(c)$ .<sup>12</sup> Free entry of domestic firms in country  $l$  implies zero expected profits in equilibrium, hence

$$\int_0^{c_D^l} \pi_D^l(c) dG(c) + \int_0^{c_X^l} \pi_X^l(c) dG(c) = f_E.$$

We also assume the same Pareto parametrization (14) for the cost draws  $G(c)$  in both countries. Given (21), the free entry condition can be re-written:

$$L^l (c_D^l)^{k+2} + L^h (\tau^h)^2 (c_X^l)^{k+2} = \gamma \phi, \quad (22)$$

where  $\phi \equiv 2(k+1)(k+2)(c_M)^k f_E$  is a technology index that combines the effects of better distribution of cost draws (lower  $c_M$ ) and lower entry costs  $f_E$ .

This free entry condition will hold so long as there is a positive mass of domestic entrants  $N_E^l > 0$  in country  $l$ .<sup>13</sup> In this paper, we focus on the case where both countries produce the differentiated good and  $N_E^l > 0$  for  $l = H, F$ . Then, since  $c_X^h = c_D^l/\tau^l$ , the free entry condition

12. We relax this assumption in the Appendix and investigate the implications of Ricardian comparative advantage.

13. Otherwise,  $\int_0^{c_D^l} \pi_D^l(c) dG(c) + \int_0^{c_X^l} \pi_X^l(c) dG(c) < f_E$ ,  $N_E^l = 0$ , and country  $l$  specializes in the numeraire. For the sake of parsimony, we rule out this case by assuming that  $\alpha$  is large enough.

(22) can be re-written

$$L^l (c_D^l)^{k+2} + L^h \rho^h (c_D^h)^{k+2} = \gamma \phi,$$

where  $\rho^l \equiv (\tau^l)^{-k} \in (0, 1)$  is an inverse measure of trade costs (the “freeness” of trade). This system (for  $l = H, F$ ) can then be solved for the cut-offs in both countries:

$$c_D^l = \left[ \frac{\gamma \phi}{L^l} \frac{1 - \rho^h}{1 - \rho^l \rho^h} \right]^{1/(k+2)}. \quad (23)$$

### 3.2. Prices, product variety, and welfare

The prices in country  $l$  reflect both the domestic prices of country- $l$  firms,  $p_D^l(c)$ , and the prices of exporters from  $h$ ,  $p_X^h(c)$ . Using (19) and (20), these prices can be written:

$$p_D^l(c) = \frac{1}{2}(p_{\max}^l + c), \quad c \in [0, c_D^l],$$

$$p_X^h(c) = \frac{1}{2}(p_{\max}^l + \tau^l c), \quad c \in [0, c_D^l/\tau^l],$$

where  $p_{\max}^l$  is the price threshold defined in (18). In addition, the cost of domestic firms  $c \in [0, c_D^l]$  and the delivered cost of exporters  $\tau^l c \in [0, c_D^l]$  have identical distributions over this support, given by  $G^l(c) = (c/c_D^l)^k$ . The price distribution in country  $l$  of domestic firms producing in  $l$ ,  $p_D^l(c)$ , and exporters producing in  $h$ ,  $p_X^h(c)$ , are therefore also identical. The average price in country  $l$  is thus given by

$$\bar{p}^l = \frac{2k+1}{2k+2} c_D^l.$$

Combining this with the threshold price in (18) determines the number of firms selling in country  $l$ :

$$N^l = \frac{2(k+1)\gamma}{\eta} \frac{\alpha - c_D^l}{c_D^l}. \quad (24)$$

These results for product variety and average prices are identical to the closed-economy case. This is driven by the matching price distributions of domestic firms and exporters in that market. Thus, welfare in country  $l$  can be written in an identical way to (17) as

$$U^l = 1 + \frac{1}{2\eta} (\alpha - c_D^l) \left( \alpha - \frac{k+1}{k+2} c_D^l \right). \quad (25)$$

Once again, welfare changes monotonically with the domestic cost cut-off, which captures the dominant effects of product variety and average prices.<sup>14</sup>

### 3.3. Number of entrants, producers, and exporters

The number of sellers (also indexing product variety) in country  $l$  is comprised of domestic producers and exporters from  $h$ . Given a positive mass of entrants  $N_E^l$  in both countries, there are  $G(c_D^l)N_E^l$  domestic producers and  $G(c_X^h)N_E^h$  exporters selling in  $l$  satisfying

14. The previously derived condition for the demand parameters  $\alpha$  and  $\eta$ , and  $k$  again ensure that  $q_0^l > 0$  as has been assumed.

$G(c_D^l)N_E^l + G(c_X^h)N_E^h = N^l$ . This condition (holding for each country) can be solved for the number of entrants in each country:

$$\begin{aligned} N_E^l &= \frac{(c_M)^k}{1 - \rho^l \rho^h} \left[ \frac{N^l}{(c_D^l)^k} - \rho^l \frac{N^h}{(c_D^h)^k} \right] \\ &= \frac{2(c_M)^k(k+1)\gamma}{\eta(1 - \rho^l \rho^h)} \left[ \frac{\alpha - c_D^l}{(c_D^l)^{k+1}} - \rho^l \frac{\alpha - c_D^h}{(c_D^h)^{k+1}} \right]. \end{aligned} \quad (26)$$

In the Appendix, we show that (26) further implies that  $c_X^l < c_D^l$  in this non-specialized equilibrium ( $N_E^l > 0$ ), so that only a subset of relatively more productive firms export. The remaining higher cost firms (with cost between  $c_X^l$  and  $c_D^l$ ) only serve their domestic market.  $G(c_D^l)N_E^l$  thus also represents the total number of firms producing in  $l$  (no firm produces in  $l$  without also serving its domestic market).

