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# Technology, Market Structure and the Gains from Trade

By

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**Abstract**

We study the gains from trade in an economy with oligopolistic competition, firm heterogeneity, and innovation. Oligopolistic competition together with free entry make markups responsive to firm productivity and trade costs. 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. Nevertheless, the downward pressure dominates and the average markup declines, deterring firms from entering the market and leading to higher market concentration. Neither the increased concentration nor the incomplete pass-through of trade costs to export markups are strong enough to compensate for the increase in competition on domestic sales. Thus the overall effect of trade on markups is pro-competitive and a key source of the associated welfare gains. In addition to markups, selection and innovation provide additional channels through which the trade-induced effect on competition impacts welfare. In a quantitative exercise, we decompose the total gains from trade into these three contributing channels; we find that innovation plays a small but non-negligible role, while the main component is equally split between the pro-competitive and the selection channel.

***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 account 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 Eckhout, 2017).[1] Large firms are also found to be key players in innovation races to obtain leadership on global markets (Bustos, 2011, Aghion et al. 2017). Standard models of international trade with heterogeneous firms, however, cannot 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 globalization. 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 characterized by oligopolistic firms heterogeneous in productivity and market power. The response of technology and market structure to lowering trade barriers shapes the welfare impact of globalization. Our main finding is that trade gives rise to large welfare gains through the pro-competitive channel – via lower markups – but also through selection, and to a lesser, but non-negligible extent, through innovation.

In particular, we build a global economy with two symmetric countries in which firms are small compared to the whole economy, but large within their own product line (Neary, 2003). The 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 gives rise to variable markups, which provides the key foundation for our analysis. Productivity differ across product lines, but the small number of firms competing head-to-head in each product line have the same level of productivity. At entry firms target a product line, and a free-entry condition ensures zero profits and pins down the number of local and foreign firms competing in each line. As a consequence, markups differ across product lines, and the equilibrium depends critically on the endogenous distribution of markups. After entry, firms decide how much resources they want to devote to production, and how much they allocate to improve their productivity via innovation. Fixed operating costs generate selection on both the domestic and export market, as well as increasing returns to scale.

As in the simple model by Brander and Krugman (1983), trade affects the economy through its effect on markups. In particular, trade liberalization reduces markups thereby increasing consumer surplus. With free entry there is no producer surplus, and consumer surplus is the sole driver of the gains from trade. We disentangle the several forces contributing to this *pro-competitive* effect of trade. First, a reduction in trade costs increases foreign competitive pressure which shrinks markups

[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.

on domestic sales. Second, exporters do not pass the whole reduction in trade costs onto foreign consumers, as they also increase markups on export sales. We show that the first force dominates and the average markup of exporting firms declines with trade liberalization. Moreover, the reduction in average markups affects the incentives of new firms to enter the market, leading to a decline in the number of active firms in each product line and to more concentrated markets. Interestingly, this anti-competitive feedback only partially offsets the effect of trade on markups which remains pro-competitive. The reduction in markups – and the consequent reduction in prices – has a direct and positive impact on welfare.

Firm heterogeneity and innovation provide some additional, indirect, channels through which the trade-induced increase in competition propagates trough the economy. In particular, the reduction in profitability triggered by trade liberalization forces less productive firms out of both the domestic and the export market. These selection effects redistribute resources toward the most productive firms, thereby increasing average productivity and, consequently, welfare. Moreover, the reduction in markups and the positive effects of selection encourages further investments in innovation. Higher innovation leads to within-firm increases in productivity which generates an additional channel of welfare gains.

In our economy variable markups are necessary for trade to be mutually beneficial; indeed, without them trade would vanish as countries are perfectly symmetric in all features, including the set of varieties produced and the productivity distribution. Variable markups trigger selection and innovation, which generates additional welfare gains from trade. Moreover, since competition, selection and innovation are jointly determined, 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 identify 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. Calibrating the model to match some aggregate and firm-level US statistics we find that, in our benchmark economy, about 10 percent of total gains from trade can be attributable to innovation while the rest is equally split between the pro-competitive and the selection effect.

**Literature review.** Our paper contributes to the 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, as it has allowed researchers to understand better the dispersed effects trade brings forth. An important challenge, however, has been to understand whether the 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 an 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.

Edmond, Midrigan and Xu (2015) present a quantitative evaluation of the pro-competitive gains from trade in the model 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, selection, and innovation gains from trade. 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.

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 an dynamic model with no long-run growth and constant markups, Atkeson and Burstein (2010) show that the role of innovation depends on the curvature of the innovation technology and on the speed of the transition 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. 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 obtainable in static models. This paper is closely related to the analysis presented here but we depart in a few critical ways. First, we adopt a more sophisticated entry structure which allows markups to vary with firm productivity, in line with empirical evidence highlighting large markup dispersion across firms. Second and more importantly, we analyze a static model without any knowledge spillovers influencing the welfare impact of innovation. Atkeson and Burstein (2010) observe that the welfare gains from the innovation response of firms to trade in endogenous growth models depend crucially on the strong knowledge spillovers typically assumed in these models. We contribute to this literature showing that in the absence of spillovers innovation has a small but 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 with free-entry by Brander and Krugman (1983). We embed this structure in a modern 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 have important implications for the new gains from trade.[2]

The complex interaction between market size, innovation and competition analyzed 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 large economies can be characterized by powerful firms undertaking strategic investment in innovation. On the one hand, firms' market power leads to heavy inefficiencies but, on the other hand, strong innovation spending 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 consider firm heterogeneity. In the closed economies analyzed 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 – markups, 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.[3]

# 2 Economic Environment

Consider a static world economy populated by two symmetric countries producing the same varieties, with the same technologies, preferences, and endowments. We assume that trade costs are of the iceberg type: $\tau > 1$ units of goods must be produced and shipped abroad for each unit sold at destination. They represent transportation costs and trade barriers created by policy. For simplicity, no fixed trade costs are assumed.

**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.

[2] In a survey, 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 by their clear empirical relevance in a world with global powerful firms.

[3] 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.

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) and recently in Bilbiie, Ghironi, and Melitz (2016) among others – allows us to separate love for variety, captured by parameter $\nu$, from $\alpha$ which determines firms' market power. The pure effect of the mass of available varieties on individual welfare is pinned down by $\nu$, and the total effect depends on $\nu + (1-\alpha)/\alpha$. In the particular CES specification of Dixit and Stiglitz (1977), $\nu = 0$ and the welfare effect of changing the mass of varieties is given by $(1-\alpha)/\alpha$. This externality vanishes in the opposite, extreme case, of $\nu = (\alpha - 1)/\alpha$, where the economy does not feature any love for variety. As shown in Benassy (1998), the equilibrium allocation does not depend on $\nu$, whose only role is determine the welfare effect of new varieties. As our global economy consists of countries symmetric in all features including the range of varieties produced, the relevant gains from trade are not related to the expansion of available varieties, and we set $\nu = (\alpha - 1)/\alpha$ to shut this aspect of the model down for most of the quantitative analysis.

