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# Technology, Market Structure and the Gains from Trade

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# Technology, Market Structure and the Gains from Trade*

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**Abstract**

We study the gains from trade in a new model with oligopolistic competition, firm heterogeneity, and innovation. Lowering trade costs reduces markups on domestic sales but increases markups on export sales, as firms do not pass the entire reduction in trade costs onto foreign consumers. Trade liberalisation can also reduce the number of firms competing in each market, thereby increasing markups on both domestic and export sales. For the majority of exporters, however, the pro-competitive effect prevails and their average markups decline. The incomplete pass-though and the reduction in the number of competitors instead dominate for top-exporters – the top 0.1% of firms – which end up increasing their markup. In a quantitative exercise we find that the aggregate effect of trade-induced markup changes is pro-competitive and accounts for the majority of the welfare gains from trade. Trade-induced changes in competition affect survival on domestic and export markets and firms' decision to innovate. All exporters, and especially the top exporters, increase their market size after liberalisation which, in turn, encourages them to innovate more. Hence, top exporters contribute negatively to welfare gains by increasing their markups but positively by increasing innovation and productivity. Firms' innovation response accounts for a small but non-negligible share of the welfare gains while the contribution of selection is U-shaped, being negative for small liberalisations and positive otherwise. A more globalised economy is therefore populated by *larger*, *fewer* and *more innovative* firms, each feature representing an important source of the gains from trade.

***Keywords:*** Gains from Trade, Heterogeneous Firms, Oligopoly, Innovation, Endogenous Markups, Endogenous Market Structure.
***JEL Classification:*** F12, F13, O31, O41.

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# 1 Introduction

Modern economies are dominated by a few global firms that are large, highly productive, and have substantial market power. The top one percent of US exporters accounts for more than 80 percent of total US trade (Bernard et al. 2016), and their market power varies both in the cross-section of these firms and along the time dimension (Hottman et al, 2016, De Loecker and Eeckhout, 2017).[1] Large firms are also found to be key players in innovation races to increase their market shares in the global economy (Bustos, 2011, Aghion et al. 2017). Standard models of international trade with heterogeneous firms, however, do not usually capture the market structure and the strategic nature of competition amongst these large players.

With global markets populated by large players where technology is at the root of firms competitiveness, it is critical to incorporate large firms into the analysis of the benefits from globalisation. In this paper we study the welfare gains from trade in an economy with heterogeneous firms where both technology and market structure are endogenously determined. Our economy is characterised by oligopolistic firms, which are heterogeneous in productivity and market power. The response of technology and market structure to lowering trade barriers shapes the welfare impact of globalisation. The main goal of the paper is to assess the contribution of competition through variable markups, selection and innovation to the gains from trade.

We build a global economy with two symmetric countries in which firms compete in a Cournot game with a small number of domestic and foreign rivals (cf. Brander and Krugman, 1983). Cournot competition within each product line generates variable markups providing the key foundation for our analysis. Productivity differs across product lines, but the small number of firms competing head-to-head in each line has identical productivity. Entry is directed to a particular line and pins down the number of local and foreign firms. As a consequence, markups differ across product lines and the equilibrium depends critically on the endogenous distribution of market power. After entry, firms decide how much resources they want to devote to production, and how much they allocate to improve their productivity via innovation. Since innovation reduces a firms' unit cost (by increasing their productivity), its benefits are larger if they can be applied to a larger quantity produced. Hence, market size is the driver of innovation. In addition, fixed operating costs generate selection on both the domestic and export market.

A reduction in trade costs increases foreign competitive pressure which shrinks markups on domestic sales. Moreover, exporters do not pass the whole reduction in trade costs onto foreign consumers, and increase their markups on export sales. Abstracting from entry, we show that the pro-competitive force dominates for all exporters and the average markup of exporting firms declines with trade liberalisation. Free entry adds an additional layer of complication to the model and we

[1] Mayer and Ottaviano (2007) find that the share of exports attributable to the top one percent of exporters is 59 percent for Germany, 44 percent for France, 42 percent for the UK, 32 percent for Italy, 77 for Hungary, 48 percent for Belgium, and 53 percent for Norway. Freud and Pierola (2015) report that the top five percent of firms account for 30 percent of export across the 32 developing countries in their study.

therefore explore its properties numerically. Calibrating the model to match some key aggregate and firm-level US statistics, we find that the increase in competition triggered by a reduction in trade costs affects the incentives of some firms to enter the market. In particular, after trade liberalisation a very small fraction of exporters – the top-0.1% – experience a decline in the number of competitors on both their domestic and foreign markets and, consequently, they charge higher markups on both markets. For the majority of exporters instead, the *pro-competitive effect* dominates and their average markups decline.

Firm heterogeneity and innovation provide additional (indirect) channels through which the trade-induced increase in competition propagates in the economy. Survival on the domestic market has negligible effects, while selection into the export markets proves to be important. Similarly to Brander and Krugman (1983), when close to autarky, trade liberalisation reduces average profits of exporters, as most of their sales are domestic and domestic markups decline with liberalisation. When the economy is fairly open, export sales are large and, by increasing export markups, trade liberalisation increases exporters average profits. In our heterogeneous firms economy this implies that moving from autarky to free trade exporting first becomes harder, survival declines, and subsequently becomes easier. This leads to a *inverted-U* relationship between trade costs and the gains from trade attributable to selection.

Trade-induced changes in markups and selection reallocate market shares across firms, thereby affecting their incentives to innovate. The market size of all exporters increases proportionally to their productivity. Larger market size pushes exporters to innovate more thereby generating an additional channel of gains from trade. Due to the reduction in the number of competitors, top exporters experience the highest increase in size and thereby providing the biggest boost to innovation. Hence, although the trade-induced increase in top exporters' market power generates welfare losses, their innovation response contributes positively to the welfare gains.

In our economy, competition, selection and innovation are jointly determined, and there are complex general equilibrium feedbacks arising from each channel. These feedbacks make the decomposition of the total gains from trade into its different sources challenging. We propose a simple method to decompose the total gains into the direct contribution of the changes in competition and the indirect contributions through selection and innovation. Going from the benchmark trade barrier to free trade, roughly corresponding to an increase in the import share of GDP from about 11% to 18%, and increases welfare by 2.7% as a compensating variation. About two thirds of these gains are accounted for by the pro-competitive effect of trade on markups. Selection accounts for 27% of the gains, although it generates losses for smaller liberalisation experiments. Innovation generates 13% of the gains. Finally, the negative effect on producers' surplus, via firm profits, reduces the overall gains by 6%.[2]

**Literature review.** Our paper contributes to a long-standing literature on the welfare gains from trade. The firm heterogeneity revolution in the empirics and theory of international trade has brought a new life to this classic question, allowing researchers to understand better the dispersed effects

[2]Free entry does not lead to zero profits in our economy, as the number of firms is discrete.

trade brings forth. An important challenge, however, has been to understand whether new models incorporating firm heterogeneity bring along new sources of welfare gains from openness. Importantly, Arkolakis, Costinot, and Rodriguez-Clare (2012) (ACR henceforth) show that in a large class of monopolistically competitive economies – all sharing the same macro restrictions but differing in the firm-level details – the selection effect originating from firm heterogeneity does not add new gains from trade. Melitz and Redding (2015), on the other hand, find that small, plausible, departures from the ACR restrictions lead to substantial new gains due to firm heterogeneity. Arkolakis, Costinot, Donaldson and Rodriguez-Clare (2017) (ACDR henceforth) extend the ACR analysis to a class of monopolistically competitive models with variable markups obtained through departures from CES demand. They find that neither firm heterogeneity nor variable markups generate new channels of welfare gains. In contrast, our Cournot oligopoly framework sits outside the class of models considered in these papers, and therefore complements the analysis therein.

Along the lines of ACR's analysis, a few papers have included innovation amongst the "micro" details of trade models, and studied whether the additional welfare gains can be related to the innovation response of heterogeneous firms to trade. In a dynamic model with constant markups (and absent of long-run growth), Atkeson and Burstein (2010) show that the role of innovation depends on the curvature of the innovation technology and on the speed of the transitional dynamics towards the steady state. In their benchmark model, and in most of their key specifications, innovation does not noticeably affect the gains from trade, unless strong knowledge spillovers are introduced.[3] In an endogenous growth model with cost-reducing innovation, variable markups and heterogeneous firms, Impullitti and Licandro (2017) find that by affecting the long-run growth rate of productivity, innovation can double the gains from trade otherwise obtainable in static models. This paper is closely related to the analysis in Impullitti and Licandro (2017) with some key critical departures. First, we adopt a more sophisticated entry structure which allows markups to vary with firm productivity, which closely aligns with the empirical evidence highlighting large markup dispersion across firms (Hottman et al. 2016). Second and more importantly, we analyse a static model without any knowledge spillovers influencing the welfare impact of innovation. We contribute to this literature showing that, even in the absence of spillovers, innovation has a non-negligible contribution to the gains from trade.

Oligopolistic trade is a road less traveled in international trade theory. Atkeson and Burstein (2008) brought it back to the big stage, showing that incomplete pass-through of cost-shocks to markups – a feature typically found in oligopoly trade models with Cournot competition – is important to explain international relative prices. The backbone model of trade under oligopoly was introduced by Brander (1981) and extended to free-entry by Brander and Krugman (1983). We embed this structure in a heterogeneous firm economy, drawing on the "small in the large and large in the small" approach to devise it in general equilibrium (Neary, 2003), and show that this class of models has important

[3]Akcigit, Ates, and Impullitti (2018) propose a new model of trade and innovation-driven growth. Calibrating it to match key statistics of the US and its major trade partners in the 1970s and 1980s they document a substantial role of innovation in shaping the long-run gains from trade.

implications for the new gains from trade.[4] More recently, Edmond, Midrigan and Xu (2015) (EMX henceforth) present a quantitative evaluation of the pro-competitive gains from trade in the framework developed by Atkeson and Burstein (2008). Their extension of the benchmark set-up with entry is similar to our model, but it features neither innovation nor selection, which is eliminated by some of the simplifying assumptions needed to accommodate entry. We complement their analysis by building a model that allows us to jointly evaluate the pro-competitive gains from trade that (additionally) arises through selection and innovation. Moreover, our paper differs from theirs also in the analysis of the pro-competitive gains. They measure the pro-competitive gains from a reduction in misallocation brought about by trade liberalization. We instead, in line with ACDR, measure the pro-competitive gains as the additional welfare gains obtainable in models with variable markups, in contrast to models where markups are constant.

The complex interaction between market size, innovation and competition analysed here touches upon the early work on technology and market structure pioneered by Dasgupta and Stiglitz (1980), further refined in Sutton (1991, 1998), and extended to general equilibrium in Peretto (1996). This line of work shows that, on the one hand, firms' market power leads to heavy inefficiencies but, on the other hand, strong innovation spending by powerful firms can offset these inefficiencies. The welfare properties of these economies depend on these two opposite forces. While these earlier papers focus on closed economy stage-games with quality/productivity improving innovation and with homogeneous firms, we extend the analysis to international trade and firm heterogeneity. In the closed economies analysed in the above papers, high market concentration is associated with high profits, leading to large inefficiencies. In our open economy, trade-induced increases in market size operate essentially through a reduction in trade costs. Indeed, lowering trade costs reduces domestic markups, thereby generating equilibria where increases in the aggregate size of the market (via globalization) produce high concentration (via exit), but with lower – not higher – average markup, and with important implications for the link between trade, market size and welfare. Moreover, trade-induced selection affects average productivity, thereby generating additional welfare gains not obtainable in models with representative firms.[5]

Taking stock, our key contribution is to the literature on the gains from trade. In most models with constant markups – as shown in ACR – selection does not generate additional gains from trade; in addition, in the models of monopolistic competition and variable markups considered in ACDR, the pro-competitive gains from trade are "elusive". Atkeson and Burstein (2010) show that there are no additional gains from innovation in new trade models with firm heterogeneity unless strong

[4] Head and Spencer (2017) attribute the recent reappearance of oligopolistic competition in international trade to the solution of some of the technical challenges presented by these models, and to their clear empirical relevance in a world with global powerful firms.

[5] Van Long et al. (2011) present a related model with oligopoly trade and firm heterogeneity in which firms innovate before entering the market, in order to study the effects of trade on innovation – abstracting from any welfare considerations. Since before entering firms do not know their productivity, innovation is homogeneous across firms. Moreover, firm-level innovation is independent of trade costs, and trade affects aggregate innovation only through its effect on the number of firms.

knowledge spillovers are introduced. We complement these findings by first showing that moving away from monopolistic competition toward oligopoly, selection has both the standard extensive and a new intensive margin, generating first negative and then positive gains from selection. Moreover, the selection effect on welfare becomes more uniformly negative the larger the love-for-variety externality. Second, we show that the pro-competitive gains, due to variable markups, robustly account for more than half of the gains from trade. Third, a simple innovation choice, not affected by any empirically hard-to-discipline knowledge spillovers generates additional non-negligible gains from trade. Fourth, we also show that the key feature driving the difference between our results and those of models with constant markups is the variable trade elasticity featured in our model. Finally, we complement EMX with an entry strategy which allows us to preserve selection and provide a more comprehensive assessment of the various channels of the gains from trade.

# 2 Economic Environment

We first provide an overview of the model and then proceed to the description of the economic environment. Consider a static world economy populated by two symmetric countries. In each of these economies there is a (measure one) mass of potential varieties of a composite consumption good, and a small number of potential firms producing each variety. Each firm can produce one variety only. Preferences are CES defined over the set of produced varieties, with an elasticity of substitution larger than one. In equilibrium, not all potential varieties are produced. There is only one factor of production, labor, which is supplied inelastically. Firms produce each variety with a production technology that is linear in labor; labor productivity differs across varieties. Production also requires a fixed operating cost. The initial productivity of all varieties is common knowledge and Pareto distributed on a bounded interval. There is also an R&D technology that firms may use to increase their productivity, after they receive their initial draw.

Firms in both countries produce the same varieties, using the same technologies. They can sell in each others' markets upon payment of an iceberg-type trade cost. In equilibrium, due to fixed production costs, a set of varieties will be sold domestically and another set will be also sold abroad by a discrete finite number of identical Cournot competitors, competing independently in the domestic and foreign markets. Two-way trade in identical goods takes place due to the "segmented market" perception which posits that each firm perceives each country as a separate market and makes separate decisions for each (Brander and Krugman, 1983). Equilibrium domestic and export markups negatively depend on the number of both domestic and foreign competitors (weighted by their market shares). For each non-exported and exported variety, the equilibrium number of competitors in each country is given by an entry condition that exhausts any potential gains from entry.