### 3.4. Reciprocal dumping and arbitrage opportunities

Brander and Krugman (1983) have shown that reciprocal dumping must occur in intra-industry trade equilibria under Cournot competition where representative firms produce a single homogeneous good in two countries. Ottaviano *et al.* (2002) show that dumping can also occur with differentiated products under monopolistic competition with representative firms. We extend this result to our current framework, where firms with heterogeneous costs produce differentiated varieties and face different residual demand price elasticities.<sup>15</sup> Given the optimal price functions  $p_D^l(c) = (c_D^l + c)/2$  and  $p_X^l(c) = \tau^h(c_X^l + c)/2$  from (20),  $c_X^l < c_D^l$  implies that  $p_X^l(c)/\tau^h < p_D^l(c)$ ,  $\forall c \geq c_X^l$ . Therefore, all exporters set Free on Board (FOB) export prices (net of incurred trade costs) strictly below their prices in the domestic market. Thus, as emphasized by Weinstein (1992), dumping does not imply predatory pricing. Furthermore, as shown by Ottaviano *et al.* (2002), dumping need not be the outcome of oligopoly and strategic interactions between firms, which are absent in our model.

As described by Feenstra, Markusen and Rose (2001), dumping behaviour is closely linked to arbitrage conditions for the re-sale of goods across markets. This same link holds in our model, where dumping by exporters from country  $l$  ( $p_X^l(c)/\tau^h < p_D^l(c)$ ) is equivalent to a no-arbitrage condition precluding the profitable export resale by a third party of a good produced and sold in country  $l$ . The dumping condition also precludes profitable resale of a good exported to country  $l$ , back in its origin country  $h$  ( $p_D^h(c)/\tau^h < p_X^h(c)$ ).<sup>16</sup>

### 3.5. The impact of trade

We previously described how the distribution of the exporters' delivered cost  $\tau^l c$  to country  $l$  matched the distribution of the domestic firms' cost  $c$  in country  $l$ . We then argued that this would lead to matching price distributions for both domestic firms in a country and exporters to that country. This argument extends to the distribution of all the other firm-level variables (mark-ups, output, revenue, and profit). Thus, the distribution of all these firm performance measures in the open-economy equilibrium are identical to those in a closed-economy case with a matching

15. In related work, Holmes and Stevens (2004) show that the assumption of lower mark-ups in non-local markets, along with differences in transport costs across sectors, can explain cross-market differences in the size distribution of firms.

16. Since  $p_X^h(c) = p_D^l(c\tau^l) > p_X^l(c\tau^l)/\tau^h = p_D^h(c\tau^l\tau^h)/\tau^h > p_D^h(c)/\tau^h$ .

cost cut-off  $c_D$ . When analysing the impact of trade, we can therefore focus on the determination of the cost cut-off governed by (23).

Comparing this new cut-off condition to the one derived for the closed economy (15) immediately reveals that the cost cut-off is lower in the open economy: trade increases aggregate productivity by forcing the least productive firms to exit. This effect is similar to that analysed in Melitz (2003) but works through a different economic channel. In Melitz (2003), trade induces increased competition for scarce labour resources as real wages are bid up by the relatively more productive firms who expand production to serve the export markets. The increase in real wages forces the least productive firms to exit. In that model, import competition does not play a role in the reallocation process due to the CES specification for demand (residual demand price elasticities are exogenously fixed and unaffected by import competition). In the current model, the impact of these two channels—via increased factor market or product market competition—is reversed: increased product market competition is the only operative channel. Increased factor market competition plays no role in the current model, as the supply of labour to the differentiated goods sector is perfectly elastic. On the other hand, import competition increases competition in the domestic product market, shifting up residual demand price elasticities for all firms at any given demand level. This forces the least productive firms to exit. This effect is very similar to an increase in market size in the closed economy: the increased competition induces a downward shift in the distribution of mark-ups across firms. Although only relatively more productive firms survive (with higher mark-ups than the less productive firms who exit), the average mark-up is reduced. The distribution of prices shifts down due to the combined effect of selection and lower mark-ups. Again, as in the case of larger market size in a closed economy, average firm size and profits increase—as does product variety.<sup>17</sup> In this model, welfare gains from trade thus come from a combination of productivity gains (via selection), lower mark-ups (pro-competitive effect), and increased product variety.

### 3.6. Market size effects

We now focus on the consequences of market size differences for cross-country characteristics in the open-economy equilibrium. Once again, these cross-country differences in firm performance measures will be determined by the differences in the cost cut-offs  $c_D^l$ , as shown in (23). This immediately highlights how costly trade does not completely integrate markets as respective country size plays an important role in determining all firm performance measures and welfare in each country: When trade costs are symmetric ( $\rho^l = \rho^h$ ), the larger country will have a lower cut-off, and thus higher average productivity and product variety, along with lower mark-ups and prices (relative to the smaller country). Welfare levels are thus higher in the larger country. Moreover, the latter will attract relatively more entrants and local producers. In short, all of the size-induced differences across countries in autarky persist (although not to the same extent). It is in this sense that costly trade does not completely integrate markets.