**Technology and market structure.** Domestic firms use labor to cover both variable production costs and a fixed operating cost $\lambda$, $\lambda > 0$. 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 productivity $z$, $z \in \mathbb{R}_{+}$, faces the following cost function

$$\ell(z) = z^{\frac{\alpha-1}{\alpha}} q(z) + \lambda, \tag{2}$$

where $\ell(z)$ represents the amount of labor required to produce $q(z)$ units of output. Variable costs are assumed to be decreasing in the firm's state of technology. A variety $z$ is domestically produced by a small number $n(z) \geq 1$ 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 (about two or three in our numerical implementation) with identical technologies. 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. 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.[4] Hence, we interpret this as a model of an economy with heterogeneous firms rather than heterogeneous industries.[5]

Our symmetric countries assumption implies that both countries produce exactly the same varieties with the same productivity distribution. This economy features two-ways trade in similar good, as in standard oligopoly trade models (e.g. Brander and Krugman, 1983).

**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, with some exported while others are not. Let us use subindices $n$ and $x$ to refer to non-exported and exported varieties, respectively. A variety $z$ is domestically produced by $n(z)$ identical firms, $n(z) \geq 1$, manufacturing perfectly substitutable goods and competing à la Cournot. All $n(z)$ firms producing the same variety $z$ have the same technology. In equilibrium, a zero profit (entry) condition endogenously determines the number of firms $n(z)$ and consequently their markups across product lines. For simplicity, $n(z)$ is assumed to belong to the real line and not to set of integers. This assumption is instrumental to have a continuous distribution of markups at equilibrium.

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

$$\Phi(\tilde{z}) = \frac{1-(\underline{\omega}/\tilde{z})^{\kappa}}{1-(\underline{\omega}/\overline{\omega})^{\kappa}}, \tag{3}$$

for $\tilde{z} \in (\underline{\omega}, \bar{\omega})$, $0 < \underline{\omega} < \bar{\omega} < \infty$, 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

$$z = A\ h(z)^{\eta}\ \tilde{z}, \tag{4}$$

where $z$ denotes the actual productivity, and $\eta \in (0,1)$ and $A > 0$ are constant parameters. The variable $h(z)$ represents labor allocated to innovation activities. All firms producing the same variety share the same initial productivity, $\tilde{z}$, undertake the same research effort, $h(z)$, and obtain the same final productivity, $z$.

[4]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.

[5]Introducing some heterogeneity between the few firms within the same product line would generalize the model without affecting the fundamental results.

# 3 Equilibrium

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

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

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 $\hat{X} = M \int x(z)^{\alpha}\, \mathrm{dF}(z) = (X/M^{v})^{\alpha}$.

Firms producing the same variety play a symmetric Cournot game. They behave non-cooperatively, and maximizes 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, omitting argument $z$ to simplify notation, is

$$\pi_n = \max_{\{q_n, h_n\}} \frac{E}{\hat{X}} \left(\hat{x}_n + q_n\right)^{\alpha-1} q_n - \Big(\underbrace{A h_n^{\eta}\, \tilde{z}}_{z}\Big)^{\frac{\alpha-1}{\alpha}} q_n - \lambda - h_n,$$

where $q_n$ is the firm's production, and $\hat{x}_n$ is the production of its direct competitors. Total consumption is therefore $x_n = \hat{x}_n + q_n$. Since labor has been adopted as the numéraire, wages are equal to one. The first order conditions for $q_n$ and $h_n$ are

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

and

$$\hat{\eta}\, z^{\frac{\alpha-1}{\alpha}}\, q_n / h_n = 1, \tag{7}$$

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

Since the equilibrium is symmetric, $x_n = n q_n$. Using this relation and rearranging equation (6) yields

$$x_n(z)^{\alpha} = \left(\frac{\theta_n E}{\hat{X}}\right)^{\frac{\alpha}{1-\alpha}} z, \tag{8}$$

where $\theta_n \equiv (n + \alpha - 1)/n$ represents the inverse of non-exporters' markups.

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

$$p_n = \frac{z^{\frac{\alpha-1}{\alpha}}}{\theta_n}. \tag{9}$$

Equation (9) brings to light 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 (2) and (8) shows that variable production costs (recall that labor is the numéraire) is given by

$$\ell_n - \lambda = z^{\frac{\alpha-1}{\alpha}} q_n = z^{\frac{\alpha-1}{\alpha}} \frac{x_n}{n} = \frac{1}{n}\left(\frac{\theta_n E}{\hat{X}}\right)^{\frac{1}{1-\alpha}} z. \tag{10}$$

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

$$h_n = \hat{\eta}\ \left(\ell_n - \lambda\right). \tag{11}$$

Since incumbent firms innovate with the aim of reducing variable production costs, the innovation effort positively depends on a firm's variable labor demand, and hence on 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 $h_n$ into the R&D technology, the productivity of this variety is given by

$$z = \mathscr{B}_n(z)\, \tilde{z}^{\frac{1}{1-\eta}}, \tag{12}$$

with $\mathscr{B}_n(z) = A^{\frac{1}{1-\eta}} \left(\frac{\hat{\eta}}{n}\left(\frac{\theta_n E}{\hat{X}}\right)^{\frac{1}{1-\alpha}}\right)^{\frac{\eta}{1-\eta}}$. In equilibrium, as shown below, $n$ depends on $z$, thus $\theta_n$ and $\mathscr{B}_n$ depend on the productivity level as well. Let us define the endogenous lower-bound of the projection of the entry distribution into the $z$ domain as $\underline{\zeta}_n = \mathscr{B}_n(\underline{\zeta}_n)\, \underline{\omega}^{\frac{1}{1-\eta}}$.[6]

**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

[6] Because of selection, product lines with productivity $\tilde{z} = \underline{\omega}$ will not be produced at equilibrium, implying that firms with productivity $z = \underline{\zeta}_n$ won't be observed.

$\hat{x}_f$, as given and solve (as before, we omit the dependence $z$ to simplify notation),

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

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,

$$\frac{E}{\hat{X}}\Big((\alpha-1)(\hat{x}_d + q_d)^{\alpha-2} q_d + (\hat{x}_d + q_d)^{\alpha-1}\Big) = z^{\frac{\alpha-1}{\alpha}}, \tag{13}$$

$$\frac{E}{\hat{X}}\Big((\alpha-1)(\hat{x}_f + q_f)^{\alpha-2} q_f + (\hat{x}_f + q_f)^{\alpha-1}\Big) = \tau z^{\frac{\alpha-1}{\alpha}}. \tag{14}$$

The first order condition for R&D labor is

$$\hat{\eta}\, z^{\frac{\alpha-1}{\alpha}} \left(q_d + \tau q_f\right)/h_x = 1. \tag{15}$$

Since the equilibrium is symmetric, i.e. $x_x = n(q_d + q_f)$, by adding equations (13) and (14), total consumption of traded varieties is given by

$$x_x(z)^{\alpha} = \left(\frac{\theta_d E}{\hat{X}}\right)^{\frac{\alpha}{1-\alpha}} z, \tag{16}$$

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

$$p = \frac{z^{\frac{\alpha-1}{\alpha}}}{\theta_d} = \frac{\tau z^{\frac{\alpha-1}{\alpha}}}{\theta_f},$$

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 penetration of foreign firms. The pro-competitive effect of trade 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, not passing the whole cost reduction onto foreign consumers. This "pricing to market" mechanism is typical of oligopoly trade models (e.g. Atkeson and Burstein (2008)).