The timing of the Cournot game is the following. First, productivity of all domestic and foreign varieties realises. Second, firms enter the market until any further potential gains from entry are exhausted; as a consequence, a finite discrete number of domestic (and foreign) firms compete in the production of each variety and some low productive varieties are not produced. Third, firms conduct R&D in order to increase their labor productivity. Finally, they decide how much labor to hire, produce and sell to consumers. In doing so, they behave as Cournot competitors.

**Preferences.** Both economies are populated by a continuum of identical consumers of measure one. Households are endowed with one unit of labor which is supplied inelastically. Labor is the numéraire. The representative consumer has "generalized CES" preferences defined on a continuum of varieties or product lines of endogenous mass $M$, $M \in [0,1]$, according to

$$X = M^{\nu} \left( \int x(z)^{\alpha} \, \mathrm{dF}(z) \right)^{\frac{1}{\alpha}}, \tag{1}$$

where $x(z)$ represents consumption of variety $z$, and $\mathrm{F}(z)$ is the equilibrium distribution of varieties across $z$. This preference structure – first introduced by Dixit and Stiglitz (1977), and further explored in Benassy (1996) – allows us to separate love for variety, captured by parameter $\nu$, $\nu \geq 1$, from $\alpha$, $\alpha \in (0,1)$, which determines firms' market power. Notice that the term within brackets is a measure of the average utility of the consumed bundle of varieties, which is then multiplied by a measure of how the mass of varieties directly affects utility. In the case of $\nu = 1$, there is no love-for-variety, since an increase in the mass of varieties is perfectly compensated by an equivalent reduction in the consumption of all varieties. The pure love-for-variety effect on welfare is then pinned down by $\nu - 1$. In the particular CES specification of Dixit and Stiglitz (1977), $\nu = 1/\alpha$ and the welfare effect of changing the mass of varieties is given by $\nu - 1 = (1-\alpha)/\alpha$. As shown in Benassy (1998), the equilibrium allocation does not depend on $\nu$, whose only role is to determine the welfare effect of the mass of varieties. As our global economy consists of countries symmetric in all features including the range of produced varieties, the relevant gains from trade are not related to the expansion of available varieties, and we set $\nu = 1$ to shut this aspect of the model down for most of the quantitative analysis.

**Entry.** We assume that there is a mass of measure one of potential varieties. In equilibrium, a mass $M \in (0,1)$ of varieties is actually produced, some of them are exported while others are not. Let us use subindices $p$ and $x$ to refer to produced but non-exported varieties and exported varieties, respectively. A variety $z$ is domestically produced by $n$ identical firms, $n \in \{1,2,3,...\}$, manufacturing perfectly substitutable goods and competing à la Cournot. All $n$ firms producing the same variety $z$ have the same technology. In equilibrium, free entry endogenously determines the number of firms $n$ and consequently their markups across product lines.

**Initial productivity and R&D.** Let $z$ denote the draw of initial productivity at entry. The entry distribution of productivity across varieties is assumed to be a bounded Pareto,

$$\Phi(z) = \frac{1-(\underline{\omega}/z)^{\kappa}}{1-(\underline{\omega}/\bar{\omega})^{\kappa}}, \tag{2}$$

for $z \in (\underline{\omega}, \bar{\omega})$, $0 < \underline{\omega} < \bar{\omega} < \infty$, with $\kappa > 1$. We have chosen the bounded Pareto for tractability reasons which will be clear later. In order to transform the initial draw of potential productivity into *actual* productivity, firms need to allocate labor resources according to the R&D technology

$$\tilde{z} = A\, h^{\eta}\, z, \tag{3}$$

where $\tilde{z}$ denotes the actual productivity, and $\eta \in (0,1)$ and $A > 0$ are constant parameters. The variable $h$ represents labor allocated to innovation activities.

**Technology and market structure.** Firms use labor to cover both variable production costs and a fixed operating cost $\lambda > 0$. Variable production costs are assumed to differ across varieties, but firms producing the same variety are assumed to share the same cost. There is then between-variety heterogeneity, but within-variety homogeneity. A firm producing a variety with potential productivity $z \in (\underline{\omega}, \bar{\omega})$, faces the following cost function

$$\ell = \tilde{z}^{\frac{\alpha-1}{\alpha}} q + \lambda, \tag{4}$$

where $\ell$ represents the amount of labor required to produce $q$ units of output, and $\tilde{z}$ the actual productivity associated to the potential productivity $z$. Variable costs are assumed to be decreasing in the firm's state of technology. A variety $z$ is domestically produced by a small endogenous number $n \in \{1,2,3,...\}$ of identical firms, manufacturing perfectly substitutable goods and competing à la Cournot. This technology is similar to the one in Melitz (2003), where an industry with a CES aggregate of differentiated varieties features different technologies across varieties. The key difference is that in Melitz (2003) a variety is produced by one firm, while here it is produced by a small number of firms with identical technologies.[6] Similar to the model in Melitz (2003), each firm competes horizontally with the many other firms producing imperfectly substitutable goods with different efficiencies, but in addition it also competes vertically with the few other firms in the same product line.[7]

Our symmetric-countries assumption implies that both countries produce exactly the same varieties

[6] In our numerical implementation, we have one or two domestic firms, some of them, the exporters, competing with one or two foreign firms.

[7] Interpreting this as a model of heterogeneous industries would not be consistent with the fact that empirically, even at the finest level of classification, sectors consist of many different goods produced by many firms. Six-digits NAICS sectors – as, for instance, Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing – comprise over thirty sectors ranging from satellites antennas, to cellular phones and televisions. Hence, we interpret this as a model of an economy with heterogeneous firms rather than heterogeneous industries. Introducing some heterogeneity between the few firms within the same product line would generalise the model without affecting the fundamental results.

with the same technology and the same productivity distribution. As we show next, this economy features two-way trade in similar goods, as in standard oligopoly trade models (e.g. Brander and Krugman, 1983).

# 3 Equilibrium

The representative household maximizes utility subject to its budget constraint. The inverse demand functions emerging from this problem are

$$p(z) \quad = \quad \frac{E}{\hat{X}}\, x(z)^{\alpha-1}, \tag{5}$$

where $p(z)$ is the price of variety $z$, $E = M \int p(z)x(z)\ \mathrm{dF}(z)$ is total household expenditure, and the auxiliary variable $\hat{X}$ is defined as $\hat{X} = M \int x(z)^{\alpha}\ \mathrm{dF}(z) = M\ (X/M^{\nu})^{\alpha}$.

Firms producing the same variety play a symmetric Cournot game. They behave non-cooperatively, and maximise their net cash flow subject to the inverse demand function in equation (5), taking the quantities produced by their competitors as given. Firms producing traded varieties – the exporters – play two independent Cournot games in the domestic and foreign markets. Hence, in what follows, two separate problems are solved, one for non-exporters and another for exporters.

**Non-exporters.** A firm producing a non-traded variety with productivity $z$ maximizes profits subject to the inverse demand function in (5). The firm's problem is given by[8]

$$\pi_p = \max_{\{q_p,h_p\}} \frac{E}{\hat{X}}\Big(\hat{x}_p + q_p\Big)^{\alpha-1} q_p - \Big(\underbrace{Ah_p^{\eta}\, z}_{\tilde{z}}\Big)^{\frac{\alpha-1}{\alpha}} q_p - \lambda - h_p,$$

where $q_p$ is the firm's production, and $\hat{x}_p$ is the production of its direct competitors. Total output (and consumption) is therefore $x_p = \hat{x}_p + q_p$. Since labor has been adopted as the numéraire, wages are equal to one. The first order conditions for $q_p$ and $h_p$ are

$$\frac{E}{\hat{X}}\Big((\alpha-1)(\hat{x}_p + q_p)^{\alpha-2} q_p + (\hat{x}_p + q_p)^{\alpha-1}\Big) = \tilde{z}^{\frac{\alpha-1}{\alpha}}, \tag{6}$$

and

$$\hat{\eta}\ \tilde{z}^{\frac{\alpha-1}{\alpha}}\ q_p/h_p = 1, \tag{7}$$

respectively, with $\hat{\eta} = \eta\,(1-\alpha)/\alpha > 0$.

Since the equilibrium is symmetric, $x_p = nq_p$. Using this relation and rearranging equation (6)

[8] We omit the dependence of any decision variable on $z$ to simplify notation.

yields

$$x_p(z,n)^\alpha = \left(\frac{\theta_p E}{\hat{X}}\right)^{\frac{\alpha}{1-\alpha}} \tilde{z}(z,n), \tag{8}$$

where $\theta_p \equiv (n+\alpha-1)/n$ represents the inverse of non-exporters' markups, and $x_p(z,n)$ denotes total demand of a non-exported variety with potential productivity $z$ produced by $n$ firms. Equilibrium productivity $\tilde{z}$ depends on initial productivity and on the number of firms, as we show below.

Using symmetry and equations (5) and (6), reveals that the equilibrium price for non-exporting firms is given by

$$p_p(z,n) = \frac{\tilde{z}(z,n)^{\frac{\alpha-1}{\alpha}}}{\theta_p}, \tag{9}$$

where $p_p(z,n)$ denotes the price of a non-exported variety with potential productivity $z$ produced by $n$ firms. Equation (9) highlights a well-known result in Cournot equilibria: the markup depends on the perceived demand elasticity, which is a function of the elasticity of substitution, $1/(1-\alpha)$, and on the number of competitors, $n$. Again exploiting symmetry together with equations (4) and (8) shows that variable production costs (recall that labor is the numéraire) is given by

$$\ell_p(z,n) - \lambda = \tilde{z}(z,n)^{\frac{\alpha-1}{\alpha}} q_p(z,n) = \tilde{z}(z,n)^{\frac{\alpha-1}{\alpha}} \frac{x_p(z,n)}{n} = \frac{1}{n}\left(\frac{\theta_p E}{\hat{X}}\right)^{\frac{1}{1-\alpha}} \tilde{z}(z,n). \tag{10}$$

Thus labor demand is positively related to productivity; more productive firms demand more inputs and produce more. Rearranging the first order condition for $h_p$, i.e. equation (7), and using the expression for labor demand above, R&D effort is given by

$$h_p(z,n) = \hat{\eta}\, \left(\ell_p(z,n) - \lambda\right). \tag{11}$$

Since incumbent firms innovate to reduce variable costs, the innovation effort positively depends on a firm's variable labor demand, and hence on the firm size. As innovation is cost reducing, firms benefit more from it if they can apply the reduction in costs to a larger quantity. More productive firms produce more, demand more labor, and make a larger R&D effort. Substituting optimal $h_p$ into the R&D technology, the productivity of this variety is given by

$$\tilde{z}_p(z,n) = \left(\mathscr{B}_p(n)\, z\right)^{\frac{1}{1-\eta}}, \quad \text{with } \mathscr{B}_p(n) = A^{\frac{1}{1-\eta}} \left(\frac{\hat{\eta}}{n}\left(\frac{\theta_p E}{\hat{X}}\right)^{\frac{1}{1-\alpha}}\right)^{\eta}. \tag{12}$$

**Exporters.** Exporters compete simultaneously in both domestic and foreign markets, which are referred to using the subindices $d$ and $f$, respectively. Notice that due to the iceberg cost, while $q_f$ denotes foreign consumption of the domestically produced good, the associated production is actually $\tau q_f$. Consequently, firms will produce $q_x = q_d + \tau q_f$ but consumers will consume $x_x = \left(q_d + q_f\right)n$, with $x_x \leq n q_x$.

Firms producing the same variety play two separate Cournot games in both the domestic and foreign markets. They take the production of competitors in the domestic and foreign markets, $\hat{x}_d$ and $\hat{x}_f$, as given and solve (as before, we omit the dependence on $z$ to simplify notation),

$$\pi_x = \max_{q_d, q_f, h_x} \underbrace{\frac{E}{\hat{X}}\left(\hat{x}_d + q_d\right)^{\alpha-1}}_{p_d} q_d + \underbrace{\frac{E}{\hat{X}}\left(\hat{x}_f + q_f\right)^{\alpha-1}}_{p_f} q_f - \Big(\underbrace{A h_x^{\eta} z}_{\tilde{z}}\Big)^{\frac{\alpha-1}{\alpha}} \left(q_d + \tau q_f\right) - \lambda - h_x. \quad (13)$$

Exporters maximize profits subject to the corresponding domestic and foreign inverse demand functions, provided in equation (5). The first order conditions for domestic sales, $q_d$, and exports, $q_f$, are, respectively,

$$\frac{E}{\hat{X}}\left((\alpha-1)(\hat{x}_d + q_d)^{\alpha-2} q_d + (\hat{x}_d + q_d)^{\alpha-1}\right) = \tilde{z}^{\frac{\alpha-1}{\alpha}}, \quad (14)$$

$$\frac{E}{\hat{X}}\left((\alpha-1)(\hat{x}_f + q_f)^{\alpha-2} q_f + (\hat{x}_f + q_f)^{\alpha-1}\right) = \tau \tilde{z}^{\frac{\alpha-1}{\alpha}}. \quad (15)$$

The first order condition for R&D labor is

$$\hat{\eta}\, \tilde{z}^{\frac{\alpha-1}{\alpha}} \left(q_d + \tau q_f\right)/h_x = 1. \quad (16)$$

Since the equilibrium is symmetric, i.e. $x_x = n(q_d + q_f)$, by adding equations (14) and (15), total consumption of traded varieties is given by

$$x_x(z,n)^{\alpha} = \left(\frac{\theta_d E}{\hat{X}}\right)^{\frac{\alpha}{1-\alpha}} \tilde{z}(z,n), \quad (17)$$

where $\theta_d = (2n + \alpha - 1)/n(1+\tau)$ represents the inverse of the markup of exporters on their domestic sales. Similarly to the case of domestic firms it can also be shown that in traded product lines

$$p_x(z,n) = \frac{\tilde{z}(z,n)^{\frac{\alpha-1}{\alpha}}}{\theta_d} = \frac{\tau \tilde{z}(z,n)^{\frac{\alpha-1}{\alpha}}}{\theta_f},$$

where $\theta_f = \tau \theta_d$ is the inverse of the markup charged on export sales. Due to the presence of trade costs, exporters charge a lower markup on their export sales, $1/\theta_f$, than on their domestic sales, $1/\theta_d$. For a given $n$, a reduction in trade costs $\tau$ raises $\theta_d$, since the domestic market becomes more competitive due to the stronger penetration of foreign firms. The pro-competitive effect of trade partially operates through this mechanism. In addition, lowering the trade cost leads to higher markups on export sales, $1/\theta_f$, because exporters enjoy a cost reduction in their shipments while domestic firms do not. Hence, exporters can optimally charge a higher markup, by not passing the whole cost reduction onto foreign consumers. This "pricing to market" mechanism is typical of oligopoly trade models, such as Brander (1981) and Brander and Krugman (1983).