Surprisingly, (23) also indicates that the size of a country's trading partner does not affect the cost cut-off (and hence all firm performance measures and welfare). This highlights some important offsetting effects of trading partner size—although the exact outcome of these trade-offs are naturally influenced by our functional form assumptions. On the export side, a larger trading partner represents increased export market opportunities. However, this increased export market size is offset by its increased “competitiveness” (a greater number of more productive firms are competing in that market, driving down mark-ups). On the import side, a larger trading

17. Comparisons of changes in the variance of all performance measures are also identical to the case of increased market size.

partner represents an increased level of import competition. In the long run, this is offset by a smaller proportion of entrants, and hence less competition in the smaller market.<sup>18</sup>

### 3.7. The open economy in the short run

We now introduce the parallel version of the economy in the short run when it is open to trade. We will use this to separately identify the short- and long-run effects of liberalization in the following section. As was the case for the closed economy, no entry and exit is possible in the short run; incumbent firms decide whether to produce or shut-down. Each country  $l$  is thus characterized by a fixed number of incumbents  $\bar{N}_D^l$  with cost distribution  $\bar{G}^l(c)$  on  $[0, \bar{c}_M^l]$ . We continue to assume that productivity  $1/c$  is distributed Pareto with shape  $k$ , implying  $G^l(c) = (c/\bar{c}_M^l)^k$ . A firm produces if it can earn non-negative profits from sales to either its domestic or export market. This leads to cost cut-off conditions for sales in either market:  $c_D^l = \sup\{c : \pi_D^l(c) \geq 0 \text{ and } c \leq \bar{c}_M^l\}$  and  $c_X^l = \sup\{c : \pi_X^l(c) \geq 0 \text{ and } c \leq \bar{c}_M^l\}$ .<sup>19</sup> Either of these cut-offs can reach their upper bound at  $\bar{c}_M^l$ , in which case all incumbent firms produce. So long as this is not the case, the cut-offs must satisfy the threshold price conditions in (24):

$$N^l = \frac{2(k+1)\gamma}{\eta} \frac{\alpha - c_D^l}{c_D^l}, \quad \text{whenever } c_D^l < \bar{c}_M^l, \quad (27)$$

$$N^h = \frac{2(k+1)\gamma}{\eta} \frac{\alpha - \tau^h c_X^l}{\tau^h c_X^l}, \quad \text{whenever } c_X^l < \bar{c}_M^l,$$

where  $N^l$  represents the endogenous number of sellers in country  $l$  in the short run. Note that  $c_X^h = c_D^l/\tau^l$  as in the long run whenever both cut-offs are below their respective upper bounds  $\bar{c}_M^h$  and  $\bar{c}_M^l$ .

There are  $\bar{N}_D^l \bar{G}^l(c_D^l)$  producers from country  $l$  who sell in their domestic market and  $\bar{N}_D^h \bar{G}^h(c_X^h)$  exporters from  $h$  to  $l$ . These numbers must add up to the total number of sellers in country  $l$ :  $N^l = \bar{N}_D^l \bar{G}^l(c_D^l) + \bar{N}_D^h \bar{G}^h(c_X^h)$ . Combining this with the threshold price conditions yield expressions for the cost cut-offs in both countries:

$$\frac{\alpha - c_D^l}{(c_D^l)^{k+1}} = \frac{\eta}{2(k+1)\gamma} \left[ \frac{\bar{N}_D^l}{(\bar{c}_M^l)^k} + \rho^l \frac{\bar{N}_D^h}{(\bar{c}_M^h)^k} \right], \quad \text{whenever } c_D^l < \bar{c}_M^l \text{ and } c_X^l < \bar{c}_M^l. \quad (28)$$

This condition clearly highlights the important role played by trading partner industrial size and import competition in the short run. An increase in the number of incumbents in country  $h$  increases import competition in country  $l$  and generates a decrease in the cost cut-off  $c_D^l$ , forcing some of the less productive firms in country  $l$  to shut down.<sup>20</sup> This effect is only offset with entry in the long run.

## 4. TRADE LIBERALIZATION

We have just shown how the firm location decision (driven by free entry in the long run) plays an important role in determining the extent of competition across markets in the open economy.

18. As highlighted by (26), differences in country size induce a larger proportion of entrants into the larger market. Equation (26) also indicates that country size differences must be bounded to maintain an equilibrium with incomplete specialization in the differentiated good sector. As country size differences become arbitrarily large, the number of entrants in the smaller country is driven to 0.

19. In the short run, it is possible for  $c_X^l > c_D^l$ , in which case firms with cost  $c$  in between these two cut-offs produce and export, but do not sell on their domestic market.

20. The overall number of sellers in country  $l$  (and hence product variety) increases as the increase in exporters from  $h$  dominates the decrease in domestic producers in  $l$ .



This location decision also crucially affects the long-run consequences of trade liberalization—especially in situations where the decreases in trade barriers are asymmetric.