The ratio of production to consumption of traded varieties,

$$\frac{q_d + \tau q_f}{q_d + q_f} = \frac{(1-n-\alpha)(1+\tau^2) + 2n\tau}{(1-\alpha)(1+\tau)} \equiv \mathscr{A} > 1, \tag{17}$$

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 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.[7]

Let us define the average markup of an exporting firm as

$$\theta_x \equiv \frac{q_d \theta_d + q_f \theta_f}{q_d + q_f} = \mathscr{A}\ \theta_d. \tag{18}$$

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 $\theta_x = \theta_d = \theta_n = (n+\alpha-1)\,/n$, since $q_f = 0$. 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 for $\tau$, the markup in foreign markets turns negative, and firms do not find it profitable to export. Under free trade, $\theta_x = \theta_d = (2n+\alpha-1)\,/2n > \theta_n$, since $\theta_f = \theta_d$.

Exporters' variable production costs are

$$\ell_x - \lambda = z^{\frac{\alpha-1}{\alpha}} \left(q_d + \tau q_f\right) = z^{\frac{\alpha-1}{\alpha}} \mathscr{A} \left(q_d + q_f\right) = \frac{\mathscr{A}}{n} \left(\frac{\theta_d E}{\hat{X}}\right)^{\frac{1}{1-\alpha}} z, \tag{19}$$

where $\ell_x$ is labor allocated to the production of goods for both the domestic and foreign markets. When comparing (19) to (10), it can be seen that for a given $z$, 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 $\theta_d > \theta_n$, and have to cover variable trade costs, as reflected by $\mathscr{A} > 1$.

Rearranging the first order condition for $h_x$, i.e. equation (15), and using the expression for labor demand above, R&D effort is given by

$$h_x = \hat{\eta}\ \left(l_x - \lambda\right). \tag{20}$$

Similarly to domestic firms, exporters' innovation effort is proportional to firm size. Since, controlling for productivity, exporters are larger than non-exporters they also innovate more. Furthermore, since productivity affects size as well, more productive exporters produce more, demand more labor and

[7] 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 $\tau \in (1, n/(n+\alpha-1))$. In order to show that, notice that the sign of the partial derivative $\frac{\partial \mathscr{A}}{\partial \tau}$ is equal to the sign of

$$(1-n-\alpha)(1+\tau)^2 + 2(2n+\alpha-1),$$

which has a zero at $1+\tau = \sqrt{\frac{2(2n+\alpha-1)}{n+\alpha-1}}$, for $\tau$ in the interval $(1, n/(n+\alpha-1))$. $\mathscr{A}$ is increasing before that maximum and decreasing after.

invest more in R&D.

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

$$z = \mathscr{B}_x(z)\, \tilde{z}^{\frac{1}{1-\eta}}, \tag{21}$$

with $\mathscr{B}_x(z) = A^{\frac{1}{1-\eta}} \left( \frac{\hat{\eta}\mathscr{A}}{n} \left( \frac{\theta_d E}{\hat{X}} \right)^{\frac{1}{1-\alpha}} \right)^{\frac{\eta}{1-\eta}}$. Since $n$ depends on $z$ at equilibrium, $\mathscr{B}_x$ is a function of $z$. In the following, let us define the upper-bound of the equilibrium productivity distribution as $\overline{\zeta}_x = \mathscr{B}_x(\overline{\zeta}_x)\, \bar{\omega}^{\frac{1}{1-\eta}}$. We summarize some key properties in the proposition below.

**Proposition 1.** *For a given $n \geq 1$, a productivity level $\tilde{z}$, $\tau \in [1, \bar{\tau}(n)]$, and $\bar{\tau}(n) = \frac{n}{n+\alpha-1}$,*

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

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

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

iii. *Firms with a higher potential productivity, $\tilde{z}$, invest more in R&D.*

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. □

For a given number of firms and initial productivity level, exporters charge lower markups both on their domestic and their total sales compared to non-exporting firms. Exporters innovate more than non-exporters. Firm size and innovation scale positively with productivity. And for a given number of firms, 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, when the number of firms is kept constant, there is an overall pro-competitive effect of trade.

Next, we allow fims 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 changes in market size.

## 3.1 Entry and Selection

We focus on an entry strategy in which firms target product lines and enter sequentially until there is no gap that can be profitably filled. Hence, firms enter product lines until profits are exhausted;

i.e. when revenues net of all variable costs equal the fixed operating cost. 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 productivity $z$ as

$$\begin{aligned}
\pi_n(z) &= p_n(z)q_n(z) - z^{\frac{\alpha-1}{\alpha}} q_n(z) - \lambda - \underbrace{\hat{\eta} z^{\frac{\alpha-1}{\alpha}} q_n(z)}_{h_n(z)} \\
&= \left(\frac{1}{\theta_n} - \left(1+\hat{\eta}\right)\right) \frac{1}{n} \left(\frac{\theta_n E}{\hat{X}}\right)^{\frac{1}{1-\alpha}} z - \lambda \\
&= \left(1 - \left(1+\hat{\eta}\right)\theta_n\right) \theta_n^{\frac{\alpha}{1-\alpha}} \frac{1}{n} \left(\frac{E}{\hat{X}}\right)^{\frac{1}{1-\alpha}} z - \lambda,
\end{aligned}$$

and recall that $\theta_n$ is a function of the number of firms, $n$. In equilibrium, the number of non-exporting firms with productivity $z$ is determined by the zero-profit (entry) condition $\pi_n(z) = 0$. Let $n_n(z)$ denote the resulting number of firms, which must satisfy

$$\frac{\theta_n(n)^{\frac{\alpha}{\alpha-1}}}{1 - \left(1+\hat{\eta}\right)\theta_n(n)} n = \left(\frac{E}{\hat{X}}\right)^{\frac{1}{1-\alpha}} \frac{z}{\lambda}, \tag{22}$$

with

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

Since the right-hand side of (22) is increasing in $z$ and the left hand side is increasing in $n$, the entry condition implies that more productive product lines have a higher number of firms.

**Proposition 2.** *The number of firms in non-exporting product lines, $n_n(z)$, is increasing in $z$, and markups, $1/\theta_n(n_n(z))$, are decreasing in $z$.*

*Proof.* See Appendix A. □

More productive non-exported product lines attract more firms, hence more productive firms operate in more competitive markets. The largest possible markup in these lines corresponds to the case of a monopolist, i.e. when $n = 1$. Thus, there is a cutoff productivity $z_n^*$,

$$z_n^* = \frac{\lambda\, \alpha^{\frac{\alpha}{\alpha-1}}}{1 - \left(1+\hat{\eta}\right)\alpha} \left(\frac{\hat{X}}{E}\right)^{\frac{1}{1-\alpha}}, \tag{EC}$$

such that varieties with productivity $z < z_n^*$ are not produced in equilibrium, since even a monopolist will make negative profits. When $z = z_n^*$ only one firm enters the market. 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 $z_n^* > \underline{\zeta}$ exists and is unique for $\underline{\zeta}$ small enough. As shown in the proof of Proposition 2, the left-hand-side of equation (22) is increasing in $n$, implying that the function $n_n(z)$ exists and is unique too. Notice also that for any non-exporters with $z > z_n^*$ we must have $1-\left(1+\hat{\eta}\right)\theta_n\left(n_n(z)\right) > 0$, otherwise firms will make negative profits and no firm will be operative in this product line.

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

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

The number of exporters, $n_x(z)$, is then determined by the zero profit (entry) condition,

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

with

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

**Conjecture 1.** *The number of firms in an exported product line, $n_x(z)$, is increasing in z, and the associated domestic markup, $1/\theta_d(n_x(z))$, and average markup, $1/\theta_x(n_x(z))$, are both decreasing in z.*[8]

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

$$z_x^* = \frac{\lambda\ \theta_d^{*\frac{\alpha}{\alpha-1}}}{1-\left(1+\hat{\eta}\right)\theta_x^*}\left(\frac{\hat{X}}{E}\right)^{\frac{1}{1-\alpha}}, \tag{XC}$$

with

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

At this cutoff productivity we observe a duopoly in both markets, with one firm from the home and one from the foreign country.