As in the standard models with oligopoly trade, a sufficient condition for firms to export is that the autarky markup is larger than the trade cost. For a given $n$, this condition identifies a trade cost $\bar{\tau} = n/(n+\alpha-1)$ above which a product line with $n$ firms is not exported.[9] As suggested by Brander and Krugman (1983) the crucial element for the existence of two-way trade in similar goods is the "segmented market" perception which posits that each firm perceives each country as a separate market and makes separate decisions for each. The economic intuition is straightforward. The marginal cost of exporting is larger than that of domestic production due to the trade cost. Since exporters charge a lower markup on export sales than on domestic sales, they produce a smaller quantity for the export market than for the domestic market. Hence, the perceived marginal revenue is higher for exports than for domestic sales, and can equal the marginal cost of exporting at positive output levels.

The ratio of production to consumption of traded varieties,

$$\frac{q_d + \tau q_f}{q_d + q_f} = \frac{(1-n-\alpha)(1+\tau^2) + 2n\tau}{(1-\alpha)(1+\tau)} \equiv \mathscr{A}(n) > 1, \tag{18}$$

measures losses associated to trade due to iceberg costs. Notice that $\mathscr{A}$ is hump-shaped in $\tau$; it is equal to one in the extreme cases of free trade, $\tau = 1$, and at the prohibitive trade costs, $\bar{\tau} = n/(n+\alpha-1)$, and above one for values in between. Intuitively when variable trade costs are at its prohibitive level, exports, $q_f$, are zero and the share of production wasted in transportation is zero, implying $\mathscr{A} = 1$. A reduction in variable trade costs induces firms to export and reduce their domestic sales. As a consequence, the waste associated with trade costs becomes positive, and $\mathscr{A}$ rises above one. At the other extreme, without any trade costs the loss must, by construction, be zero, and any increase in trade cost increases $\mathscr{A}$ above one.[10] Let us define the average markup of an exporting firm as

$$\theta_x \equiv \frac{q_d\theta_d + q_f\theta_f}{q_d + q_f} = \mathscr{A}\ \theta_d, \tag{19}$$

which follows from the definition of $\mathscr{A}$ and from $\theta_f = \tau\theta_d$. For a given $n$, when variable trade costs are at the prohibitive level, $\bar{\tau}(n) = n/(n+\alpha-1)$, then $\theta_x = \theta_d = \theta_p = (n+\alpha-1)/n$, since $q_f = 0$. Under free trade, $\theta_x = \theta_d = (2n+\alpha-1)/(2n) > \theta_p$, since $\theta_f = \theta_d$.

Exporters' variable production costs are

$$\begin{aligned} \ell_x(z,n) - \lambda &= \tilde{z}^{\frac{\alpha-1}{\alpha}} \left(q_d(z,n) + \tau q_f(z,n)\right) \\ &= \tilde{z}^{\frac{\alpha-1}{\alpha}} \mathscr{A}\left(q_d(z,n) + q_f(z,n)\right) = \frac{\mathscr{A}}{n}\left(\frac{\theta_d E}{\hat{X}}\right)^{\frac{1}{1-\alpha}} \tilde{z}(z,n), \end{aligned} \tag{20}$$

where $\ell_x$ is labor allocated to the production of goods for both the domestic and foreign markets. When

[9] Another way to see this is that $\theta_f$, which is increasing in $\tau$, reaches one at $\tau = \bar{\tau}(n)$; thus at any larger value of $\tau$, the export markup turns negative and firms do not find it profitable to export.

[10] Formally, $\mathscr{A}$ is equal to one in free trade, $\tau = 1$, and at the prohibitive trade cost, $\tau = n/(n+\alpha-1)$. It is easy to see that $\mathscr{A}$ is larger than one for $\tau \in (1, n/(n+\alpha-1))$. Notice that the sign of the partial derivative $\partial\mathscr{A}/\partial\tau$ is equal to the sign of $(1-n-\alpha)(1+\tau)^2 + 2(2n+\alpha-1)$, which has a zero at $1+\tau = \sqrt{2(2n+\alpha-1)/(n+\alpha-1)}$, for $\tau$ in the interval $(1, n/(n+\alpha-1))$. $\mathscr{A}$ is increasing before that maximum and decreasing after.

comparing (20) to (10), it can be seen that for a given $\tilde{z}$, exporters face larger variable costs than non-exporters; this is due to the fact that exporters produce more since they face smaller markups, as reflected by $\theta_d > \theta_p$, and have to cover variable trade costs, as reflected by $\mathscr{A} > 1$.

Rearranging the first order condition for $h_x$, i.e. equation (16), and using the expression for labor demand above, R&D effort is given by

$$h_x(z,n) = \hat{\eta} \, \left(l_x(z,n) - \lambda\right). \tag{21}$$

Similarly to domestic firms, exporters' innovation effort is proportional to firm size. Controlling for productivity, exporters are larger than non-exporters and they therefore also innovate more. Furthermore, since productivity affects size as well, more productive exporters produce more, demand more labor and invest more in R&D.

Substituting optimal $h_x$ in the R&D technology, the productivity of this variety becomes

$$\tilde{z}(z,n) = \left(\mathscr{B}_x(n)\, z\right)^{\frac{1}{1-\eta}}, \quad \text{with } \mathscr{B}_x(n) = A^{\frac{1}{1-\eta}} \left(\frac{\hat{\eta}\mathscr{A}}{n}\left(\frac{\theta_d E}{\hat{X}}\right)^{\frac{1}{1-\alpha}}\right)^{\eta} \tag{22}$$

We summarize some key properties of the model without free entry in the proposition below.

**Proposition 1.** *For a given $n \in \{1,2,3,...\}$, initial productivity level $z$, $\tau \in \left[1, \bar{\tau}(n)\right]$, and $\bar{\tau}(n) = n/(n+\alpha-1)$,*

*i. Exporters' average markup is smaller than their domestic markups which is smaller than non-exporters' markup*

$$\alpha \leq \theta_p(n) \leq \theta_d(n) \leq \theta_x(n) \leq 1.$$

*ii. Exporters are larger and innovate more than non-exporters.*

*iii. Firms with a higher initial productivity, $z$, innovate more.*

*iv. Holding $n$ constant, a reduction in $\tau$ reduces the domestic markup, $1/\theta_d(n)$, increases the export markup, $1/\theta_f(n)$, and reduces the average markup of any exporter, $1/\theta_x(n)$.*

*Proof.* See Appendix A. □

Hence, abstracting from free entry, trade liberalization decreases exporters' markups on domestic sales, increases that on export sales, and decreases their average markup on total sales. This suggests that although our economy features incomplete pass-through of the reduction in trade costs onto prices, the increase in export markups is never sufficiently strong to offset the pro-competitive effect on domestic markups. In other words, in an oligopolistic open economy with Cournot competition and CES demand, when the number of firms is kept constant, there is an overall pro-competitive effect of trade. Next, we allow firms to enter in each product line and characterize the general equilibrium of our economy where innovation and market structure are jointly determined and respond to trade liberalization.

## 3.1 Entry and Selection

We focus on an entry strategy in which firms target product lines and enter until profits become negative. In our full-information economy, a specific entry cost would play the same role of the fixed operating cost, so we set it to zero for simplicity.

**Non-exporters.** Using the conditions for equilibrium prices and quantities above, we can write non-exporters' profits for a variety with potential productivity $z$ as

$$\begin{aligned}\pi_p(z,n) &= p_p(z,n)q_p(z,n) - \tilde{z}(z,n)^{\frac{\alpha-1}{\alpha}} q_p(z,n) - \lambda - \underbrace{\hat{\eta}\tilde{z}(z,n)^{\frac{\alpha-1}{\alpha}} q_p(z,n)}_{h_p(z,n)} \\ &= \left(1-\left(1+\hat{\eta}\right)\theta_p\right)\theta_p(n)^{\frac{\alpha}{1-\alpha}} \frac{1}{n}\left(\frac{E}{\hat{X}}\right)^{\frac{1}{1-\alpha}} \tilde{z}(z,n) - \lambda.\end{aligned}$$

In equilibrium, since profits are monotonically decreasing in $n$, the number of non-exporting firms with potential productivity $z$ is determined by the free entry conditions $\pi_n(z,n) \geq 0 > \pi_n(z,n+1)$. Since profits are linear in $\tilde{z}$, we can define a sequence of cutoff productivities $\tilde{z}^*_p(z,n)$, for $n \in \{1,2,3,...\}$, such that $\tilde{z}^*_p(z,n)$ solves

$$\frac{\theta_p(n)^{\frac{\alpha}{\alpha-1}}}{1-\left(1+\hat{\eta}\right)\theta_p(n)}\, n = \left(\frac{E}{\hat{X}}\right)^{\frac{1}{1-\alpha}} \frac{\tilde{z}^*_p(z,n)}{\lambda}, \tag{23}$$

with

$$\theta_p(n) = \frac{n+\alpha-1}{n}.$$

The cutoffs defined in actual productivities, $\tilde{z}$, monotonically map into cutoffs defined in potential productivities, $z$, according to $z^*_p(n) = \tilde{z}^*_p(z,n)^{1-\eta}/\mathscr{B}_n(n)$. Varieties with potential productivity $z \in \{z^*_p(n), z^*_p(n+1)\}$ will be produced by $n$ identical firms and they will make positive profits. Since the right-hand side of (23) is increasing in $\tilde{z}^*_p(z,n)$ and the left hand side is increasing in $n$, the entry condition implies that more productive product lines have a higher number of firms. The largest possible markup in these lines corresponds to the case of a monopolist, i.e. when $n = 1$. Thus, there is a cutoff potential productivity $z^*_p(1)$, such that varieties with potential productivity $z < z^*_p(1)$ are not produced in equilibrium, since even a monopolist will make negative profits. When $z = z^*_p(1)$ only one firm enters and produces in this line. Notice that $1-\left(1+\hat{\eta}\right)\alpha > 0$, since $\hat{\eta} = \eta\ (1-\alpha)/\alpha$ and $\eta \in (0,1)$, meaning that an interior solution $z^*_p(1) > \underline{\omega}$ exists and is unique for $\underline{\omega}$ small enough. Notice also that for any non-exporter with $z > z^*_p(1)$, we must have $1-\left(1+\hat{\eta}\right)\theta_p\left(n\right) > 0$, otherwise firms will make negative profits and no firm will be operative in this product line.

**Exporters.** Similarly, exporters' profits are

$$\begin{aligned}\pi_x(z,n) &= p_x(z,n)\big(q_d(z,n)+q_f(z,n)\big) - \tilde{z}(z,n)^{\frac{\alpha-1}{\alpha}}\big(q_d(z,n)+\tau q_f(z,n)\big) \\ &\qquad - \lambda - \underbrace{\hat{\eta}\tilde{z}^{\frac{\alpha-1}{\alpha}}\big(q_d(z,n)+\tau q_f(z,n)\big)}_{h_x(z,n)} \\ &= \big(1-\big(1+\hat{\eta}\big)\theta_x(n)\big)\theta_d(n)^{\frac{\alpha}{1-\alpha}}\frac{1}{n}\left(\frac{E}{\hat{X}}\right)^{\frac{1}{1-\alpha}}\tilde{z}(z,n)-\lambda.\end{aligned}$$

The number of exporters with potential productivity $z$ is determined by the conditions $\pi_x(z,n) \geq 0 > \pi_x(z,n+1)$. We can then define a sequence of cutoff productivities $\tilde{z}_x^*(z,n)$, for $n \in \{1,2,3,...\}$, such that $\tilde{z}_x^*(z,n)$ solves

$$\frac{\theta_d(n)^{\frac{\alpha}{\alpha-1}}}{1-\big(1+\hat{\eta}\big)\theta_x(n)}\, n = \left(\frac{E}{\hat{X}}\right)^{\frac{1}{1-\alpha}}\frac{\tilde{z}_x^*(z,n)}{\lambda}, \tag{24}$$

with

$$\theta_d(n) = \frac{2n+\alpha-1}{n(1+\tau)}, \quad \text{and} \quad \theta_x(n) = \mathscr{A}(n)\ \theta_d(n).$$

The cutoffs defined in actual productivities monotonically map into cutoffs defined in potential productivities according to $z_x^*(n) = (\tilde{z}_x^*(z,n))^{1-\eta}/\mathscr{B}_x(n)$. Varieties with actual productivity $z \in \{z_x^*(n), z_x^*(n+1)\}$ will be produced by $n$ identical firms.

Similarly to what we found for non-exporters, more productive exported products are populated with more firms and, as a consequence, more productive exporters operate in more competitive markets. The cutoff productivity for exporters is given by $z_x^*(1)$.[11] At this cutoff productivity we observe a duopoly in both markets, with one domestic and one foreign firm.

Let us now introduce two important considerations that restrict the parameter set. We first discuss the issue for the export cutoff, $z_x^*(1)$, and then we move on to the general case including all exported product lines with $z \in (z_x^*(1), \bar{\omega})$. The first parametric restriction is related to the prohibitive iceberg cost. Recall that at $z = z_x^*(1)$, $n$ is equal to one, implying that the prohibitive iceberg cost for this product line is $1/\alpha$. This implies that in order for the marginal variety to be traded, the iceberg trade cost has to satisfy $\tau < 1/\alpha$, otherwise there will be no trade at all. The second parametric restriction is related to the positivity of net revenues. Recall that, $\theta_x^*(1)$ is decreasing in $\tau$. Let us then evaluate $z_x^*(1)$ at $\tau = 1$, where $\theta_x^*(1)$ will take on its largest value. In this case, for $z_x^*(1)$, to be positive, it is required that $\eta < \alpha/(1+\alpha) < 1/2$, otherwise $1-\big(1+\hat{\eta}\big)\theta_x^*(1) \leq 0$ and no firm would like to produce in this product line. Under this restriction, the marginal firm will always make positive net revenues for $\tau \in (1, 1/\alpha)$, since increasing $\tau$ reduces $\theta_x^*(1)$.