#### 4.1. *Bilateral liberalization*

Before illustrating the consequences of asymmetric liberalization, we first quickly describe the case of symmetric liberalization. Here, we assume that trade costs are symmetric,  $\tau^H = \tau^F = \tau$ , and analyse the effects of decreases in  $\tau$  (increases in  $\rho^H = \rho^F = \rho$ ). In this case, the equilibrium cut-off condition (23) can be written:

$$c_D^l = \left[ \frac{\gamma \phi}{L^l(1 + \rho)} \right]^{1/(k+2)}. \quad (29)$$

Bilateral liberalization thus increases competition in both markets, leading to proportional changes in the cut-offs (and hence proportional increases in aggregate productivity) in both countries.<sup>21</sup> The effects of such liberalization are thus qualitatively identical to those described for the transition from autarky to the open economy: Product variety increases as a result of the increased competition, which also induces a decrease in mark-ups and prices. Again, welfare rises from a combination of higher productivity, lower mark-ups, and increased product variety.

Symmetric trade liberalization induces all of the same qualitative results in the short run. Although these effects do not depend on relative country size (so long as the differentiated good is produced in both countries), differences in country size nevertheless induce important changes in the relative pattern of entry in the long run following liberalization. Assuming  $L^l > L^h$ , the positive entry differential  $N_E^l - N_E^h$  widens with liberalization as entry in the bigger market becomes relatively more attractive. This also induces a growing differential in the number of domestic producers  $N_D^l - N_D^h$  (see Appendix for proofs).

#### 4.2. *Unilateral liberalization*

We now describe the effects of a unilateral liberalization by country  $l$  (an increase in  $\rho^l$ , holding  $\rho^h$  constant). Given the cut-off condition (23), this leads to an increase in the cost cut-off  $c_D^l$  (less competition in the liberalizing country)—whereas the cut-off  $c_D^h$  in the country's trading partner decreases, indicating an increase in competition there. The liberalizing country thus experiences a welfare loss while its trading partner experiences a welfare gain.<sup>22</sup> As previously mentioned, these results are driven by the change in firm location induced by entry in the long run. Equation (26) indicates that the number of entrants  $N_E^l$  in the liberalizing country decreases, while the number of entrants in the other country,  $N_E^h$ , increases.

In order to isolate the direct impact of liberalization from the long-run effects generated by entry, we now turn to the short-run responses to unilateral liberalization by country  $l$ . The equilibrium condition (28) for the short-run cut-offs clearly shows that the cost cut-off  $c_D^l$  decreases in response to this liberalization—while the cost cut-off in  $h$ ,  $c_D^h$ , remains unchanged. This highlights the pro-competitive effects of unilateral liberalization in the short run. Although the increase in import competition in  $l$  forces some of the least productive firms there to exit, product variety  $N^l$  nevertheless increases as the increased number of exporters to  $l$  dominates the decrease in domestic producers  $N_D^l$  (see (27)). Welfare in the liberalizing country (in the short

21. As indicated by (26), the number of entrants in the smaller economy is driven to 0 when trade costs drop below a threshold level—and the smaller economy no longer produces the differentiated good. We assume that trade costs remain above this threshold level.

22. Once again, the response of the cut-offs determines the response in all the other country level variables.

run) therefore rises from a combination of higher productivity, lower mark-ups, and increased product variety (welfare in the trading partner remains unchanged in the short run). These results clearly underline how the welfare loss associated with unilateral liberalization is driven by the shift in the pattern of entry (favouring the non-liberalizing trading partner) in the long run.

These long-run effects of liberalization on firm “de-location” have been extensively studied in previous work (see, for example, Venables, 1985, 1987; Horstmann and Markusen, 1986; and the synthesis in Helpman and Krugman, 1989, ch. 7; and Baldwin *et al.*, 2003, ch. 12). The novel features in our work show how this type of liberalization also affects firm selection, aggregate productivity, product variety, and mark-ups within a single model.<sup>23</sup>

#### 4.3. Preferential liberalization

So far, our analysis has been restricted to two countries. This has generated a rich set of insights on the combined impact of market size and trade liberalization on industry performance and welfare. However, focusing on two countries in isolation neglects the effects of a country’s position within an international trading network (which is determined by the whole matrix of bilateral trade barriers). When all trade barriers are symmetric, the insights of a multicountry model are a straightforward extension of the two-country case. However, new insights arise when bilateral barriers are allowed to differ.

While our model can easily deal with any number of countries of any size along with an arbitrary matrix of trade costs (see Appendix), considering three countries of equal size is enough to recover some of these related insights. We therefore introduce a third trading partner  $T$ , with  $L^T = L^H = L^F = L$ . Countries differ in terms of trade barriers that are assumed to be pairwise symmetric, with  $\rho^{lh} = (\tau^{lh})^{-k} = (\tau^{hl})^{-k}$  measuring the “freeness” of trade between countries  $l = \{H, F, T\}$  and  $h \neq l$ . Similarly,  $\rho^{lt}$  and  $\rho^{ht}$  measure the “freeness” of trade between  $l$  and  $h$ , and the third country  $t \neq l \neq h$ . As with the case of unilateral liberalization, preferential trade liberalization (non-proportional changes in these three bilateral trade barriers) induces important shifts in the pattern of entry across countries in the long run. Once again, we analyse both the long-run and short-run effects of such liberalization.