[8] We have numerically found that the derivative with respect to $n$ of the left-hand side of (23) is strictly positive in a large grid containing five points for $n \in \{1,2,3,4,5\}$, 20 points for $\alpha \in (.05,.95)$, times 20 points for both $\eta \in (0,\bar{\eta})$, $\bar{\eta} = \frac{\alpha}{2\times 5+\alpha-1}$ and $\tau \in (1,\bar{\tau})$, $\bar{\tau} = \frac{5}{5+\alpha-1}$. The prohibitive iceberg cost is evaluated at 5 which corresponds to the maximum $n$ in the grid. The same applies to the maximum value of $\eta$, $\bar{\eta}$. These conditions are also satisfied in the benchmark calibration and in the robustness analysis presented in Tables 4 and D.1.

Let us now introduce two important considerations that restrict the parameter set. We will discuss first the issue for the export cutoff, $z_x^*$, and then we will move on to the general case including all exported product lines with $z \in (z_x^*, \overline{\zeta}_x)$. The first parametric restriction is related to the prohibitive iceberg cost. Recall that at $z = z_x^*$, by definition $n(z_x^*) = 1$, 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, $\theta_x^*$ is decreasing in $\tau$. Let us then evaluate $z_x^*$ at $\tau = 1$, where $\theta_x^*$ will take on its largest value. In this case, for $z_x^*$ to be positive, it is required that $\eta < \alpha/(1+\alpha) < 1/2$, otherwise $1 - \left(1+\hat{\eta}\right)\theta_x^* \leq 0$ 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 $\theta_x^*$.

In the general case, for $z \in (z_x^*, \overline{\zeta}_x)$, the number of domestic firms, $n_x(z)$, is increasing in $z$, which makes the prohibitive iceberg cost, $\bar{\tau}(n) = n/(n+\alpha-1)$, decreasing in productivity $z$. The maximum number of exporters corresponds to $z = \overline{\zeta}_x$, with an associated prohibitive iceberg cost $\bar{\tau}\left(n_x(\overline{\zeta})\right)$; the maximum value of $\tau$ that allows all product lines $z \in (z_x^*, \bar{\zeta}_x)$ to profitably export. In the following, we will assume that $\tau < \bar{\tau}\left(n_x(\overline{\zeta})\right)$. 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 initial productivity. Finally, it is required that $1 - (1+\hat{\eta})\theta_x(n_x(z))$ is positive for all $z \in (z_x^*, \overline{\zeta}_x)$. 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 $\eta < \alpha/\left(2n_x(\overline{\zeta}_x)+\alpha-1\right)$. We summarize these restrictions in the following assumption.

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

$$\begin{aligned} \tau &< \bar{\tau}\left(n_x(\overline{\zeta})\right) < 1/\alpha, \\ \eta &< \alpha/\left(2n_x(\overline{\zeta}_x)+\alpha-1\right) < \alpha/(1+\alpha) < 1/2. \end{aligned}$$

Using conditions (EC) and (XC) we can write the ratio between the two cutoffs as

$$\frac{z_x^*}{z_n^*} = \frac{1-\left(1+\hat{\eta}\right)\alpha}{1-\left(1+\hat{\eta}\right)\theta_x^*} \left(\frac{\alpha}{\theta_d^*}\right)^{\frac{\alpha}{1-\alpha}} > 1, \tag{EC-XC}$$

which depend on parameters $\alpha$ and $\tau$; strictly exceeds one for $\tau \in (1, 1/\alpha)$; and is equal to one for $\tau = \bar{\tau}(1) = 1/\alpha$. Under the parameter restrictions discussed above we know that $\tau$ is bounded by the prohibitive iceberg cost corresponding to the most productive variety $\bar{\zeta}$, $\tau < \bar{\tau}\left(n_x(\overline{\zeta})\right) < 1/\alpha$, which leads us to the following result.

**Proposition 3.** *Exporters are more productive than non-exporters.*

*Proof.* See Appendix A. □

Finally, combining Propositions 1 and 3 suggests that exporters are more productive, larger, and invest more in R&D, relative to non-exporters. Moreover there is an additional feedback generated by entry. Exporters operate in more competitive product lines which, on the one hand, implies lower markups and therefore a larger firm size, $q$. On the other hand, a larger number of firms entails that each firm has a smaller share of the market, as shown by equations (10) and (19), which thereby reduces the firm size. We cannot analytically establish a size and innovation difference between exporters and non-exporters. Later, however, we show numerically that exporters are more productive, face fiercer competition, and are larger and innovate more than non-exporting firms.

## 3.2 General Equilibrium

**Equilibrium mass of operative varieties $M$.** Given that the total mass of product lines is one and only those with productivity $z > z_n^*$ are produced, the mass of operative varieties is given by

$$M = 1 - \Phi(\tilde{z}_n^*) = 1 - \Phi(\mathscr{B}_n(z_n^*)^{\eta-1} z_n^{*\,1-\eta}). \tag{24}$$

The mass of potential varieties is bounded from above at one, and since selection necessarily reduces the mass of operative varieties, it must also induce some welfare losses that need to be more than compensated for by productivity gains in order for trade to improve welfare. That is, the model is set up to put us in the worse position possible to get welfare gains from trade-induced selection.[9]

**Equilibrium Distribution.** In equilibrium, varieties are not produced for $z < z_n^*$; they are produced but non-traded for $z \in (z_n^*, z_{nx}^*)$; and produced and traded for $z \in (z_x^*, \overline{\zeta}_x)$. Notice that the exporters' initial productivity cutoff is given by $\tilde{z}_x^* = \mathscr{B}_x(z_x^*)^{\eta-1} z_x^{*\,1-\eta}$. Since $\mathscr{B}_n(z)$ is smaller than $\mathscr{B}_x(z)$, the productivity of the marginal non-exporter, $z_{nx}^* = \mathscr{B}_n(z_{nx}^*)\, \tilde{z}_x^{*\,1/(1-\eta)}$, is smaller than the productivity of the marginal exporter, $z_x^*$, implying a hole in the equilibrium productivity distribution; i.e. there may be no firms with productivity $z \in \left(z_{nx}^*, z_x^*\right)$.

Let $\phi(\tilde{z})$ denote the density associated to the entry distribution $\Phi(\tilde{z})$; i.e., $\phi(\tilde{z}) = \Phi'(\tilde{z})$ for $\tilde{z} \in (\underline{\omega}, \bar{\omega})$. For simplicity, define $g_i(z)$ as $g_i(z) \equiv \mathscr{B}_i(z)^{\eta-1} z^{1-\eta}$, for $i = \{n, x\}$. From equations (12) and (21), $\tilde{z} = g_n(z)$ for $z \in (z_n^*, z_{nx}^*)$ and $\tilde{z} = g_x(z)$ for $z \in (z_x^*, \overline{\zeta}_x)$. Consequently, the entry density may be written as a function of $z$, for $i = \{n, x\}$, according to

$$\varphi_i(z) = \phi\left(g_i(z)\right) g_i'(z).$$

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

From equation (24),

$$\int_{z_n^*}^{z_{nx}^*} \varphi_n(z)\mathrm{d}z + \int_{z_x^*}^{\overline{\zeta}_x} \varphi_x(z)\mathrm{d}z = 1 - \Phi(\tilde{z}_n^*) = M.$$

The equilibrium density, $\mathrm{f}(z)$, is then given by $\mathrm{f}(z) = \varphi(z)/M$, with associated cumulative distribution $\mathrm{F}(z)$.