In the general case, for $z \in (z_x^*(1), \bar{\omega})$, the number of domestic firms is weakly monotonically

[11] Notice that in this case

$$\theta_d^*(1) = \frac{1+\alpha}{1+\tau} \quad \text{and} \quad \theta_x^*(1) = \frac{1+\alpha}{1-\alpha}\ \frac{2\tau-(1+\tau^2)\alpha}{(1+\tau)^2}.$$

increasing in $z$, which makes the prohibitive iceberg cost, $\bar{\tau}(n) = n/(n+\alpha-1)$, decreasing in actual productivity $z$. The maximum number of exporters $\bar{n}_x$ corresponds to $z = \bar{\omega}$, with an associated prohibitive iceberg cost $\bar{\tau}(\bar{n}_x)$; the maximum value of $\tau$ that allows all product lines $z \in (z_x^*(1), \bar{\omega})$ to be profitably exported. In the following, we will assume that $\tau < \bar{\tau}(\bar{n}_x)$. Notice, that with an unbounded productivity distribution very productive firms would face very low prohibitive tariffs and, as a consequence, the model would predict that for plausible levels of the trade cost the most productive firms would not export. To avoid this restrictive condition we have chosen to work with a bounded Pareto distribution for the initial productivity. Finally, it is required that $1-(1+\hat{\eta})\theta_x(n)$ is positive for all $z \in (z_x^*(1), \bar{\omega})$. Following a similar argument as above, $\eta$ has to be smaller than $\alpha/(2n+\alpha-1)$, which in turn is smaller than $\alpha/(1+\alpha)$. The assumption that guarantees that net revenues of exporters are everywhere strictly positive is then $\eta < \alpha/(2\bar{n}_x+\alpha-1)$. We summarize these restrictions in the following assumption.

**Assumption 1**. We assume that the following restrictions hold:

$$\begin{aligned} \tau &< \bar{\tau}(\bar{n}_x) < 1/\alpha, \\ \eta &< \alpha/(2\bar{n}_x+\alpha-1) < \alpha/(1+\alpha) < 1/2. \end{aligned}$$

Under the parameter restrictions in Assumption 1 above, we know that $\tau$ is bounded by the prohibitive iceberg cost corresponding to the most productive variety, $\tau < \bar{\tau}(\bar{n}_x) < 1/\alpha$.

A question which naturally arises is whether there can simultaneously exist an equilibrium without any trade at all? The answer is no. To see this, suppose that negative trade is ruled out, such that the optimization problem in (13) is subject to the constraint $q_f \geq 0$. Under a no-trade equilibrium, this constraint would be binding, as otherwise there would be profitable (trade) deviations. If the constraint $q_f \geq 0$ is binding, equations (14) and (15) would then satisfy

$$\frac{E}{\hat{X}}\left((\alpha-1)\frac{x_d^{\alpha-1}}{n} + x_d^{\alpha-1}\right) = \tilde{z}^{\frac{\alpha-1}{\alpha}}, \tag{25}$$

$$\frac{E}{\hat{X}} x_d^{\alpha-1} < \tau \tilde{z}^{\frac{\alpha-1}{\alpha}}. \tag{26}$$

Combining these equations leads to the condition $\tau > n/(\alpha-1+n)$, which violates Assumption 1.

## 3.2 General Equilibrium

**Equilibrium mass of operative varieties $M$.** The potential mass of product lines is one and only those product lines with productivity $z > z_p^*(1)$ are being produced, so the mass of operative varieties is given by

$$M = 1 - \Phi(z_p^*(1)). \tag{27}$$

The mass of potential varieties is bounded from above at one, and since selection necessarily reduces the mass of operative varieties, it must induce some welfare losses via this channel. As a consequence, when love for variety is positive, the model is set up to put us in the worse possible position to get welfare gains from trade-induced selection. In the benchmark model we shut down love for variety but we explore this feature in the robustness analysis.[12]

**Market clearing and aggregation.** To close the model we specify the labor market clearing condition,

$$\sum_{n=1}^{\bar{n}_p-1} n \int_{z_p^*(n)}^{z_p^*(n+1)} \big(\ell_p(z,n)+h_p(z,n)\big)\phi(z)\mathrm{d}z + \bar{n}_p \int_{z_p^*(\bar{n}_p)}^{z_x^*(1)} \big(\ell_p(z,\bar{n}_p)+h_p(z,\bar{n}_p)\big)\phi(z)\mathrm{d}z \\ + \sum_{n=1}^{\bar{n}_x-1} n \int_{z_x^*(n)}^{z_x^*(n+1)} \big(\ell_x(z,n)+h_x(z,n)\big)\phi(z)\mathrm{d}z + \bar{n}_x \int_{z_x^*(\bar{n}_x)}^{\bar{\omega}} \big(\ell_x(z,\bar{n}_x)+h_x(z,\bar{n}_x)\big)\phi(z)\mathrm{d}z = 1, \quad (28)$$

where $\phi(z)$ is the productivity density correspondent to the cdf in equation (2). In equilibrium, $\bar{n}_p$ and $\bar{n}_x$ correspond to the maximum number of non-exporting and exporting firms, respectively. Precisely, $\bar{n}_p$ represents the number of firms producing the most productive non-exported variety, the one with potential productivity just smaller than $z_x^*(1)$. While $\bar{n}_x$ is the number of firms producing and exporting the most productive variety; i.e. the one with productivity $z=\bar{\omega}$.

Substituting equilibrium demands for all varieties into equation (1), using the auxiliary variable $\hat{X} = M\big(X/M^{\nu}\big)^{\alpha}$, welfare can be written as

$$X = EM^{\nu-1}\bar{z}^{\frac{1-\alpha}{\alpha}}, \quad (29)$$

where

$$E = 1 + \sum_{n=1}^{\bar{n}_p-1} n \int_{z_p^*(n)}^{z_p^*(n+1)} \pi_p(z,n)\phi(z)\mathrm{d}z + \bar{n}_p \int_{z_p^*(\bar{n}_p)}^{z_x^*(1)} \pi_p(z,\bar{n}_p)\phi(z)\mathrm{d}z \\ + \sum_{n=1}^{n_x-1} n \int_{z_x^*(n)}^{z_x^*(n+1)} \pi_x(z,n)\phi(z)\mathrm{d}z + \bar{n}_x \int_{z_x^*(\bar{n}_x)}^{\bar{\omega}} \pi_x(z,\bar{n}_x)\phi(z)\mathrm{d}z, \quad (30)$$

is total expenditure, which includes wages and the profits of all those inframarginal firms with initial

[12] In the standard Melitz model for example, the mass of entrants is an equilibrium object which responds to trade liberalisation. It follows that an increase in the mass of entrants can compensate the reduction in varieties produced by selection, thereby leading to post-liberalisation scenarios with a larger mass of varieties and associated welfare gains.

productivity $z$ laying between cutoffs, and

$$\bar{z} = \frac{1}{M}\sum_{n=1}^{\bar{n}_p-1}\left(\theta_p(n)^{\frac{\alpha}{1-\alpha}}\int_{z_p^*(n)}^{z_p^*(n+1)}\tilde{z}(z,n)\phi(z)\mathrm{d}z + \theta_p(\bar{n}_p)^{\frac{\alpha}{1-\alpha}}\int_{z_p^*(\bar{n}_p)}^{z_x^*(1)}\tilde{z}(z,\bar{n}_p)\phi(z)\mathrm{d}z\right)$$
$$+\frac{1}{M}\sum_{n=1}^{n_x-1}\left(\theta_d(n)^{\frac{\alpha}{1-\alpha}}\int_{z_x^*(n)}^{z_x^*(n+1)}\tilde{z}(z,n)\phi(z)\mathrm{d}z + \theta_d(\bar{n}_x)^{\frac{\alpha}{1-\alpha}}\int_{z_x^*(\bar{n}_x)}^{\bar{\omega}}\tilde{z}(z,\bar{n}_x)\phi(z)\mathrm{d}z\right), \quad (31)$$

is a measure of aggregate productivity, weighing the productivity of each variety by a monotone transformation of the corresponding markup. The equilibrium distribution $F(z)$ is the entry distribution $\Phi(z)$ truncated at $z_p^*(1)$; more precisely, $F(z) = \Phi(z)/M$, since at equilibrium $M = 1-\Phi(z_p^*(1))$. This argument justify the terms $1/M$ on the right-hand-side of (31). Equilibrium welfare, $X$, is pinned down by the mass of firms and this aggregate productivity measure. The love for variety parameter, $\nu$, is crucial in shaping the contribution of varieties and therefore of selection to welfare.

# 4 Numerical analysis

We discipline the model's predictive scope using US data before numerically exploring its key properties. In particular, we calibrate the six parameters $\alpha$, $\lambda$, $\bar{\omega}$, $\kappa$, $\tau$, and $\eta$, to reproduce some key US firm-level and aggregate statistics.[13] We target an R&D-to-sales ratio of 2.4%, which is the 1975-1995 average in Compustat; and an export share of GDP of 9.4 for the same period (World Development Indicators). We also target a share of exporting firms to total firms of 18% (Bernard et al. 2003); the average Herfindhal Index of employment in manufacturing in 2012 reported by Autor et al. (2017); a size (employment) advantage of exporters of 99% (Bernard et al., 2007); and an average markup of 34.6% (Hottman et al., 2016).

The lower bound $\underline{\omega}$ simply pins down the location of the distribution, so we normalize it to one without any loss of generality. The R&D technology $A$ is a scale parameter which does not affect the equilibrium, but merely controls the link between the actual productivity $\tilde{z}$ and the initial level $z$ (see Appendix C). We set $A$ to 1.48 in order for the difference between the actual productivity $\tilde{z}$ and the initial level $z$ to be on average 1%, roughly matching the US long run TFP annual growth rate (Penn

[13] In our model firms operating in the same product line have the same production technologies and produce perfectly substitutable goods. Although the model is highly stylized, an empirical counterpart of a product line could be, for example, smart phones. In this line a few top-end powerful firms share the global market and operate with similar productivities. To get a sense of the empirical mapping, in NAICS industry classification, our smart phone example belongs to sector 334220, "Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing". This sector includes a large set of products ranging from Airborne radios to cellular phones, from smart phones to televisions (more than 30 different and quite broadly defined types of products). A product line in our model cannot be NAICS 334220, since we have a small number of firms (up to three in the calibration) competing tightly in the production of highly substitutable goods: Iphone 7 competes with Samsung Galaxy s7, but not with Sony Smart TV SD9. Hence, if we think about our product lines as sectors, there would not be a clear empirical counterpart for them, not even at the 6-digit level. For this reason, we interpret our model as a model of heterogeneous firms and target firm-level moments in the data.

World tables).[14]

Table 1: Summary of calibration targets.

| Calibration target | Data | Model | Source |
|---|---|---|---|
| R&D to sales ratio | 2.4% | 3.1% | Compustat |
| Export share of GDP | 9.4% | 11.2% | WDI World Bank |
| Share of exporters | 18% | 15.3% | Bernard et al. (2007) |
| HHI for employment | 0.55 | 0.56 | Autor et al. (2017) |
| Average markup | 34.6% | 40.3% | Hottman et al. (2016) |
| Relative size of exporters | 97% | 100.1% | Bernard et al. (2007) |

*Notes.* This table lists the empirical targets and their corresponding model moments. The six calibrated parameters are jointly determined and do not correspond one-by-one to a specific target.

Table 2: Summary of calibrated parameters.

| Parameter | Interpretation | Value |
|---|---|---|
| $1/(1-\alpha)$ | Elasticity of substitution | 3.27 |
| $\lambda$ | Fixed cost of production | 0.33 |
| $\bar{\omega}$ | Upper bound of the Pareto distribution | 7.08 |
| $\kappa$ | Shape of the Pareto distribution | 4.94 |
| $\tau$ | Iceberg trade cost | 1.12 |
| $\eta$ | Elasticity of the innovation function | 0.17 |

*Notes.* This table lists the calibrated parameters and their values. The parameters are jointly determined to minimize the distance between the empirical moments in Table 1 and the model counterparts.

Table 1 shows the model fit and Table 2 summarizes the calibrated parameters. Albeit stylized, the model provides a decent fit for all the targeted statistics.[15]

## 4.1 Equilibrium properties

**Cross sectional properties.** Figure 1 illustrates the key endogenous variables as a function of the initial productivity $z$. In line with Proposition 1, we see that markups decline with productivity;

[14]It is possible to interpret our static model as a special case of a dynamic model. Hence, it is useful to have the productivity jump mimicking the long-run growth rate in the data.

[15]These calibration targets were chosen in order for the baseline model with a discrete number of firms and an earlier version where the number of firm is a real number (Impullitti, Licandro and Rendahl, 2017) to have similar outcomes. Comparing the two versions allows us to assess the potential limitations of ignoring the "integer constraint", a shortcut frequently used to introduce entry in Cornot models. The integer constraint constitutes an important hurdle that has limited the use of Cournot models in the trade literature (Neary, 2010).

non-exporting firms have higher markups than exporters; and since exporters charge a higher markup on the domestic market, the average markup $1/\theta_x$ is smaller than the domestic markup $1/\theta_d$. More productive firms are larger and innovate more. Notice, in particular, that there is a jump in both size and innovation at the export cutoff, consistent with *part ii.* in Proposition 1: exporters are larger and innovate more than non-exporters.

In each non-exported product line there is only one firm. The least productive traded products also feature one firm per country, a total of two firms then compete in the global market in those lines. The most productive exporters instead face competition on both markets by one other national firm along with two foreign firms. These firms compete in more productive product lines which attract more competitors. The higher number of competitors is a further reason for exporters charging lower markups on their average sales than non-exporters.[16] Notice that the higher number of firms in top exporters product lines also generates a drop in firm size and innovation due to the lower market size of each firm in those lines.

Since more productive firms innovate more, innovation generates an equilibrium distribution of productivity that is more skewed than the distribution at entry. In particular, the top-right panel of Figure 1 suggests that the slope of the (log-log) equilibrium distribution, which is shaped by the innovation choice, is substantially flatter.