**4.3.1. Long-run equilibrium.** With three countries of equal size, the free entry condition (22) in country  $l$  becomes

$$(c_D^l)^{k+2} + \rho^{lh} (c_D^h)^{k+2} + \rho^{ht} (c_D^t)^{k+2} = \frac{\gamma \phi}{L} \quad l = \{H, F, T\}, \quad t \neq l \neq h.$$

This provides a system of three linear equations in the three domestic cut-offs. When pairwise trade barriers are symmetric, the long-run cut-offs are given by

$$c_D^l = \left[ \frac{\gamma \phi}{L} \frac{(1 - \rho^{ht})[1 + \rho^{ht} - (\rho^{lh} + \rho^{lt})]}{1 + 2\rho^{lh}\rho^{lt}\rho^{ht} - (\rho^{lh})^2 - (\rho^{lt})^2 - (\rho^{ht})^2} \right]^{1/(k+2)}. \quad (30)$$

The corresponding number of sellers  $N^l$  in country  $l$  is still given by (24), while the number of entrants solve  $N_E^l + \rho^{lh} N_E^h + \rho^{lt} N_E^t = N^l (c_M/c_D^l)^k$ .

In (30), international differences in cut-offs stem from the relative freeness measure  $(1 - \rho^{ht})[1 + \rho^{ht} - (\rho^{lh} + \rho^{lt})]$ , which implies that the cut-off is lowest in a country  $l$  with

23. Since most of the previous literature assumes representative firms, the link between trade policy and aggregate productivity (via firm selection into the domestic market) and product variety (via firm selection into export markets) is absent.

the lowest sum of bilateral barriers (highest  $\rho^{lh} + \rho^{lt}$ ). In effect, this country is the best export base or “hub”. Moreover, since  $\rho^{ht}$  enters the expression of the cut-off for country  $l$ , any change in bilateral trade costs affects all three countries. This has important implications for preferential trade agreements.<sup>24</sup> To see this as clearly as possible, consider three countries with initially symmetric trade barriers ( $\rho^{lt} = \rho$ ). The initial cut-offs are then identical and equal to (see (30))

$$c_D = \left[ \frac{\gamma \phi}{L} \frac{1}{1 + 2\rho} \right]^{1/(k+2)} \tag{31}$$

A preferential trade agreement is then introduced between  $H$  and  $F$ , inducing  $\rho^{HF} = \rho' > \rho = \rho^{FT} = \rho^{HT}$ . The new trade regime affects the cut-offs for all countries. From (30), the cut-offs in the liberalizing countries are then

$$c_D^H = c_D^F = \left[ \frac{\gamma \phi}{L} \frac{1 - \rho}{1 - 2\rho^2 + \rho'} \right]^{1/(k+2)}, \tag{32}$$

while the cut-off in the third country is given by

$$c_D^T = \left[ \frac{\gamma \phi (1 - \rho) + (\rho' - \rho)}{L (1 - 2\rho^2 + \rho')} \right]^{1/(k+2)}. \tag{33}$$

The number of entrants in all three countries are given by (recall that  $c_D^H = c_D^F$ )

$$N_E^H = N_E^F = \frac{2(c_M)^k (k + 1)\gamma}{\eta(1 - 2\rho^2 + \rho')} \left[ \frac{\alpha - c_D^H}{(c_D^H)^{k+1}} - \rho \frac{\alpha - c_D^T}{(c_D^T)^{k+1}} \right],$$

$$N_E^T = \frac{2(c_M)^k (k + 1)\gamma}{\eta(1 - 2\rho^2 + \rho')} \left[ (1 + \rho') \frac{\alpha - c_D^T}{(c_D^T)^{k+1}} - 2\rho \frac{\alpha - c_D^H}{(c_D^H)^{k+1}} \right].$$

Comparing (31)–(33), it is easily verified that preferential liberalization leads to lower cut-offs in the liberalizing countries and a higher cut-off in the third country. Thus, average costs, prices, and mark-ups also decrease in the liberalizing countries while they rise in the third country. The liberalizing countries become better “export bases”: they gain better access to each other’s market while maintaining the same ease of access to the third country’s market. Thus, preferential liberalization leads to long-run welfare gains for the liberalizing countries, along with a welfare loss for the excluded country.

**4.3.2. Short run.** In order to highlight how the welfare loss in the third country is driven by the long-run shift in the pattern of entry, we briefly characterize the short-run response to the liberalization agreement between  $H$  and  $F$ . The short-run equilibrium in country  $l$  solves

$$\frac{\alpha - c_D^l}{(c_D^l)^{k+1}} = \frac{\eta}{2(k + 1)\gamma} \left[ \frac{\bar{N}_D^l}{(\bar{c}_M^l)^k} + \rho^{lh} \frac{\bar{N}_D^h}{(\bar{c}_M^h)^k} + \rho^{lt} \frac{\bar{N}_D^t}{(\bar{c}_M^t)^k} \right],$$

where the number of incumbents  $\bar{N}_D^l$  and their productivity distribution on  $[0, \bar{c}_M^l]$  are fixed in all countries, as in the previous short-run examples. When these numbers and distributions are symmetric (same  $\bar{N}$  and  $\bar{c}_M$ ), the country with the best accessibility (highest  $\rho^{hl} + \rho^{lt}$ ) will have the lowest cut-off  $c_D^l$ . This country will have the lowest number of operating firms

24. In the Appendix, we show how such “third-country effect” can also be integrated in a gravity equation.

$N_D^l = \bar{N}_D^l G(c_D^l)$ , but the highest number of sellers  $N^l$  (see (27)). Since the preferential liberalization between  $H$  and  $F$  does not affect accessibility to the third country ( $\rho = \rho^{FT} = \rho^{HT}$ ), the cut-off in the latter is unaffected by the preferential liberalization in the short run. As in the case of unilateral liberalization, it is the long-run change in entry behaviour that is responsible for reduced competition and lower welfare in the excluded third country. On the other hand, the liberalizing countries gain in both the short run (via the direct pro-competitive effect) and the long run, when the pro-competitive effect is reinforced by the beneficial impact of increased entry.