**Labor Market Clearing.** The labor market clears when labor demand is equal to labor supply. That is,

$$\begin{aligned}\int_{z_n^*}^{z_{nx}^*} n_n(z)\big(\ell_n(z)+h_n(z)\big)\varphi_n(z)\mathrm{d}z + \int_{z_x^*}^{\bar{\zeta}_x} n_x(z)\big(\ell_x(z)+h_x(z)\big)\varphi_x(z)\mathrm{d}z = \\ M\left(\int_{z_n^*}^{z_{nx}^*} p_n(z)x_n(z)\mathrm{dF}_n(z) + \int_{z_x^*}^{\overline{\zeta}_x} p_x(z)x_x(z)\mathrm{dF}_x(z)\right) = \\ E = 1. \qquad \text{(MC)}\end{aligned}$$

Since the free-entry condition imposes zero profits for all operative varieties, it also implies that $p_i(z)x_i(z)/n_i(z) = \ell_i(z)+h_i(z)$ for $i = \{n,x\}$. Recall that aggregate labor supply (and endowment) is equal to one and that labor is the numéraire (i.e. the wage is one). Moreover, since profits are zero in all product lines, total income is just labor income. Since income can only be spent on consumption goods, total expenditure has to be equal to unity too.

**Aggregation.** Substituting equilibrium demands for all varieties into equation (1), the auxiliary variable $\hat{X}$ becomes

$$\begin{aligned}\hat{X} &= E^{\alpha}(M\bar{z})^{1-\alpha} = (M\bar{z})^{1-\alpha}, \\ X &= M^{\nu+\frac{1-\alpha}{\alpha}}\,\bar{z}^{\frac{1-\alpha}{\alpha}},\end{aligned} \tag{25}$$

where

$$\bar{z} = \frac{1}{M}\left(\int_{z_n^*}^{z_{nx}^*} \theta_n(z)^{\frac{\alpha}{1-\alpha}}\, z\,\varphi_n(z)\mathrm{d}z + \int_{z_x^*}^{\overline{\zeta}_x} \theta_d(z)^{\frac{\alpha}{1-\alpha}}\, z\,\varphi_x(z)\mathrm{d}z\right), \tag{26}$$

is a measure of average productivity. In particular, $\bar{z}$ weighs the productivity of each variety by a monotone transformation of the corresponding markup as perceived by domestic consumers. Equilibrium welfare, $X$, is then pinned down by the mass of firms and this average productivity measure. The love for variety parameter, $\nu$, is crucial in shaping the contribution of new varieties to welfare.

**Equilibrium Definition.** For a given point in the parameter set $\Psi = \{\alpha,\lambda,\eta,A,\tau,\kappa,\underline{\omega},\bar{\omega}\}$, with the associated values of $\theta_d^*$ and $\theta_x^*$, an equilibrium is

i. A function $n(z)$ implicitly defined by $n_n(z)$, for $z \in (z_n^*, z_{nx}^*)$,

$$\frac{\theta_n(n_n)^{\frac{\alpha}{\alpha-1}}}{1-\left(1+\hat{\eta}\right)\theta_n(n_n)}\, n_n = \frac{z}{\lambda\, M\bar{z}}, \tag{27}$$

and $n_x(z)$, for $z \in (z_x^*, \bar{\zeta}_x)$,

$$\frac{\theta_d(n_x)^{\frac{\alpha}{\alpha-1}}}{1-\left(1+\hat{\eta}\right)\theta_x(n_x)}\, n_x = \frac{z}{\lambda\, M\bar{z}}, \tag{28}$$

with[10]

$$\theta_n(n) = \frac{n+\alpha-1}{n}, \qquad \theta_d(n) = \frac{2n+\alpha-1}{n(1+\tau)}, \qquad \theta_x(n) = \mathscr{A}(n)\ \theta_d(n),$$

and

$$\mathscr{A}(n) = \frac{(1-n-\alpha)(1+\tau^2)+2n\tau}{(1-\alpha)(1+\tau)}.$$

ii. An entry probability density function $\varphi(z)$ for $z \in (z_n^*, z_{nx}^*)$ defined as

$$\varphi_n(z) = \phi\left(g_n(z)\right) g_n'(z),$$

and for $z \in (z_x^*, \overline{\zeta}_x)$ defined by

$$\varphi_x(z) = \phi\left(g_x(z)\right) g_x'(z),$$

with $g_i(z) \equiv \mathscr{B}_i(z)^{\eta-1} z^{1-\eta}$, for $i = \{n, x\}$,[11] and

$$\mathscr{B}_n(z) = A^{\frac{1}{1-\eta}} \left( \frac{\hat{\eta}}{n(z)}\ \frac{\theta_n\left(n(z)\right)^{\frac{1}{1-\alpha}}}{M\bar{z}} \right)^{\frac{\eta}{1-\eta}}, \quad \mathscr{B}_x(z) = A^{\frac{1}{1-\eta}} \left( \frac{\hat{\eta}\mathscr{A}\left(n(z)\right)}{n(z)}\ \frac{\theta_d\left(n(z)\right)^{\frac{1}{1-\alpha}}}{M\bar{z}} \right)^{\frac{\eta}{1-\eta}}. \tag{29}$$

iii. A vector of boundaries $\{z_n^*, z_{nx}^*, z_x^*, \overline{\zeta}_x\}$ satisfying the conditions,[12]

$$z_n^* = \frac{\lambda\ \alpha^{\frac{\alpha}{\alpha-1}}}{1-(1+\hat{\eta})\alpha} M\bar{z}, \tag{30}$$

[10] The functional form of $n_n(z)$ and $n_x(z)$ only depend on the endogenous composite variable $(M\bar{z})$ and some of the parameters in $\Psi$. The boundaries $z_n^*, z_{nx}^*, z_n^*, \overline{\zeta}_x$ are endogenous.

[11] Notice that the density distribution $\varphi(z)$ only depends on the endogenous variable $M\bar{z}$ and the parameters in $\Psi$, along with the endogenous boundaries $\{z_n^*, z_{nx}^*, z_n^*, \bar{\zeta}_x\}$.

[12] Notice that the conditions defining the boundaries only depend on the endogenous variables $M\bar{z}$ and the parameters in $\Psi$

$$z_x^* = \frac{\lambda \, {\theta_d^*}^{\frac{\alpha}{\alpha-1}}}{1-(1+\hat{\eta})\theta_x^*} M\bar{z}, \tag{31}$$

$$\frac{z_{nx}^*}{\mathscr{B}_n(z_{nx}^*)} = \frac{z_x^*}{\mathscr{B}_x(z_x^*)}, \tag{32}$$

$$\overline{\zeta}_x = \mathscr{B}_x(\overline{\zeta}_x) \; \bar{\omega}^{\frac{1}{1-\eta}}. \tag{33}$$

iv. The endogenous composite variable $M\bar{z}$ is defined by

$$M\bar{z} = \int_{z_n^*}^{z_{nx}^*} \theta_n\big(n_n(z)\big)^{\frac{\alpha}{1-\alpha}} \, z\,\varphi_n(z)\mathrm{d}z + \int_{z_x^*}^{\overline{\zeta}_x} \theta_d\big(n_x(z)\big)^{\frac{\alpha}{1-\alpha}} \, z\,\varphi_x(z)\mathrm{d}z. \tag{34}$$

Notice that the objects in the right-hand-side of (34) depend on $M\bar{z}$. An equilibrium value of $M\bar{z}$ is then a fixed point of (34).