**Trade liberalisation: cross-section.** In order to gain intuition, here we analyse the effect on the key cross-sectional outcomes of halving the variable trade costs $\tau$ from its benchmark value of about 1.12 to 1.06. The results are shown in Figure 2. Lower trade costs have no impact on the number of non-exporting firms and, consequently, on their markups. Other key outcomes of non-exporting firms, size and innovation, are essentially unaffected. The bulk of the trade-induced adjustment is experienced by exporting firms.

The effects of trade on exporters' markups in Proposition 1, which abstracted from entry, are only in part confirmed in the free entry equilibrium. The less productive exporters reduce their domestic markup, and increase their export markup, not passing the full reduction in trade costs to foreign consumers. Moreover, the pro-competitive effect on domestic markups dominates and the average markup declines with trade liberalisation, thereby confirming the analytical results without free entry. Top exporters instead deviate from the predictions of Proposition 1: although their export markups increase with trade, as for all other exporters, their domestic markups increase instead of decline. The reason being that the number of firms per country within each product line drops from two to one, and this anti-competitive effect is stronger than the pro-competitive effect directly generated by a reduction of the trade cost. When trade costs decline, each foreign firm exerts a stronger competitive pressure on home firms, but there are less firms from both countries competing in each product line. The latter

[16] This coarse distribution of the number of firms across product lines is a result of the benchmark calibration. Different calibration strategies can deliver more variation of the equilibrium number of firms across the productivity support. We have performed the analysis under different calibrations and the key results hold robustly. Simulations are available upon request.

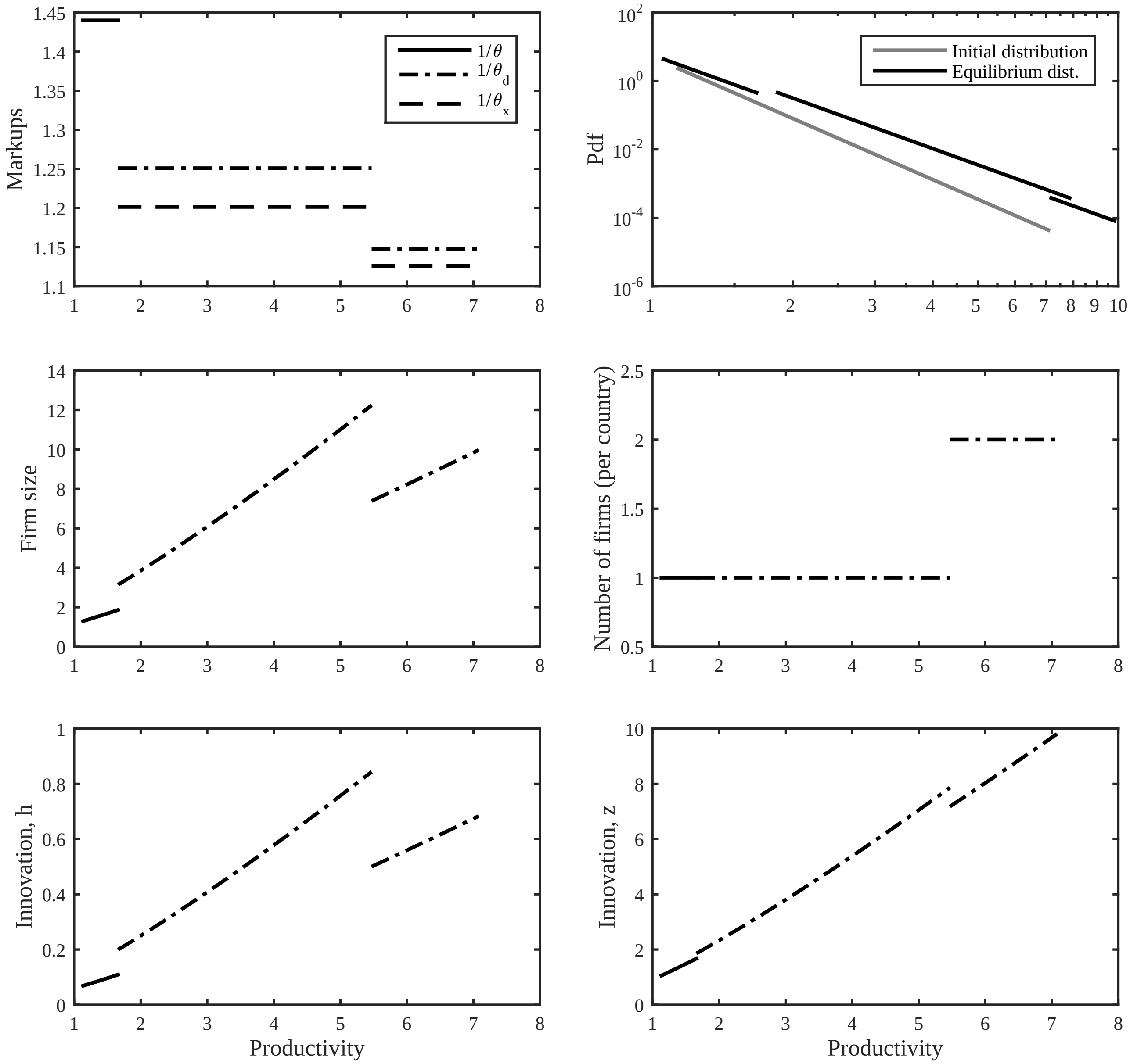


Figure 1: Cross-sectional equilibrium outcomes

*Notes.* For the bottom four graphs, the solid lines depict the outcome for non-exporting firms and the dashed lines illustrates the same quantity for exporting firms. For the top right graph, the grey solid line depicts the exogenous (Pareto) distribution, and the black solid line the endogenous distribution after innovation. *Productivity* refers to the initial draw $z$.

effect dominates and the overall effect of trade liberalisation for top exporters is *anti-competitive*.[17] Comparing this result with that of Proposition 1 suggests that the combination of free entry and the incomplete pass-through of the trade cost onto export markups, can produce an overall anti-competitive effect of trade. Abstracting from free entry instead, leads to a pro-competitive effect of trade on

[17] This result differ from the version with $n$ as a real number in Impullitti et al. (2017), where the decline in the number of firms does not dominate and the effect of trade on all exporters is pro-competitive.

markups.

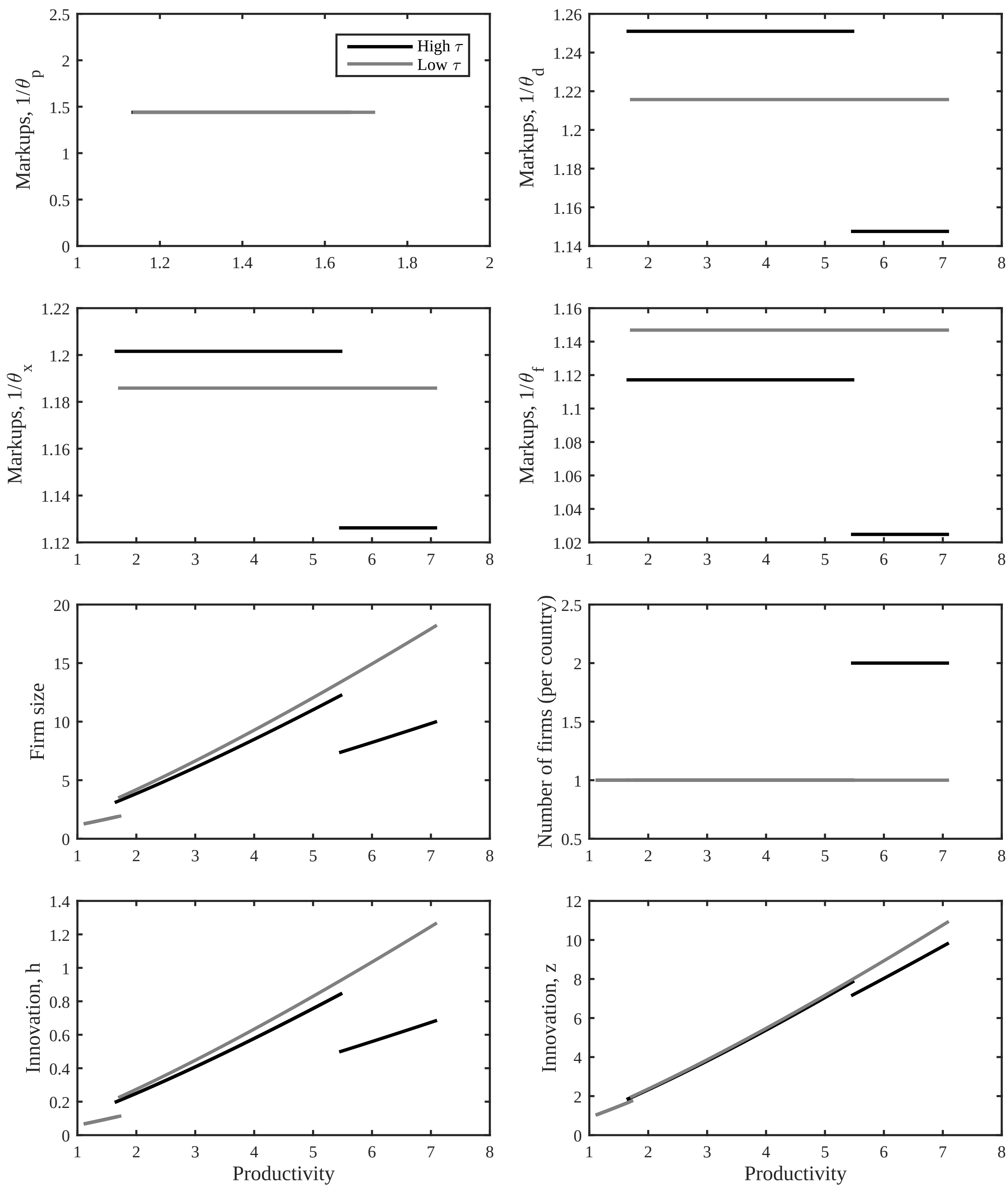


Figure 2: Trade liberalisation: cross-sectional outcomes

*Notes.* The black solid line replicates Figure 1. The grey lines show the equilibrium outcome at a lower trade cost, $\tau = 1.06$. *Productivity* refers to $\tilde{z}$. Calculations are described in the main text.

We now dig deeper into the link between trade and the number of firms. Following the drop in markups, two adjustments allow the free-entry condition (24) to hold: first, as profits decline, some firms are forced to *exit* and, consequently, in some product lines the equilibrium number of firms declines. Second, profitability can be restored by increasing productivity through *innovation*. Equations (20) and (21) reveal that equilibrium innovation for exporters is decreasing in the average markup. Higher trade-induced competition lowers oligopolistic distorsions yielding larger firm size and higher incentives to innovate. The feedback from innovation to competition is straightforward, as more productive product lines have a larger market size and can therefore accommodate more firms.[18]

Figure 2 suggests that both adjustments are at work. For top exporters, trade liberalisation reduces the number of firms from two to one in each country, generating substantial increase in innovation. As markups are smaller when $n$ is larger, a stronger decrease in $n$ is needed to compensate the same change in $\tau$ in more competitive product lines and re-establish free entry. In other words, the elasticity of profits to changes in the number of firms is lower in more competitive product lines, and it takes a stronger decline in $n$ to affect profits and restore free-entry. In our benchmark economy, for less productive exporters the elasticity of profit is sufficiently high to leave the number of firms unchanged.

Finally, trade liberalisation increases firms size, innovation and productivity for all exporters but the effect is stronger for top exporting firms. This is again related to the effect on the number of firms. Since trade does not affect the number of firms in less productive exported product lines, their increase in size, innovation and productivity is smaller. In top exporting product lines, the drop in the number of firms triggers a large jump in all those outcome variables.

Taking stock. A more globalised economy is populated by *bigger*, *fewer* and more *innovative* firms. The top exporters charge a higher markup on their average sales, while the remaining exporters' average markup decreases. Whether the overall effect of trade on markups is *pro-competitive* or *anti-competitive* results from the aggregation of these opposite forces to which we turn next.

**Trade liberalisation: aggregate effects.** In Figure 3 we show the path of several key aggregate variables when moving from the benchmark trade cost to free trade. To ensure a reasonable level of comparability between exporters and non-exporters, the figure illustrates the percent changes in each variable; we report the changes in levels in Table 3.

Liberalizing trade leaves the average markup of non-exporters essentially unchanged.[19] The average markup of exporting firms instead declines from about 20% to 18%. This is driven by the

[18] In the previous version, Impullitti et al. (2017), we show that, in line with the early literature on innovation and endogenous market structure (e.g. Dasgupta and Stiglitz, 1980, and Sutton, 1991), the relationship between market size, the number of firms and innovation is shaped by the characteristics of demand and of the innovation technology. High substitutability across goods implies that markups and profits are less sensitive to changes in the number of firms, so the entry margin is less successful in restoring the free-entry condition and we observe a large drop in the number of firms. A more efficient R&D technology implies that innovation is more effective in restoring free-entry and, as a consequence, a smaller adjustment to the number of firms is needed. Similar forces are operating here, we omit them for brevity, as they would distract the reader from the main scope of the paper.

[19] The number of non-exporters is $n = 1$ for all product lines, implying that the markup is $1/\alpha$. Since $n$ remains equal to one for all product lines after trade liberalisation, the markup of non-exporters does not change.

less productive exporters which, as shown in Figure 2, reduce their average markups as trade costs decline. This effect is due to a substantial reduction in exporters' markups on domestic sales which outpaces the increase in their markups on export sales. The anti-competitive effect of trade on top exporters' markup does not dominate as the top exporters account only for 0.0163% of firms in the economy. Although these are only a few firms, they are very large, so one might wonder whether a revenue or employment based measure of the average markup might respond differently to trade than the unconditional average markup. However, the employment weighted average exporters markup drops by 1.74% when the economy goes from benchmark trade to free trade, almost identical to the 1.77% decline in the unconditional average markup of exporters. Interestingly, along with a reduction in firms' market power trade liberalisation generates a substantial increase in market concentration. We measure concentration as the ratio of the sales of the 5% more productive firms to the average sales. These top firms' revenues are about 2.4 times higher than an average firm at $\tau = 1.12$, and about 2.65 times higher at $\tau = 1$.