## 5. CONCLUSION

We have presented a rich, though tractable, model that predicts how a wide set of industry performance measures (productivity, size, price, mark-up) respond to changes in the world trading environment. Our model incorporates heterogeneous firms and endogenous mark-ups that respond to the toughness of competition in a market. In such a setting, we show how market size induces important changes in industry performance measures: larger markets exhibit tougher competition resulting in lower average mark-ups and higher aggregate productivity. We also show how costly trade does not completely integrate markets and thus does not obviate these important consequences of market size differences across trading partners.

We then analyse several different trade liberalization scenarios. Our model highlights the pro-competitive effects of increased import competition and its effect on mark-ups, productivity, and product variety in the liberalized import market. Our model also echoes the findings in previous work that show how the short-run gains of asymmetric liberalization can be reversed by shifts in the pattern of entry in the long run. However, our model additionally incorporates the important feedbacks between entry and firm selection into domestic and export markets.

Although each of these individual channels for trade-induced gains have been previously analysed in models with different structures, we believe it is important to show how all of these channels can be captured within a single unified framework. This framework develops a new and very tractable way of describing how differences in market size and trade costs across trading partners affect the distribution of key firm-level performance measures across markets. We hope that this provides a useful foundation for future empirical investigations.

## APPENDIX

### A.1. Variance of firm performance measures

Let  $\sigma_c^2 = [\int_0^{c_D} (c - \bar{c})^2 dG(c)]/G(c_D)$  denote the variance of the firm cost draws. As was mentioned earlier in the main text, the variance of all the firm performance measures can be written as simple expressions of this variance:

$$\begin{aligned}\sigma_p^2 &= \frac{1}{4}\sigma_c^2, \quad \sigma_q^2 = \frac{L^2}{4\gamma^2}\sigma_c^2, \\ \sigma_\mu^2 &= \frac{1}{4}\sigma_c^2, \quad \sigma_r^2 = \frac{L^2}{16\gamma^2}\sigma_c^2,\end{aligned}$$

where  $\sigma_z^2 = [\int_0^{c_D} [z(c) - \bar{z}]^2 dG(c)]/G(c_D)$  and  $\bar{z}$  denote the variance and mean of a firm performance measure  $z(c)$ . Given the chosen parametrization for the cost draws,  $\sigma_c^2 = [k/(k+1)^2(k+2)]c_D^2$ .

### A.2. Multiple countries, asymmetric trade costs, and comparative advantage

Our model can be readily extended to a setting with an arbitrary number of countries, asymmetric trade costs, and comparative advantage. Let  $M$  denote the number of countries, indexed by  $l = 1, \dots, M$ . As in the main text  $\rho^{lh} = (\tau^{lh})^{-k} \in (0, 1]$  measures the “freeness” of trade for exports from  $l$  to  $h$ . When trade costs are interpreted in a wide sense as all distance-related barriers, then within country trade may not be costless, and we allow for any  $\rho^{ll} \in (0, 1]$ . We introduce comparative advantage as technology differences that affect the distribution of the firm-level productivity

draws. For tractability, we assume that firm productivity  $1/c$  is distributed Pareto with shape  $k$  in all countries, but allow for differences in the support of the distributions via differences in the upper-bound cost  $c_M^l$ . The cost draws in country  $l$  thus have a distribution  $G^l(c) = (c/c_M^l)^k$ . Whenever  $c_M^l < c_M^h$ , country  $l$  will have a comparative advantage with respect to country  $h$  in the differentiated good sector: entrants in country  $l$  have a better chance of getting higher productivity draws.<sup>25</sup>

In this extended model, the free entry condition (22) in country  $l$  becomes

$$\sum_{h=1}^M \rho^{lh} L^h (c_D^h)^{k+2} = \frac{2\gamma(k+1)(k+2)f_E}{\psi^l}, \quad l = 1, \dots, M,$$

where  $\psi^l = (c_M^l)^{-k}$  is an index of comparative advantage. This yields a system of  $M$  equations that can be solved for the  $M$  equilibrium domestic cut-offs using Cramer's rule:

$$c_D^l = \left( \frac{2(k+1)(k+2)f_E\gamma}{|P|} \frac{\sum_{h=1}^M |C_{hl}|/\psi^h}{L^l} \right)^{1/(k+2)}, \tag{A.1}$$

where  $|P|$  is the determinant of the trade freeness matrix

$$P \equiv \begin{pmatrix} \rho_{11} & \rho_{12} & \dots & \rho_{1M} \\ \rho_{21} & \rho_{22} & \dots & \rho_{2M} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{M1} & \rho_{M2} & \dots & \rho_{MM} \end{pmatrix},$$

and  $|C_{hl}|$  is the cofactor of its  $\rho_{hl}$  element. Cross-country differences in cut-offs now arise from three sources: own country size ( $L^l$ ), as well as a combination of market access and comparative advantage ( $\sum_{h=1}^M |C_{hl}|/\psi^h$ ). Countries benefiting from a larger local market, a better distribution of productivity draws, and better market accessibility have lower cut-offs.