**Some equilibrium properties.** Although the model does not allow for an analytically tractable investigation of the effects of trade on the endogenous variables of our economy, we can gain some general insights by further analyzing the equilibrium conditions. First, notice that the trade cost $\tau$ only shows up in the definition of $\theta_d(n)$ and $\mathscr{A}(n)$, as well as in values of $\theta_d^* = \theta_d(1)$ and $\theta_x^* = \theta_x(1)$. Consequently, trade liberalization directly affects the equilibrium through the exporters' markups only. The equilibrium allocations then react to the direct effect of trade liberalization through competition. Selection and innovation, in turn, are triggered by the changes in markups, and represent additional transmission mechanisms and channels of gains/losses from trade. But all effects of trade in this economy are originally triggered by variable markups. Indeed, since in our framework countries are identical along all dimensions – including the varieties they produce – there would be no trade without variable markups.

Second, trade liberalization induces a reduction in markups and, as will become clearer later, increases concentration through a reduction in the number of firms in each product line. The first part of this statement comes from part iv. of Proposition 1, where, for a given number of firms, we showed that trade liberalization triggers an increase in foreign competition, and decreases the average markups of exporters. Next we provide an intuition for the second part of the statement, which we later illustrate numerically. The zero profit condition in equation (28) suggests a reduction in the number of domestic competitors in response to trade liberalizations, to compensate for the reduction in net revenues generated by the increase in foreign competition. The resulting reduction in the number of domestic firms in each traded product line, $n_x(z)$, partially offsets the direct, negative, effect on markups. Markets for traded product lines then become *more concentrated* (the number of domestic firms declines and market shares increase) but also *more competitive*, since stronger foreign competition shrinks markups. Interestingly, freer trade leads to a global economy populated by fewer and larger firms, but with less market power.

# 4 Numerical analysis

Although the model is too stylized for a proper quantitative analysis, we discipline its 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 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); a productivity advantage of exporters of 23%; a size advantage of exporters of 50% (Bernard et al., 2007); and an average markup of 34.6% (Hottman et al., 2016). The lower bound, $z_{\min}$, simply pins down the location of the distribution, so we normalize it to one without loss of generality. Similarly the R&D technology, $A$, is a scale parameter which does not affect the equilibrium, but merely controls the link between the actual productivity $z$ and the initial level $\tilde{z}$ (see Appendix C). We set $A$ to 1.48 in order for the difference between the average productivity $z$ and the average initial level $\tilde{z}$ to be 1%, roughly matching the US long run TFP annual growth rate (Penn World tables).[14]

Table 1 shows the model fit and Table 3 summarizes the calibrated parameters. Albeit stylized, the model provides a decent fit for all the targeted statistics.

## 4.1 Equilibrium properties

### 4.1.1 Cross sectional properties

In this section, we show and discuss the cross-sectional properties of the model. Figure 1 illustrates the key endogenous variables as a function of the initial productivity $\tilde{z}$. In line with Proposition 1 and Conjecture 1, we can see that markups decline with productivity; non-exporting firms have higher markups than exporters; and since exporters charge a higher markup on the domestic market, the

[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.

[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.

Table 1: Summary of calibration targets.

| Calibration target | Data | Model | Source |
|---|---|---|---|
| R&D to sales ratio | 2.4% | 2.4% | Compustat |
| Export share of GDP | 8.6% | 9.4% | WDI World Bank |
| Share of exporters | 18% | 15.3% | Bernard et al. (2003) |
| Relative size of exporters | 1.5 | 1.48 | Bernard et al. (2007) |
| Average markup | 34.6% | 34.7% | Hottman et al. (2016) |
| Relative prod. of exporters | 23% | 25.5% | 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. The calculations and targets are described in the main text.

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 | 8.58 |
| $\kappa$ | Shape of the Pareto distribution | 4.95 |
| $\tau$ | 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. The calculations and targets are described in the main text.

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. Consistent with Proposition 2 and Conjecture 1, there are more firms in more productive product lines and, as a consequence, more productive firms charge lower markups. Intuitively, more efficient product lines are more profitable and attract a larger number of firms, hence each firm in those lines face more intense competition.[15] Notice that at the export cutoff, $z_x^*$, the number of firms is equal to one, but the markups are smaller than for the marginal non-exporter, $z_{nx}^*$. This highlights an important property of our economy: due to the presence of trade costs, some exporting firms can face fewer competitors than some non-exporters and at the same time having lower markups and therefore weaker market power.

Notice that due to the structure of the innovation technology in equation (4), it is possible for the

[15]Note that the exporters close to the export cutoff operate in product lines where the number of domestic firms is close to one by definition of the entry strategy. Their average markup is still lower than that of non-exporting firms due to the presence of foreign firms in their product line.