The domestic and the export cutoffs show similar changes, which are roughly about 1-1.5 percent increase when comparing the benchmark outcome with that of free trade. It is interesting to notice though that the export cutoff in Figure 3 displays an inverted U-shape. This feature is related to a classic result in trade models under oligopoly which was first highlighted in Brander and Krugman (1983). At high trade costs, exporters' profits are mainly coming from domestic sales. Since a reduction in trade costs increases their profits on export sales (which are small) and reduces those on domestic sales (which are large), their average profits decline. At the other extreme, when trade costs are low, a substantial part of profits comes from export sales, and a reduction in trade costs increases average exporters' profits. The equivalent of this mechanisms in our heterogeneous firms economy affects selection into the export market. In particular, when trade costs are high, the declining average profits of marginal exporters triggered by trade liberalisation pushes them out of foreign markets, thereby increasing the export cutoff. Conversely, in more open economies further liberalisation has a positive effect on the average profits of exporting firms and the threshold for exporting declines.

Table 3: Summary of aggregate effects.

| | | Size | Cutoffs | Markups | TFP |
|---|---|---|---|---|---|
| Exporters | $\tau = 1.12$ | 4.03 | 1.66 | 1.20 | 6.95 |
| | $\tau = 1.00$ | 4.79 | 1.68 | 1.18 | 9.74 |
| Non-exporters | $\tau = 1.12$ | 1.48 | 1.14 | 1.44 | 1.25 |
| | $\tau = 1.00$ | 1.48 | 1.15 | 1.44 | 1.27 |

*Notes.* This table illustrates the effects *in levels* of reducing $\tau$ from 1.12 to 1 for the aggregate/average variables illustrated in Figure 3. Innovation is illustrated using average TFP, rather than labor allocated towards innovation.

As a consequence of lower markups and less firms in top exporters' product lines, the average firm size of exporters increases substantially, while non-exporting firms show only negligible changes. The

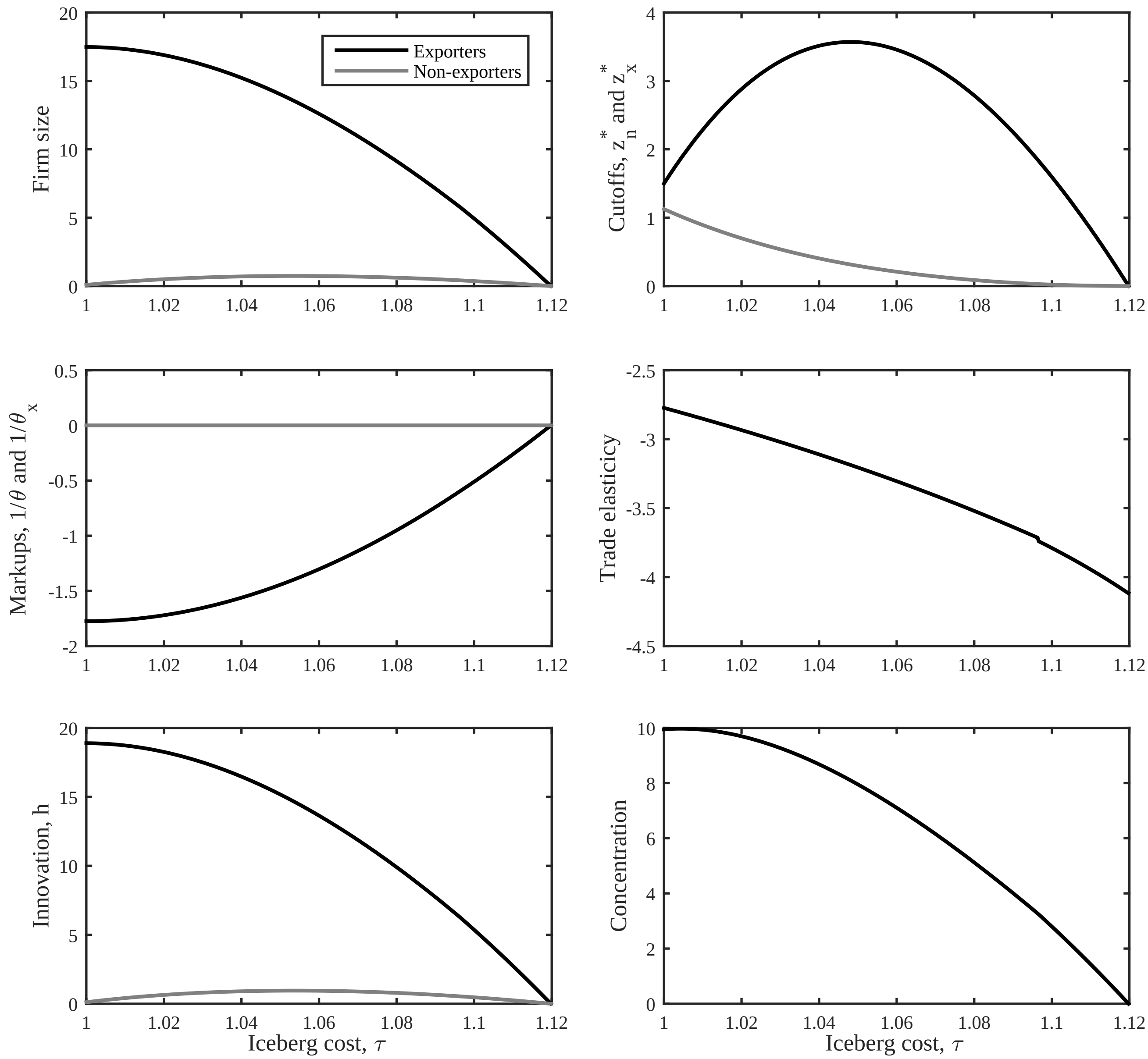


Figure 3: Trade liberalisation: aggregate outcomes

*Notes.* All graphs, except for the elasticities, illustrate the percentage change in each variable relative to the benchmark. Concentration is measured as the average sales of the 5% most productive firms as a share of average sales.

average size of exporters, in fact, increases by 17.5% from benchmark to free trade. Since innovation is driven by firm size, exporters are also key drivers of the innovation effect induced by trade liberalisation, with the aggregate innovation effort by exporters increasing by about 18% from benchmark to free trade.

Finally, we show that the trade elasticity – the elasticity of the average export to total sales ratio – varies substantially with the size of liberalisation. Trade is very elastic to changes in trade costs close to the benchmark, but this elasticity (in absolute value) is almost halved close to free trade. Hence the increase in trade volume generated by a decrease in the variable trade cost is substantially higher in more closed economies than in more open ones. This result will be useful later in discussing the connection between our findings and some key results in the literature.

Taking stock. In line with our cross-sectional findings, trade liberalisation leads to an aggregate economy that is *more selective*, *more innovative*, and populated by larger firms operating in *more concentrated* but also *more competitive* markets. Next, we analyse how these key forces contribute to shape the welfare gains from trade.[20]

## 4.2 Gains from trade structure

In this section we study the gains from trade and decompose them into their different sources. We reduce the trade cost from its benchmark level, which we here denote $\tau_0$, towards one and compute the welfare gains of moving from each intermediate level of $\tau$ with respect to the benchmark. Since our global economy consists of countries that are symmetric in all features including the mass of varieties produced, there are no variety gains from trade. For this reason we set $v$ equal to one in order to eliminate the love for variety entirely.[21] We later perform robustness on this choice.

Without love for variety, welfare is given by $X(\tau) = E\bar{z}^{\frac{1-\alpha}{\alpha}}$, where $X(\tau)$ emphasizes that equilibrium welfare depends on iceberg cost parameter $\tau$. The components $E$ and $\bar{z}$ were previously defined in equations (30) and (31), and only depend on markups, innovation via productivity, and the cutoffs. The compensating variation, CV, of liberalizing trade from some arbitrary $\tau$ to $\tau_\varepsilon = \tau + \mathrm{d}\tau$ is given by $CV(\tau_\varepsilon, \tau) = 100 \times (\ln(X(\tau_\varepsilon) - \ln(X(\tau)))$. Thus, a first-order Taylor approximation of $CV(\tau_\varepsilon, \tau)$ around $\tau_\varepsilon = \tau$ is given by

$$CV(\tau_\varepsilon, \tau) \approx \frac{\mathscr{D}E}{\mathscr{D}\tau}\mathrm{d}\tau + \frac{\mathscr{D}I}{\mathscr{D}\tau}\mathrm{d}\tau + \frac{\mathscr{D}M}{\mathscr{D}\tau}\mathrm{d}\tau + \frac{\mathscr{D}S}{\mathscr{D}\tau}\mathrm{d}\tau, \tag{32}$$

where the terms $\mathscr{D}Y/\mathscr{D}\tau$ – for $Y = E, I, M, S$ – represent the marginal changes in the compensating variation due to marginal changes in expenditures, innovation, markups and selection, respectively, induced by a marginal change in the iceberg cost, $\tau$. Differently from models of trade with heterogeneous firms and monopolistic competition (e.g. Melitz, 2003), here selection is characterised by both the standard extensive margin and an additional intensive margin. The former operates via the across-varieties survival cutoffs $z_p^*(1)$ and $z_x^*(1)$ and the latter through the within-variety cutoffs generated by the free entry condition, $z_p^*(n)$ and $z_x^*(n)$. These terms are lengthy and involves numerous sums of partial derivatives of the various components of $X(\tau)$, and are therefore fully spelled out in Appendix B.1. While equation (32) is useful in decomposing local welfare gains into the various sources underlying the gains from trade, it is only accurate around the vicinity of some initial $\tau$. Thus, to fully explore and decompose the welfare gains from trade into its underlying sources – expenditures, innovation, markups, and selection – we proceed by using the globally valid decomposition according

[20] Table D1 in the Appendix shows that these results are strongly robust across different parameter specifications.

[21] It should also be noted that there exist no clear empirical discipline on the size of the parameter $v$.

to

$$CV(\tau', \tau_0) = \underbrace{\int_{\tau_0}^{\tau'} \frac{\mathscr{D}E}{\mathscr{D}\tau} \mathrm{d}\tau}_{\text{Expenditures}} + \underbrace{\int_{\tau_0}^{\tau'} \frac{\mathscr{D}I}{\mathscr{D}\tau} \mathrm{d}\tau}_{\text{Innovation}} + \underbrace{\int_{\tau_0}^{\tau'} \frac{\mathscr{D}M}{\mathscr{D}\tau} \mathrm{d}\tau}_{\text{Markups}} + \underbrace{\int_{\tau_0}^{\tau'} \frac{\mathscr{D}S}{\mathscr{D}\tau} \mathrm{d}\tau}_{\text{Selection}}. \tag{33}$$

Figure 4 reports the results of this exercise.

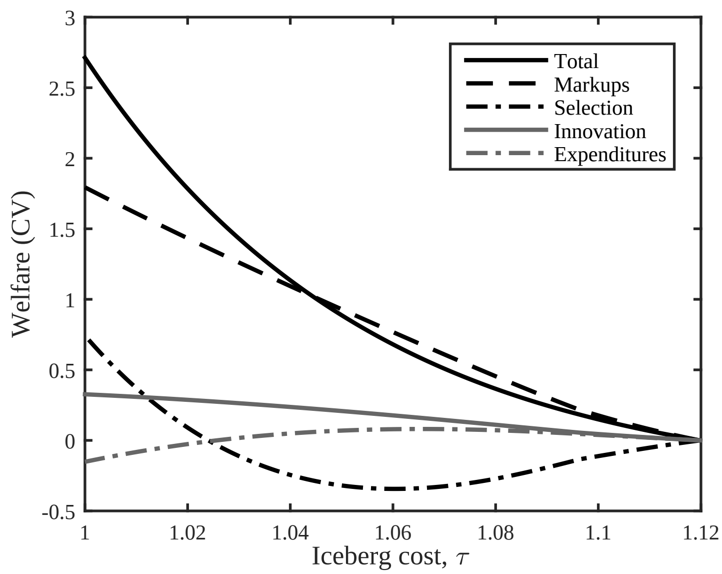


Figure 4: Gains from trade: decomposition

Welfare increases with the size of trade liberalisation. Moving from the benchmark trade cost to free trade generates a 2.7% increase in the compensating variation. Roughly two thirds of this total gain can be attributed to the effect of trade on markups, the pro-competitive effect on exporters shown in Figure 3. As mentioned above, this effect operates through an intensive and an extensive margin: the first derives from the stronger competitive pressure produced by a given number of foreign firms when trade costs drop, and leads to a reduction in markups. The extensive margin operates through the free-entry condition: trade-induced increases in competition make survival harder for firms in each product line, thereby reducing their number and increasing their markups. This margin effect dominates only for top exporters which are a small fraction of firms in the economy, and the overall effect of trade on markups is pro-competitive.[22]

*Innovation* accounts for 13% of the total gains from benchmark to free trade. This effect is driven by the response of exporters, as shown in Figure 2: the incentive to innovate is proportional to firm size and more productive exporters experience larger increases in their size. Firm size and innovation increase is particularly large for top exporters due to the reduction in the number of firms in those product lines. The gains from *selection* follows an U-shaped pattern. Starting from the benchmark trade level, small reductions in trade costs generate welfare losses, while wider reductions produce

[22] As shown in Figure 3, the average markup declines.

gains which increase progressively with the size of liberalisation. This pattern is related to the path of the export cutoff which, as discussed above, is linked to the classical U-shape effect of trade on average profits in oligopoly models. When trade costs start declining from the benchmark value, the export cutoff increases and the share of exporting firms drops. Since exporters are the engine of the gains from trade, a decline in the share of exporters generates losses. When the trade cost reaches a certain threshold however, the export cutoff starts dropping, the economy adds more exporters and welfare increases.

Finally, there is a small and non monotonic effect via expenditure. This is related to the impact of trade on the profits of the infra-marginal firms which is, in turn, driven again by the non-monotonic response of the export cutoff to trade costs. Small reductions in the trade costs from the benchmark reduce the share of exporters and, since these firms have lower markups, aggregate profits surge. Further liberalisation increases the share of exporters thereby reducing aggregate profits. Moving from the benchmark trade cost to free trade generates about a 0.16% welfare loss due to the reduction in aggregate profits.

**Robustness.** Table 4 shows that the decomposition results are robust to local parameter changes. In most parametrisations the pro-competitive effect account for the bulk of the gains, always robustly above two thirds. Selection generates between 21% and 29% of the gains, and the innovation share is between 11% and 14%. Higher substitutability across goods (i.e. a higher value of $\alpha$) implies a more pronounced role of markups in the determination of the gains from trade. Intuitively, the more substitutable goods are the higher is the responsiveness of markups to changes in trade cost. Also quite intuitive is the larger selection effect obtained when the initial productivity distribution is more dispersed (lower $\kappa$).