The mass of sellers  $N^l$  in each country  $l$  (including domestic producers in  $l$  and exporters to  $l$ ) is still given by (24). Given a positive mass of entrants  $N_E^l$  in all countries, there are  $G^l(c_D^l)N_E^l$  domestic producers and  $\sum_{h \neq l} G^l(c_X^{hl})N_E^h$  exporters selling in  $l$ , where  $c_X^{hl}$  is the export cut-off from  $h$  to  $l$ . This implies

$$\sum_{h=1}^M \rho^{hl} \psi^h N_E^h = \frac{N^l}{(c_D^l)^k}.$$

The latter provides a system of  $M$  linear equations that can be solved for the number of entrants in the  $M$  countries using Cramer's rule:<sup>26</sup>

$$N_E^l = \frac{2(k+1)\gamma}{\eta|P|\psi^l} \sum_{h=1}^M \frac{(\alpha - c_D^h)|C_{lh}|}{(c_D^h)^{k+1}}. \tag{A.2}$$

Given  $N_E^l$  entrants in country  $l$ ,  $N_E^l G^l(c_D^l)$  firms survive and produce for the local market. Among the latter,  $N_E^l G^l(c_X^l)$  export to country  $h$ .

### A.3. A gravity equation

Our multilateral model with heterogeneous firms, asymmetric trade costs, and comparative advantage also yields a gravity equation for aggregate bilateral trade flows. An exporter with cost  $c$  from country  $h$  generates export sales  $r_X^{lh}(c) = p_X^{lh}(c)q_X^{lh}(c)$  where (see (19) and (20))

$$p_X^{lh}(c) = \frac{\tau^{lh}}{2}(c_X^{lh} + c) = \frac{1}{2}(c_D^h + \tau^{lh}c),$$

$$q_X^{lh}(c) = \frac{L^h \tau^{lh}}{2\gamma}(c_X^{lh} - c) = \frac{L^h}{2\gamma}(c_D^h - \tau^{lh}c).$$

25. The distribution of productivity draws in  $l$  stochastically dominates that in  $h$ .

26. We use the properties that relate the freeness matrix  $P$  and its transpose in terms of determinants and cofactors.

Aggregating these export sales  $r_X^{lh}(c)$  over all exporters from  $l$  to  $h$  (with cost  $c \leq c_X^{lh}$ ) yields the aggregate bilateral exports from  $l$  to  $h$ :<sup>27</sup>

$$\begin{aligned} \text{EXP}^{lh} &= N_E^l \int_0^{c_X^{lh}} r_X^{lh}(c) dG^l(c) \\ &= N_E^l \frac{L^h}{4\gamma} \int_0^{c_D^h/\tau^{lh}} [(c_D^h)^2 - (\tau^{lh}c)^2] dG^l(c) \\ &= \frac{1}{2\gamma(k+2)} N_E^l \psi^l L^h (c_D^h)^{k+2} (\tau^{lh})^{-k}. \end{aligned} \tag{A.3}$$

This gravity equation determines bilateral exports as a log-linear function of bilateral trade barriers and country characteristics. As in Eaton and Kortum (2002) and Helpman, Melitz and Rubinstein (2007), (A.3) reflects the joint effects of country size, technology (comparative advantage), and geography on both the extensive (number of traded goods) and intensive (amount traded per good) margins of trade flows. Similarly, (A.3) highlights how—holding the importing country size fixed—tougher competition in that country (lower average prices, reflected by a lower  $c_D^l$ ) dampens exports by making it harder for potential exporters to break into that market.

A.4. Selection into export markets

In this section, we show that the assumption of a non-specialized equilibrium where both countries produce the differentiated good ( $N_E^l > 0$ ,  $l = H, F$ ) implies that only a subset of relatively more productive firms choose to export in either country ( $c_X^l < c_D^l$ ,  $l = H, F$ ). In the text, we showed that the number of entrants  $N_E^l$  satisfied (26). Thus,

$$\begin{aligned} N_E^l > 0 &\iff \frac{\alpha - c_D^l}{(c_D^l)^{k+1}} > \rho^l \frac{\alpha - c_D^h}{(c_D^h)^{k+1}} \\ &\iff \frac{\alpha - c_D^l}{\alpha - c_D^h} \left( \frac{c_D^h}{c_D^l} \right)^{k+1} > \rho^l \\ &\iff \frac{\frac{\alpha}{\tau^l} - c_X^h}{\alpha - c_D^h} \left( \frac{c_D^h}{c_X^h} \right)^{k+1} > 1, \end{aligned}$$

which is incompatible with  $c_X^h \geq c_D^h$ . Therefore,  $c_X^h < c_D^h$  for  $h = H, F$ .

A.5. Bilateral liberalization

In this section, we prove a set of results for the two country model with different country sizes and symmetric trade barriers. Some results are already mentioned in the main text, while others complement the latter and provide a more detailed characterization of the effects of bilateral liberalization.

When trade barriers are symmetric,  $\rho^l = \rho^h = \rho$ , the number of entrants from (26) can be simplified to

$$N_E^l = \frac{(c_M)^k}{1 - \rho^2} \left[ \frac{N^l}{(c_D^l)^k} - \rho \frac{N^h}{(c_D^h)^k} \right]. \tag{A.4}$$

Among these entrants, only

$$N_D^l = G(c_D^l) N_E^l = \left( \frac{c_D^l}{c_M} \right)^k N_E^l, \tag{A.5}$$

firms survive and produce. Without loss of generality, we assume  $L^l > L^h$ . The following results then apply:

1. The domestic cut-off is lower in the larger country:  $c_D^l < c_D^h$ .

*Proof.* Follows directly from (29).