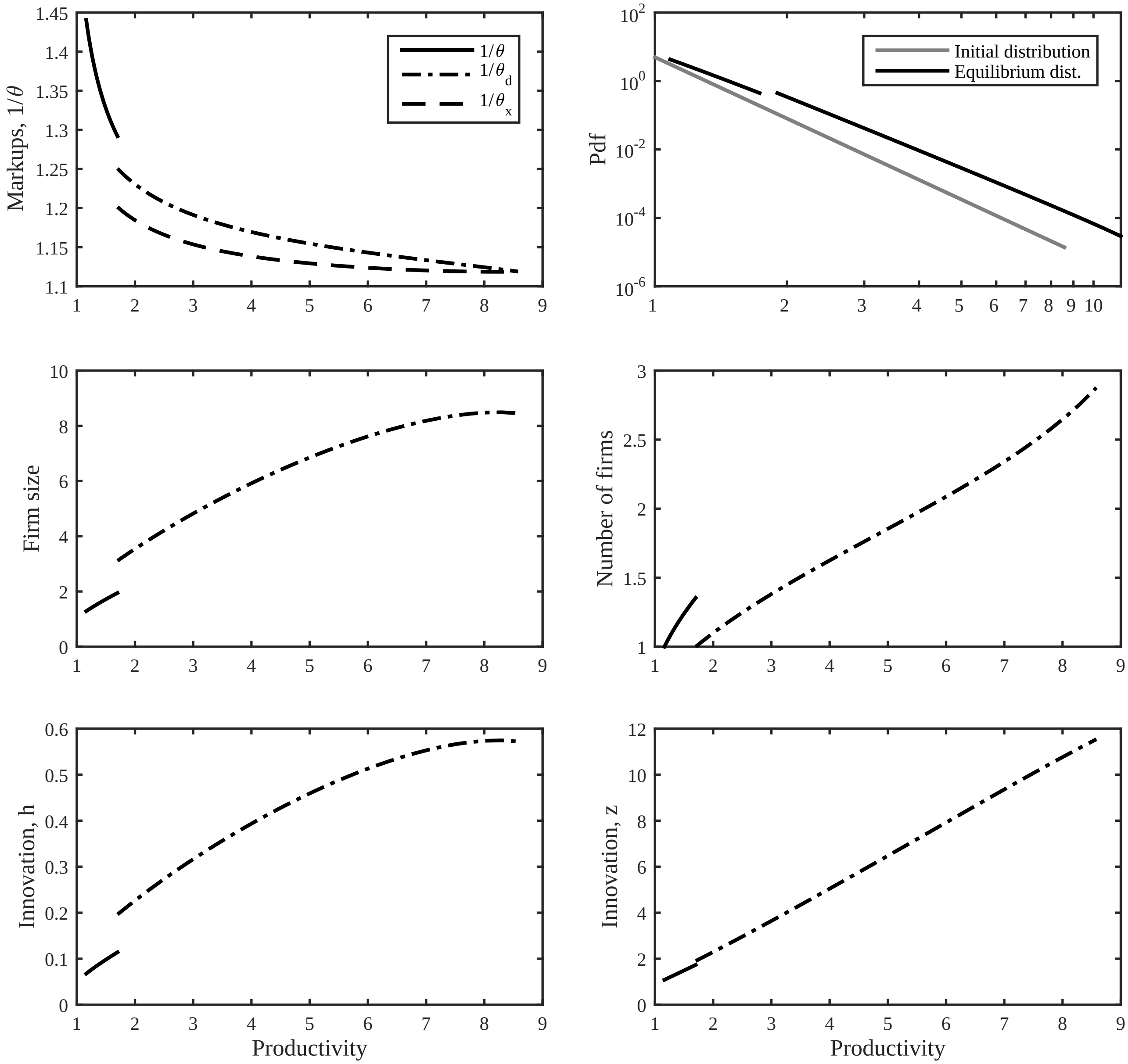


Figure 1: Cross-sectional size, markup and productivity

*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 $\tilde{z}$. Calculations are described in the main text.

equilibrium productivity level, $z$, to be lower than the initial draw $\tilde{z}$. As innovation affects the degree to which the potential draw at entry is transformed in actual productivity. The scale parameter $A$ controls the link between initial and actual productivity, and for a sufficiently high value of this parameter the actual productivity is larger than the entry one. As we want to interpret our framework as one modeling firm innovative efforts, and possibly as a simplified version of a dynamic innovation model, we chose a value for $A$ high enough for the actual productivity $z$ to be larger than the initial $\tilde{z}$.

Finally, 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 graph of Figure 1 suggests that the slope of the (log-log) equilibrium distribution, which is shaped by the innovation choice, is clearly flatter. It is also fairly constant, meaning that the equilibrium distribution is close to a double bounded-Pareto. Thus in our economy the dispersion of firm productivity is endogenous and trade liberalization leads to more heterogeneity.

### 4.1.2 Trade liberalization

In Figure 2, we analyze the effects of halving the variable trade costs $\tau$ from its benchmark value of about 1.12 to 1.06. We first show the effect of trade liberalization on the key endogenous variables at the firm level and then analyze the effects on the aggregate economy.

**Cross-sectional effects.** Lower trade costs have a negligible impact on the number of non-exporting firms per product line and consequently on their markups. In line with Proposition 1, exporters reduce their domestic markup due to fiercer foreign competition, and increase their export markup via the incomplete pass-through mechanism previously discussed. Compared to the results in Proposition 1, our simulations show that the pro-competitive effect is strong, and therfore that the average markup of any exporting firm declines with trade liberalization even when we allow for entry. Indeed, the number of firms declines in each exported product line, and the more so the higher the initial productivity draw. Hence, neither the incomplete pass-through operating via an increase in export markups nor the additional anti-competitive effect triggered by entry can offset the downward pressure of trade on markups. We can conclude that trade liberalization has pro-competitive effects which are large and, as we later show later, robust.

We now dig deeper into the link between trade barriers and the number of firms. In our economy, the increase in market size produced by a reduction in trade costs has a *direct effect* on exporters' average markups, since it increases the competitive threat posed by foreign firms. Lower average markups affect market concentration, firm size and innovation. We can illustrate these effects using the equilibrium free-entry condition from equation (23),

$$\frac{\theta_d(n)^{\frac{\alpha}{\alpha-1}}}{1-\left(1+\hat{\eta}\right)\theta_x(n)}\, n = \frac{z}{M\bar{z}\lambda},$$

where we have used equation (25) to substitute out $\hat{X}$, and the equilibrium condition $E = 1$. Since the left-hand side of this equation is increasing in $n$, a reduction in exporters markup $(1/\theta_d$ and $1/\theta_x)$ reduces profitability in each of their respective product lines.[16] Following the drop in markups, two adjustments allow the free-entry condition to hold: first, as profit declines, some firms *exit* from each

[16]In the proof of Proposition 1 we show that the left-hand side increases in $n$.

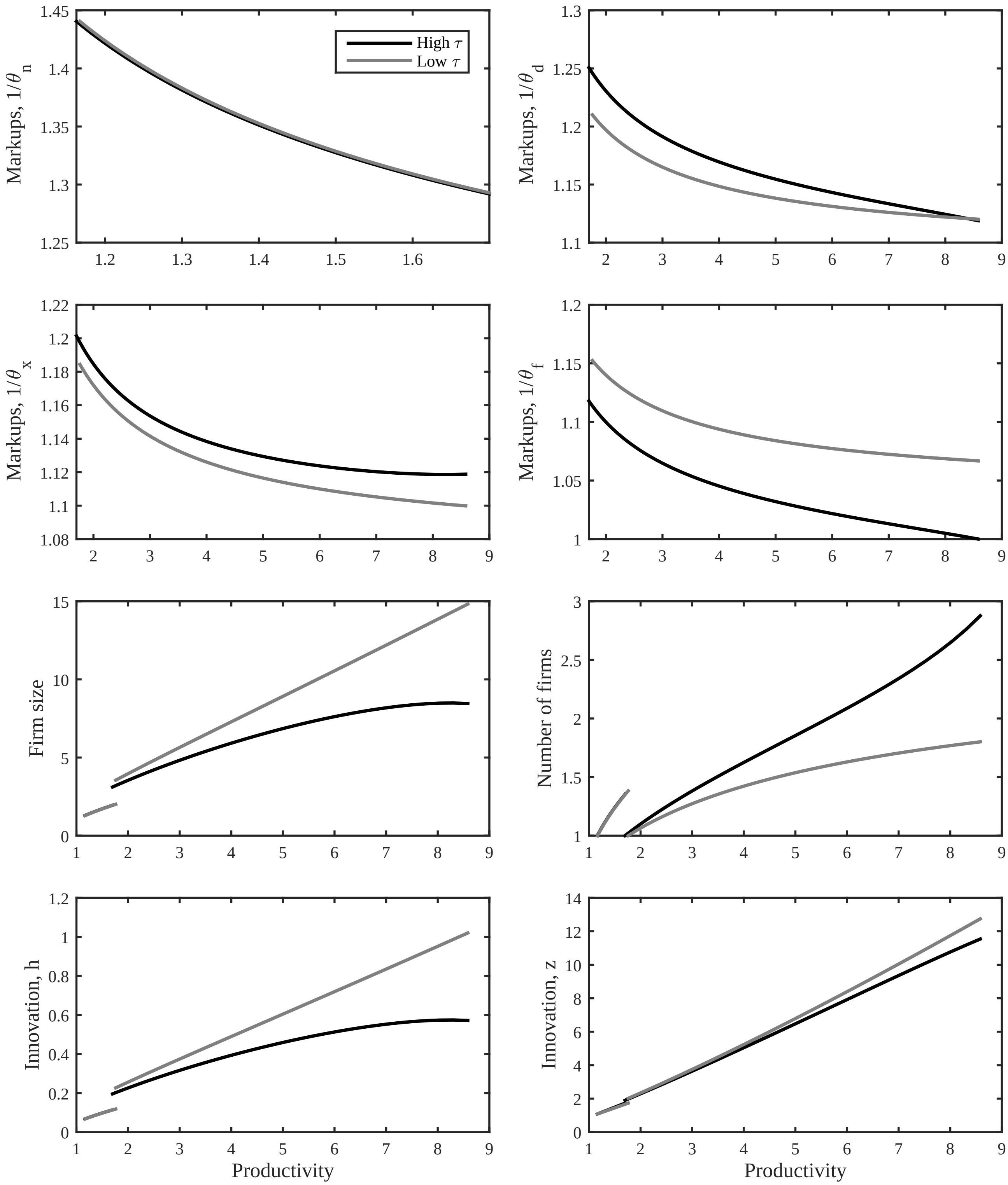


Figure 2: Trade liberalization: cross-sectional outcomes

*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.