Table 4: Robustness of welfare gains.

| | Benchmark | $\bar{\alpha}$ | $\underline{\alpha}$ | $\bar{\eta}$ | $\underline{\eta}$ | $\bar{\kappa}$ | $\underline{\kappa}$ | $\underline{\nu}$ |
|---|---|---|---|---|---|---|---|---|
| Total | 2.71 | 2.52 | 2.91 | 2.81 | 2.62 | 2.35 | 3.12 | 1.32 |
| Markups | 69% | 72% | 65% | 68% | 70% | 67% | 70% | 139% |
| Selection | 25% | 21% | 29% | 24% | 25% | 28 % | 21% | -53% |
| Innovation | 12% | 13% | 11% | 14% | 11% | 12% | 14% | 26% |
| Expenditures | -6% | -6% | -5% | -6% | -6% | -7% | -5% | -12% |

*Notes.* This table illustrates the welfare gains from reducing the iceberg cost, $\tau$, from 1.12 to 1 under eight different parameterizations. The total gains are calculated according to equation (29), and the decomposition according to equation (33). The decomposition is expressed as a percentage of the respective total gain. A parameter denoted $\bar{x}$ ($\underline{x}$) indicates an increase (decrease) of that parameter's value by 10% relative to benchmark. The parameter $\underline{\nu}$ is set to 1.25.

The role of innovation is, perhaps unsurprisingly, enhanced by a more efficient innovation technology (i.e. a higher value of $\eta$). Finally, notice that the total gains, as well as the share attributable to selection, drop by about half when the love for variety externality is in effect. In particular we set the externality, $\nu$, in equation (29) to 1.25. Not surprisingly, with a stronger love for variety, the loss of product lines due to selection more than offsets the benefits from reallocating market shares from less to more productive firms, leading to a negative overall contribution of selection. The gains arising from lower markups increase massively, and those coming from innovation also record a substantial increase.

# 5 Discussion

Arkolakis et al. (2012) (ACR) show that in a class of models satisfying three macro-level restrictions, the gains from trade are related to two sufficient statistics: the domestic trade share and the trade elasticity. Furthermore, these gains are independent of the different microeconomic details of the model. The macroeconomic restrictions are: $(i)$ balanced trade; $(ii)$ aggregate profits is a constant share of aggregate revenues; and $(iii)$, a CES demand system with a constant elasticity of trade with respect to variable trade costs. They show that the standard intra-industry trade model of Krugman (1980) and its heterogeneous firm version, Melitz (2003) with an unbounded Pareto distribution, meet these restrictions, and therefore a given increase in the domestic trade share produces the same gains in both models. Our oligopolistic model exists outside the ACR's class since it violates restrictions $(ii)$ and $(iii)$. The integer constraint implies that inframarginal firms, those with productivity between two contiguous free entry cutoffs defined in (23) and (24), make positive profits, which vary with trade costs. Moreover, while we do have a CES demand system, the elasticity of trade to trade cost is not constant, as shown in Figure 3.

Although our model is outside the ACR class, it is useful to ask whether once the changes in the trade elasticity are properly taken into account, the ACR formula provides a good approximation of the gains from trade in our economy. To accomplish this, we follow ACR, which show that in a large class of models the gains from trade can be expressed as

$$GFT = \frac{1}{\sigma} log \left( \frac{\lambda_d}{\lambda_d^{'}} \right),$$

where $\lambda_d$ and $\lambda_d^{'}$ are the share of expenditures on domestic goods before and after the change in the trade cost, respectively, and $\sigma$ is the trade elasticity defined as

$$\sigma = \frac{\mathrm{d} log \frac{1-\lambda_d}{\lambda_d}}{\mathrm{d} log \tau}.$$

Table 5 shows the gains from trade computed with the ACR formula and the associated trade elasticity, which we calculate using our model. The ACR gains of moving from autarky to 11.2% import share (our calibrated value) and from 11.2% to 18% import share (which approximates free trade in our economy) are computed using the ex-post elasticity, the elasticity at the end of the liberalisation experiment, while the gains from autarky to 18% import share are computed using the average elasticity in this trade interval.

Table 5: Gains from trade using ACR

| Change in export share | 0 to 11.2 | 11.2 to 18 | 0 to 18 |
|---|---|---|---|
| Gains from trade: ILR | 3.60 | 2.71 | 6.32 |
| Trade elasticity | 2.27 | 8.81 | 3.70 |
| Gains from trade: ACR | 5.22 | 0.91 | 5.36 |

*Notes.* We use ex-post elasticity in the computation of the ACR gains, except for the 0 to 18 experiment where we take an average elasticity.

As one would expect the gains are larger when the economy is fairly closed than for further liberalisation of a sufficiently open economy. The ACR formula predicts larger gains of opening a fairly closed economy compared to our model and smaller gains of further liberalizations. This is due to the different values of the ex-post trade elasticity. In the last column, where we compute the ACR gains using the average elasticity we find that the ACR formula provides a good approximation of the gains from trade in our economy. As observed by Edmond, Midrigan and Xu (2015) (EMX henceforth), who perform a similar exercise for their economy, one could expect the ACR formula to approximate the gains as important aspects of markup variation are captured by the trade elasticity and thus key features of variable markups are embedded in this formula.

Arkolakis et al. (2017) (ACDR) compute the pro-competitive effect of trade in a class of models with monopolistic competition, heterogeneous firms, and variable markups obtained via non-CES demand. The pro-competitive effect is defined as the differential impact of trade liberalization on welfare in models with variable markups compared to those obtained in models with constant markups. The comparison is made between models sharing the same macro restrictions but differing in the microeconomic details. They show that trade liberalization, on the one hand, reduces domestic markups, thereby reducing domestic distortions and generating welfare gains. On the other hand, it increases foreign markups because exporters do not pass the whole reduction in trade costs to consumers. This incomplete pass-through generates welfare losses. ACDR find that under translog preferences the two effects cancel out and thus the pro-competitive effects are "elusive" and variable markups do not produce any additional gains compared to the standard CES demand system. Furthermore, they show that when preferences are non-homothetic, the incomplete pass-through effect dominates, and the pro-competitive effect is negative.

In our oligopolistic economy, the pro-competitive effect of trade is shaped by similar forces. Abstracting from selection and innovation, the gains directly attributable to variable markups are due to the reduction in exporters' domestic markups and the welfare losses are due to the incomplete pass-through. We show analytically that abstracting from free entry, the incomplete pass-through never dominates and the pro-competitive effect is always positive (Proposition 1). With free entry our model features an additional channel of welfare losses, which is the reduction in the number of firms in the top exporters' product lines, leading to increases in the average markups charged by these firms. This can potentially offset the pro-competitive effect but although these firms are very large, they are too few to drive the aggregate effect of trade on markups.

EMX analyse pro-competitive gains from trade in a quantitative model with firm heterogeneity and Cournot competition. We depart from their analysis in three important dimensions. First, in line with ACDR, our pro-competitive gains are measured as the additional benefit of trade produced by variable markups over those generated in economies with constant markups. While for EMX the pro-competitive effect of trade is measured by the reduction in misallocation. Second, EMX benchmark model does not allow free entry, and their extension to free entry shuts down the selection margin of trade. Third, firms in their economy do not innovate. The key contribution of our model with respect to EMX is that, as shown in Figure 4, we can fully separate the gains from variable markups, from selection, and from innovation. We find that each of these channels represent a substantial contribution to the gains from trade.

# 6 Conclusion

This paper proposes an exploration of the gains from trade in an economy where technology and market structure respond to changes in openness. In this economy, trade generates welfare gains by increasing foreign competitive pressure on firms forcing them to reduce their markups. Like in standard trade models of oligopolistic competition trade liberalisation reduces domestic markups and increases export markups. We show that in a global economy where the number of firms does not change, possibly due to prohibitive barriers to entry, the competitive pressure on domestic markups dominates and the overall effect of trade on markups are pro-competitive. In economies with free entry, the competitive pressure generated by trade leads to a reduction in the number of firms in some product lines. We find that this drop in the number of firms increases market concentration and markups for the top-exporting firms, which although large they are too few to affect the aggregate outcomes which remains robustly pro-competitive.

In our economy with firm heterogeneity and endogenous technical change, the gains from trade operate through a selection and an innovation channel as well. Higher product market competition reallocates market shares across firms with different productivities thereby increasing average productivity and welfare. Competition and selection contribute to make surviving firms larger, thereby rising their incentives to innovate. Our quantitative decomposition of the contribution of each of these channels to the overall gains from trade suggests that variable markups play the major role, whereas selection and innovation play a smaller but non-negligible part.

# A Proof Proposition 1

i. Notice that for $n \geq 1$

$$\theta_n(n) = \frac{n+\alpha-1}{n} = 1 - \frac{1-\alpha}{n} \geq \alpha.$$

Moreover, since $\tau \leq \frac{n}{n+\alpha-1}$,

$$\frac{\theta_d(n)}{\theta_n(n)} = \frac{2n+\alpha-1}{n+\alpha-1}\frac{1}{1+\tau} \geq 1.$$

Finally, since $\mathscr{A}(n) \geq 1$, then $\theta_x(n) \geq \theta_d(n)$. The fact that $\theta_x(n) \leq 1$ is shown in point iv. below.

ii. Comparing (10), (11) and (12) and the definition of $\mathscr{B}_n(z)$ with (20), (21) and (22) and the definition of $\mathscr{B}_x(z)$, it is easy to show that, for a given $n$, $\ell_x(z) \geq \ell_n(z)$ and $h_x(z) \geq h_n(z)$.

iii. The effect of productivity on size and innovation follows directly from (10) and (11) for non-exporters, and (20) and (21) for exporters.

Notice that, for a given $n$, both $\mathscr{B}_n$ and $\mathscr{B}_x$ are independent of z, implying that from (12) and (22)

$$\frac{\partial z}{\partial \tilde{z}} = \frac{1}{1-\eta}\;\frac{z}{\tilde{z}} > 0,$$

meaning that $z$ and $\tilde{z}$ move both in the same direction.

iv. Notice that

$$\frac{\partial \theta_d(n)}{\partial \tau} = -\frac{\theta_d(n)}{1+\tau} < 0, \quad \frac{\partial \theta_f(n)}{\partial \tau} = \frac{\theta_d(n)}{1+\tau} > 0, \quad \text{and} \quad \frac{\partial \theta_x(n)}{\partial \tau} = -\frac{2n(\tau-1)\theta_d(n)^2}{(1-\alpha)(1+\tau)} < 0.$$

Moreover, $\lim_{\tau->1} \theta_x(n) = \frac{2n+\alpha-1}{2n} \leq 1$, for $n \geq 1$, which completes the proof of point i. above.

# B Computational details

The key equations used to solve the model are

$$
\begin{aligned}
\tilde{z}_p(n,z;\Delta) &= A^{\frac{1}{1-\eta}}\left[\frac{\hat{\eta}}{n}(\theta_p\Delta)^{\frac{1}{1-\alpha}}\right]^{\frac{\eta}{1-\eta}} z^{\frac{\eta}{1-\eta}},\\
\tilde{z}_x(n,z;\Delta) &= A^{\frac{1}{1-\eta}}\left[\frac{\hat{\eta}}{n}\mathscr{A}(\theta_d\Delta)^{\frac{1}{1-\alpha}}\right]^{\frac{\eta}{1-\eta}} z^{\frac{\eta}{1-\eta}},\\
\pi_p(n,z;\Delta) &= (1-(1+\hat{\eta})\theta_p)\theta_p^{\frac{\alpha}{1-\alpha}}\frac{1}{n}\Delta^{\frac{1}{1-\alpha}}\tilde{z}_p(n,z;\Delta)-\lambda,\\
\pi_x(n,z;\Delta) &= (1-(1+\hat{\eta})\theta_x)\theta_d^{\frac{\alpha}{1-\alpha}}\frac{1}{n}\Delta^{\frac{1}{1-\alpha}}\tilde{z}_x(n,z;\Delta)-\lambda,\\
L_p(n,z;\Delta) &= (1+\hat{\eta})\left[(\theta_p\Delta)^{\frac{1}{1-\alpha}}\tilde{z}_p(n,z;\Delta)\right]+n\lambda,\\
L_x(n,z;\Delta) &= (1+\hat{\eta})\left[\mathscr{A}(\theta_d\Delta)^{\frac{1}{1-\alpha}}\tilde{z}_x(n,z;\Delta)\right]+n\lambda,
\end{aligned}
$$

where $\Delta$ is defined as $\Delta = E/\hat{X}$; $\tilde{z}_i(n,z;\Delta)$ denotes optimal productivity post innovation; $\pi_i(n,z;\Delta)$ denotes profits; and $L_i(n,z;\Delta)$, denotes total labor demand for each variety, i.e. $L_i(n,z;\Delta) = n(\ell_i + h_i)$. The algorithm used to solve for the equilibrium of the model is as follows:

i. Guess for a value of $\Delta$.

ii. Obtain $\bar{n}_x$ as the largest integer which satisfies

$$\pi_x(\bar{n}_x,\bar{\omega};\Delta)\geq 0.$$

We subsequently obtain $z_x^*(n)$ as the solution to

$$\pi_x(n,z_x^*(n);\Delta)=0, \quad \text{for } n=1,\dots,\bar{n}_x-1.$$

We obtain $\bar{n}_p$ as the largest integer which satisfies

$$\pi_p(\bar{n}_p,z_x^*(1);\Delta)\geq 0,$$

and again obtain $z_p^*(n)$ as the solution to

$$\pi_p(n,z_p^*(n);\Delta)=0, \quad \text{for } n=1,\dots,\bar{n}_p-1.$$

iii. Given these cut-offs we create $\bar{n}_p+\bar{n}_x$ grids: $\vec{z}_p(n)=\{z_p^*(n),\dots,z_p^*(n+1)-\varepsilon\}$ and $\vec{z}_x(n)=\{z_x^*(n),\dots,z_x^*(n+1)-\varepsilon\}$.

iv. Given the pairs $(\vec{z}_p(n),\{1,\dots\bar{n}_p\})$ and $(\vec{z}_x(n),\{1,\dots\bar{n}_x\})$ we use numerical integration to calculate

$$L(\Delta)=\sum_{n=1}^{\bar{n}_p-1}\int_{z_p^*(n)}^{z_p^*(n+1)}L_p(n,z;\Delta)\phi(z)\mathrm{d}z+\int_{z_p^*(\bar{n}_p)}^{z_x^*(1)}L_p(\bar{n}_p,z;\Delta)\phi(z)\mathrm{d}z$$
$$+\sum_{n=1}^{\bar{n}_x-1}\int_{z_x^*(n)}^{z_x^*(n+1)}L_x(n,z;\Delta)\phi(z)\mathrm{d}z+\int_{z_x^*(\bar{n}_x)}^{\bar{\omega}}L_x(\bar{n}_x,z;\Delta)\phi(z)\mathrm{d}z\phi(z)\mathrm{d}z,$$

v. If $L(\Delta)$ is greater than one we adjust the guess of $\Delta$ downwards, and vice versa, and return to step i. If $L(\Delta)\approx 1$ the procedure has converged.