27. The integration measure  $G^l(c_X^h)$  represents the proportion of entrants  $N_E^l$  in  $l$  that export to  $h$ .



2. There are more sellers in the larger country:  $N^l > N^h$ .

*Proof.* Given 1, follows directly from (24).

3. There are more entrants in the larger country:  $N_E^l > N_E^h$ .

*Proof.* Given 1 and 2, follows directly from (A.4).

4. There are more local producers in the larger country:  $N_D^l > N_D^h$ .

*Proof.* Given (A.4) and (A.5),

$$N_D^l = \frac{1}{1-\rho^2} \left[ N^l - \rho N^h \left( \frac{c_D^l}{c_D^h} \right)^k \right]. \tag{A.6}$$

The result then follows directly from 1 and 2.

5. Trade liberalization reduces the domestic cut-off differential:  $d(c_D^h - c_D^l)/d\rho < 0$ .

*Proof.* Given (29), the result follows directly from

$$c_D^h - c_D^l = \left[ \frac{\gamma\phi}{1+\rho} \left( \frac{1}{L^h} - \frac{1}{L^l} \right) \right]^{1/(k+2)} > 0.$$

6. Trade liberalization increases the cross-country difference in the number of sellers:  $d(N^l - N^h)/d\rho > 0$ .

*Proof.* Given (29) and (27), the result follows directly from

$$\begin{aligned} N^l - N^h &= \frac{2(k+1)\gamma\alpha}{\eta} \left( \frac{1}{c_D^l} - \frac{1}{c_D^h} \right) \\ &= \frac{2(k+1)\gamma\alpha}{\eta} \left( \frac{1+\rho}{\gamma\phi} \right)^{1/(k+2)} \left[ (L^l)^{1/(k+2)} - (L^h)^{1/(k+2)} \right] > 0. \end{aligned}$$

7. Trade liberalization increases the cross-country difference in the number of entrants:  $d(N_E^l - N_E^h)/d\rho > 0$ .

*Proof.* Given (29), (24), and (A.4),

$$\begin{aligned} N_E^l - N_E^h &= \frac{(c_M)^k}{1-\rho} \left[ \frac{N^l}{(c_D^l)^k} - \frac{N^h}{(c_D^h)^k} \right] \\ &= \frac{2(k+1)\gamma}{\eta} \frac{(c_M)^k}{1-\rho} \left[ \frac{\alpha - c_D^l}{(c_D^l)^{k+1}} - \frac{\alpha - c_D^h}{(c_D^h)^{k+1}} \right] > 0. \end{aligned}$$

Then,

$$\begin{aligned} \frac{d(N_E^l - N_E^h)}{d\rho} &= \frac{2(k+1)\gamma(c_M)^k}{\eta} \frac{1}{(1-\rho)^2} \left[ \frac{\alpha - c_D^l}{(c_D^l)^{k+1}} - \frac{\alpha - c_D^h}{(c_D^h)^{k+1}} \right] \\ &\quad + \frac{2(k+1)\gamma(c_M)^k}{\eta(k+2)} \frac{1}{(1+\rho)(1-\rho)} \left[ \frac{\alpha(k+1) - kc_D^l}{(c_D^l)^{k+1}} - \frac{\alpha(k+1) - kc_D^h}{(c_D^h)^{k+1}} \right] \\ &> 0. \end{aligned}$$

8. Trade liberalization increases the cross-country difference in the number of producers:  $d(N_D^l - N_D^h)/d\rho > 0$ .

*Proof.* Given (29) and (A.6),

$$\begin{aligned} N_D^l - N_D^h &= \frac{1}{1-\rho^2} \left\{ N^l \left[ 1 + \rho \left( \frac{c_D^h}{c_D^l} \right)^k \right] - N^h \left[ 1 + \rho \left( \frac{c_D^l}{c_D^h} \right)^k \right] \right\} \\ &= \frac{1}{1-\rho^2} \left\{ N^l \left[ 1 + \rho \left( \frac{L^l}{L^h} \right)^{k/(k+2)} \right] - N^h \left[ 1 + \rho \left( \frac{L^h}{L^l} \right)^{k/(k+2)} \right] \right\}. \end{aligned}$$

Furthermore,

$$\begin{aligned} \frac{dN^l}{d\rho} &= \frac{dN^l}{dc_D^l} \frac{dc_D^l}{d\rho} = \frac{2(k+1)\gamma\alpha}{\eta(k+2)} \frac{1}{c_D^l} \frac{1}{1+\rho}, \\ \frac{dN^h}{d\rho} &= \frac{dN^h}{dc_D^h} \frac{dc_D^h}{d\rho} = \frac{2(k+1)\gamma\alpha}{\eta(k+2)} \frac{1}{c_D^h} \frac{1}{1+\rho} < \frac{dN^l}{d\rho}. \end{aligned}$$

Given  $(L^l/L^h)^{k/(k+2)} > (L^h/L^l)^{k/(k+2)}$ , then  $d(N_D^l - N_D^h)/d\rho > 0$ .

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