In the numerical implementation we use 50 logarithmically spaced grid points for all grids, and a quasi-Newton method to obtain the values of $z_p^*(n)$ and $z_x^*(n)$, $\forall n$. We use linear interpolation to construct the functions $L_p(n,z;\Delta)$ and $L_x(n,z;\Delta)$ and global adaptive quadrature to numerically calculate $L(\Delta)$. Lastly, we use Brent's method to find the equilibrium value of $\Delta$. All root-finding operations have a maximum tolerance value of $1e(-10)$.

## B.1 Welfare decompositon

The decomposition is given by

$$CV(\tau',\tau_0)=\underbrace{\int_{\tau_0}^{\tau'}\frac{\mathscr{D}E}{\mathscr{D}\tau}\mathrm{d}\tau}_{\text{Expenditures}}+\underbrace{\int_{\tau_0}^{\tau'}\frac{\mathscr{D}I}{\mathscr{D}\tau}\mathrm{d}\tau}_{\text{Innovation}}+\underbrace{\int_{\tau_0}^{\tau'}\frac{\mathscr{D}M}{\mathscr{D}\tau}\mathrm{d}\tau}_{\text{Markups}}+\underbrace{\int_{\tau_0}^{\tau'}\frac{\mathscr{D}S}{\mathscr{D}\tau}\mathrm{d}\tau}_{\text{Selection}}.$$

Using Leibniz rule, the partial effects of the various sources are given by

$$\frac{\mathscr{D}I}{\mathscr{D}\tau}=\frac{1-\alpha}{\alpha}\frac{1}{\bar{z}}\left(\sum_{n=1}^{\bar{n}_p-1}\left(\theta_p(n)^{\frac{\alpha}{1-\alpha}}\frac{\partial\tilde{z}(z,n)}{\partial\tau}\int_{z_n^*(n)}^{z_p^*(n+1)}\phi(z)\mathrm{d}z+\theta_p(\bar{n}_p)^{\frac{\alpha}{1-\alpha}}\frac{\partial\tilde{z}(z,\bar{n}_p)}{\partial\tau}\int_{z_p^*(\bar{n}_p)}^{z_x^*(1)}\phi(z)\mathrm{d}z\right)\right.$$
$$\left.+\sum_{n=1}^{\bar{n}_x-1}\left(\theta_d(n)^{\frac{\alpha}{1-\alpha}}\frac{\partial\tilde{z}(z,n)}{\partial\tau}\int_{z_x^*(n)}^{z_x^*(n+1)}\phi(z)\mathrm{d}z+\theta_d(\bar{n}_x)^{\frac{\alpha}{1-\alpha}}\frac{\partial\tilde{z}(z,\bar{n}_x)}{\partial\tau}\int_{z_x^*(\bar{n}_x)}^{\bar{\omega}}\phi(z)\mathrm{d}z\right)\right),$$

$$\frac{\mathscr{D}M}{\mathscr{D}\tau}\mathrm{d}\tau=\frac{1-\alpha}{\alpha}\frac{1}{\bar{z}}\sum_{n=1}^{n_x-1}\left(\frac{\alpha}{1-\alpha}\theta_d(n)^{\frac{2\alpha-1}{1-\alpha}}\frac{\partial\theta_d(n)}{\partial\tau}\int_{z_x^*(n)}^{z_x^*(n+1)}\tilde{z}(z,n)\phi(z)\mathrm{d}z\right.$$
$$\left.+\frac{\alpha}{1-\alpha}\theta_d(\bar{n}_x)^{\frac{2\alpha-1}{1-\alpha}}\frac{\partial\theta_d(\bar{n}_x)}{\partial\tau}\int_{z_x^*(\bar{n}_x)}^{\bar{\omega}}\tilde{z}(z,\bar{n}_x)\phi(z)\mathrm{d}z\right),$$

$$
\begin{aligned}
\frac{\mathscr{D}S}{\mathscr{D}\tau} = \frac{1-\alpha}{\alpha}\frac{1}{\bar{z}}\Bigg(\sum_{n=1}^{\bar{n}_p-1}\Bigg(\theta_p(n)^{\frac{\alpha}{1-\alpha}}\Bigg[\tilde{z}(z_p^*(n+1),n)\phi(z_p^*(n+1))\frac{\partial z_p^*(n+1)}{\partial\tau} - \tilde{z}(z_n^*(n),n)\phi(z_n^*(n))\frac{\partial z_n^*(n)}{\partial\tau}\Bigg] \\
+\theta_p(\bar{n}_p)^{\frac{\alpha}{1-\alpha}}\Bigg[\tilde{z}(z_x^*(1),\bar{n}_p)\phi(z_x^*(1))\frac{\partial z_x^*(1)}{\partial\tau} - \tilde{z}(z_p^*(\bar{n}_p),\bar{n}_p)\phi(z_p^*(\bar{n}_p))\frac{\partial z_p^*(\bar{n}_p)}{\partial\tau}\Bigg]\Bigg) \\
+\sum_{n=1}^{\bar{n}_x-1}\Bigg(\theta_d(n)^{\frac{\alpha}{1-\alpha}}\Bigg[\tilde{z}(z_x^*(n+1),n)\phi(z_x^*(n+1))\frac{\partial z_x^*(n+1)}{\partial\tau} - \tilde{z}(z_x^*(n),n)\phi(z_x^*(n))\frac{\partial z_x^*(n)}{\partial\tau}\Bigg] \\
-\theta_d(\bar{n}_x)^{\frac{\alpha}{1-\alpha}}\tilde{z}(z_x^*(\bar{n}_x),\bar{n}_x)\phi(z_x^*(\bar{n}_x))\frac{\partial z_x^*(\bar{n}_x)}{\partial\tau}\Bigg)\Bigg) - \frac{\alpha-1}{\alpha}\phi(z_p^*(1))\frac{\partial z_p^*(1)}{\partial\tau},
\end{aligned}
$$

with $\partial\theta_d(n)/\partial\tau = -\theta_d(n)/(1+\tau)$. All remaining derivatives are computed by numeric differentiation using finite differencing and the integral by quadrature using the rectangular method. Both numeric procedures uses a step-size of $\mathrm{d}\tau = 1e(-4)$.

# C Further derivations

**R&D Productivity scaler.** From the analyses above, it is clear that any change in $A$ makes $M\bar{z}$ move proportionally. Since $M = 1-\Phi(z_p^*(1))$ is not affected by changes in $A$, $\bar{z}$ changes proportionally with $A$. Consequently the equilibrium does not depend on $A$, but on the equilibrium distribution of $z$. Hence, there is always an $A$ that makes $\tilde{z} > z$, for all operative varieties. We can then compute equilibrium for a given $A$, say $A = 1$, find the solution, and then rescale $A$ in order to get any arbitrary value of $z$.

**Trade elasticity.** Here we derive $\lambda_d$, the proportion of domestic sales over total sales, necessary to compute the trade elasticity. Total revenues of non-exporting firms can be written as,

$$
R_n = \frac{z_x^*(1)\bar{\theta}}{M\bar{z}}\left(\sum_{n=1}^{\bar{n}_p-1}\left(\frac{\theta_p(n)}{\bar{\theta}}\right)^{\frac{\alpha}{1-\alpha}}\int_{z_p^*(n)}^{z_p^*(n+1)}\tilde{z}(z,n)\phi(z)\mathrm{d}z + \left(\frac{\theta_p(\bar{n}_p)}{\bar{\theta}}\right)^{\frac{\alpha}{1-\alpha}}\int_{z_p^*(\bar{n}_p)}^{z_x^*(1)}\tilde{z}(z,n)\phi(z)\mathrm{d}z\right),
$$

where $\bar{\theta}$ is average markup,

$$
\begin{aligned}
\bar{\theta} = &\frac{1}{M}\left(\sum_{n=1}^{\bar{n}_p-1}\theta_p(n)\int_{z_p^*(n)}^{z_p^*(n+1)}\phi(z)\mathrm{d}z + \theta_p(\bar{n}_p)\int_{z_p^*(\bar{n}_p)}^{z_x^*(1)}\phi(z)\mathrm{d}z\right) \\
&+\frac{1}{M}\left(\sum_{n=1}^{\bar{n}_x-1}\theta_d(n)\int_{z_x^*(n)}^{z_x^*(n+1)}\phi(z)\mathrm{d}z + \theta_d(\bar{n}_x)\int_{z_x^*(\bar{n}_x)}^{\bar{\omega}}\phi(z)\mathrm{d}z\right).
\end{aligned}
$$

Total revenues of exporting firms on their domestic sales are,

$$R_d = \frac{\bar{\theta}}{M\bar{z}} \left( \sum_{n=1}^{\bar{n}_x - 1} \frac{\tau - \mathscr{A}(n)}{\tau - 1} \left( \frac{\theta_d(n)}{\bar{\theta}} \right)^{\frac{\alpha}{1-\alpha}} \int_{z_x^*(n)}^{z_x^*(n+1)} \tilde{z}(z,n)\phi(z)\mathrm{d}z + \frac{\tau - \mathscr{A}(\bar{n}_x)}{\tau - 1} \left( \frac{\theta_d(\bar{n}_x)}{\bar{\theta}} \right)^{\frac{\alpha}{1-\alpha}} \int_{z_x^*(\bar{n}_x)}^{\bar{\omega}} \tilde{z}(z,n)\phi(z)\mathrm{d}z \right).$$

Total revenues of exporting firms from their export sales are

$$R_f = \frac{\bar{\theta}}{M\bar{z}} \left( \sum_{n=1}^{\bar{n}_x - 1} \frac{\mathscr{A}(n) - 1}{\tau - 1} \left( \frac{\theta_d(n)}{\bar{\theta}} \right)^{\frac{\alpha}{1-\alpha}} \int_{z_x^*(n)}^{z_x^*(n+1)} \tilde{z}(z,n)\phi(z)\mathrm{d}z + \frac{\mathscr{A}(\bar{n}_x) - 1}{\tau - 1} \left( \frac{\theta_d(\bar{n}_x)}{\bar{\theta}} \right)^{\frac{\alpha}{1-\alpha}} \int_{z_x^*(\bar{n}_x)}^{\bar{\omega}} \tilde{z}(z,n)\phi(z)\mathrm{d}z \right).$$

Total revenues is $R = R_n + R_d + R_f$, and the share of domestic sales is then

$$\lambda_d = \frac{R_n + R_d}{R}.$$

# D Robustness

Table D1 shows a summary of the effects of trade liberalization on economic aggregates, under six different parameterizations. That is, the table provides as robustness equivalent to Table 4.

Table D1: Robustness of aggregate effects.

| | | Bench. | $\bar{\alpha}$ | $\underline{\alpha}$ | $\bar{\eta}$ | $\underline{\eta}$ | $\bar{\kappa}$ | $\underline{\kappa}$ |
|---|---|---|---|---|---|---|---|---|
| *Firm size* | | | | | | | | |
| Exporters | $\tau = 1.12$ | 4.03 | 4.46 | 3.64 | 4.33 | 3.77 | 3.94 | 4.14 |
| | $\tau = 1.00$ | 4.79 | 6.00 | 4.09 | 5.22 | 4.44 | 4.68 | 4.94 |
| Domestic | $\tau = 1.12$ | 1.48 | 1.89 | 1.20 | 1.52 | 1.44 | 1.47 | 1.48 |
| | $\tau = 1.00$ | 1.48 | 1.91 | 1.20 | 1.52 | 1.44 | 1.47 | 1.48 |
| *TFP* | | | | | | | | |
| Exporters | $\tau = 1.12$ | 6.95 | 4.87 | 7.97 | 7.50 | 6.50 | 8.40 | 5.75 |
| | $\tau = 1.00$ | 9.74 | 8.69 | 10.5 | 10.8 | 8.92 | 11.1 | 8.67 |
| Domestic | $\tau = 1.12$ | 1.25 | 1.30 | 1.23 | 1.24 | 1.27 | 1.22 | 1.29 |
| | $\tau = 1.00$ | 1.27 | 1.33 | 1.24 | 1.26 | 1.28 | 1.23 | 1.31 |
| *Cutoffs* | | | | | | | | |
| Exporters | $\tau = 1.12$ | 1.66 | 1.64 | 1.66 | 1.69 | 1.63 | 1.63 | 1.70 |
| | $\tau = 1.00$ | 1.68 | 1.72 | 1.68 | 1.73 | 1.64 | 1.65 | 1.74 |
| Domestic | $\tau = 1.12$ | 1.14 | 1.20 | 1.11 | 1.14 | 1.13 | 1.11 | 1.17 |
| | $\tau = 1.00$ | 1.15 | 1.22 | 1.12 | 1.15 | 1.14 | 1.12 | 1.18 |
| *Markups* | | | | | | | | |
| Exporters | $\tau = 1.12$ | 1.20 | 1.16 | 1.22 | 1.20 | 1.20 | 1.20 | 1.20 |
| | $\tau = 1.00$ | 1.18 | 1.13 | 1.20 | 1.18 | 1.18 | 1.18 | 1.18 |
| Domestic | $\tau = 1.12$ | 1.44 | 1.31 | 1.52 | 1.44 | 1.44 | 1.44 | 1.44 |
| | $\tau = 1.00$ | 1.44 | 1.31 | 1.52 | 1.44 | 1.44 | 1.44 | 1.44 |

*Notes.* This table illustrates the effects of reducing the iceberg cost, $\tau$, from 1.12 to 1 on the aggregate/average variables under seven different parameterizations. A parameter denoted $\bar{x}$ ($\underline{x}$) indicates an increase (decrease) of that parameter's value by 10% relative to benchmark. The calculations are described in section 4.1.

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