product line, which, in equilibrium, winds up accommodating a smaller number of firms. Second, profitability can be restored by increasing productivity, $z$, through *innovation*. In fact, equation (20) reveals that equilibrium innovation is decreasing in the average markup.[17]

Figure 2 suggests that both adjustments are at work. Trade liberalization reduces the average markup for all exporting firms; the number of firms drops; and firm size and innovation increase. Notice that these effects are stronger for firms with a higher initial productivity draw. This result is generated by two different adjustment mechanisms. First, since a reduction in $\tau$ reduces markups and profits in all exported product lines, a decline in the number of firms, $n$, helps to restore free entry by lowering average costs. In our economy, markups are smaller the larger $n$ is, and this implies that a larger decrease in $n$ is needed to compensate the same change in $\tau$ in more competitive product lines.[18] 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 the free-entry condition. Moreover, a reduction in markups increases the price elasticity of demand which, in turn, magnifies sales of firms with low marginal cost. Hence, by magnifying the link between firm productivity and size, trade liberalization generates increases in size and innovation primarily amongst the most productive firms: the top exporters.

A more globalized economy is then populated by *bigger* and *fewer* firms operating in *more competitive* markets. The pro-competitive effect of a reduction in the trade cost on markups is stronger than the anti-competitive effect due exit. Intuitively, although trade liberalization reduces the number of firms in both economies, lower trade costs imply that home firms experience a stronger competitive threat from a smaller number of large foreign firms – strong enough to reduce their market power. This direct effect of trade costs on markups is the driving force of the pro-competitive effect of globalization, and it allows us to generate a global economy that is both more competitive, more innovative, and features more concentrated markets. In Appendix D we show the response of the sales concentration ratios to changes in trade costs. Before liberalization the top 10% of firms have about 22.6% of the market and under free trade they command about 25%. Similar increases can be seen among the top 1% and 5% of firms. Although the scope of this paper is not to explain such stylized facts, it is worth noticing that this finding is in line with recent empirical evidence showing that markets are becoming more concentrated (Autor et. al., 2017, Head, and Spencer, 2017). Our model suggests that globalization could be one of the driving forces of the observed dynamics of market concentration. To the best of our knowledge this is a new hypothesis, that would interesting to explore in future applications of this new framework.

Similarly to the early literature on innovation and endogenous market structure (e.g. Dasgupta and Stiglitz, 1980, and Sutton, 1991), the relationship between market size, competition and innovation is

[17] Since innovation is increasing in $\mathscr{A}\theta_d^{\frac{1}{1-\alpha}}$, it is also increasing in $\theta_x = \mathscr{A}\theta_d$.

[18] Let us illustrate the mechanism by differentiating the definition of $\theta_d(n)$ in equation (23) assuming $\mathrm{d}\theta_d(n) = 0$. The implicit derivative $\partial n/\partial \tau$ measures the change in $n$ required to compensate a change in $\tau$ in order for $\theta_d$ to remain unchanged. It is easy to see that this derivative is proportional to $n^2$, meaning that a larger change in $n$ is required the larger $n$ is to compensate for the negative effect of the decline in $\tau$ on profits.

shaped by the characteristics of demand (e.g. substitutability across varieties) and by the innovation technology. Figure 3 shows the percentage change in the number of firms brought about by trade liberalization under different values of the parameters $\alpha$, which regulates substitutability across varieties, and $\eta$, determining the curvature of the innovation technology.

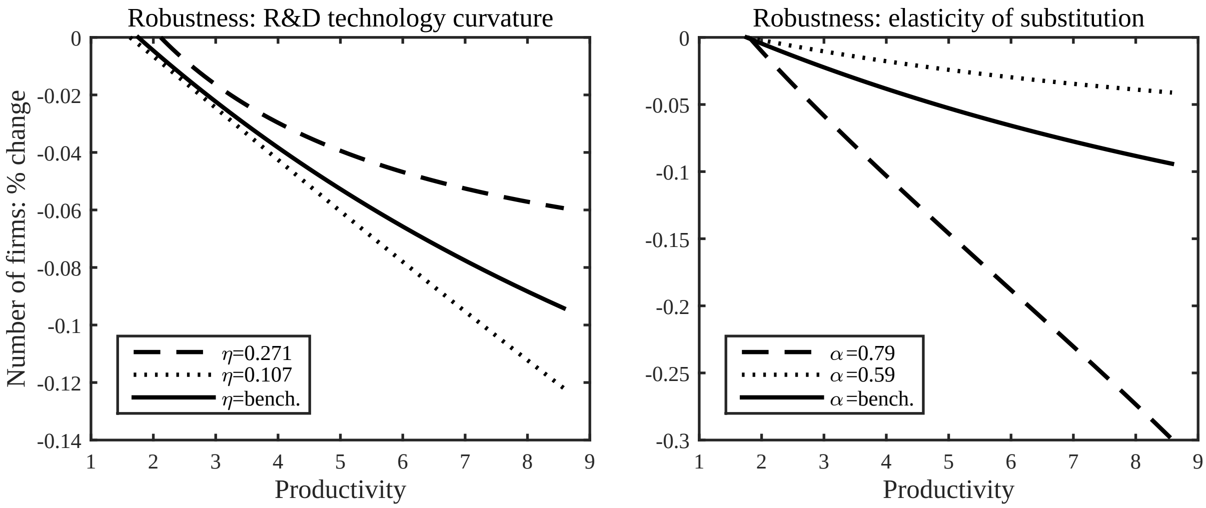


Figure 3: Elasticity of substitution, R&D technology and market structure

*Notes. Productivity* refers to $\tilde{z}$, % changes are computed reducing $\tau$ from its benchmark to 1.06. Calculations are described in the main text.

When varieties are more substitutable, 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 lower degree of decreasing returns in R&D (i.e. a larger value for $\eta$) instead, leads to a lower drop in the number of firms. The reason is that a more efficient R&D technology implies that innovation is more effective at restoring free-entry and, as a consequence, a smaller adjustment to the number of firms is needed.[19]

**Aggregate effects.** After inspecting the effects of trade on key cross-sectional variables we move on to analyze the aggregate effects. In Figure 4 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, registering only movements of second order. The average markup of exporting firms instead declines from about 18% to 16%. This decline is driven by a substantial reduction in exporters' markups on domestic sales which outpaces the increase in their markups on export sales.

[19]In a closed economy with homogeneous firm and a partial equilibrium model of process innovation under oligopoly, Sutton (1998) shows that a high elasticity of substitution across goods and highly efficient R&D technology generate equilibria where large markets are associated with high innovation and high concentration.

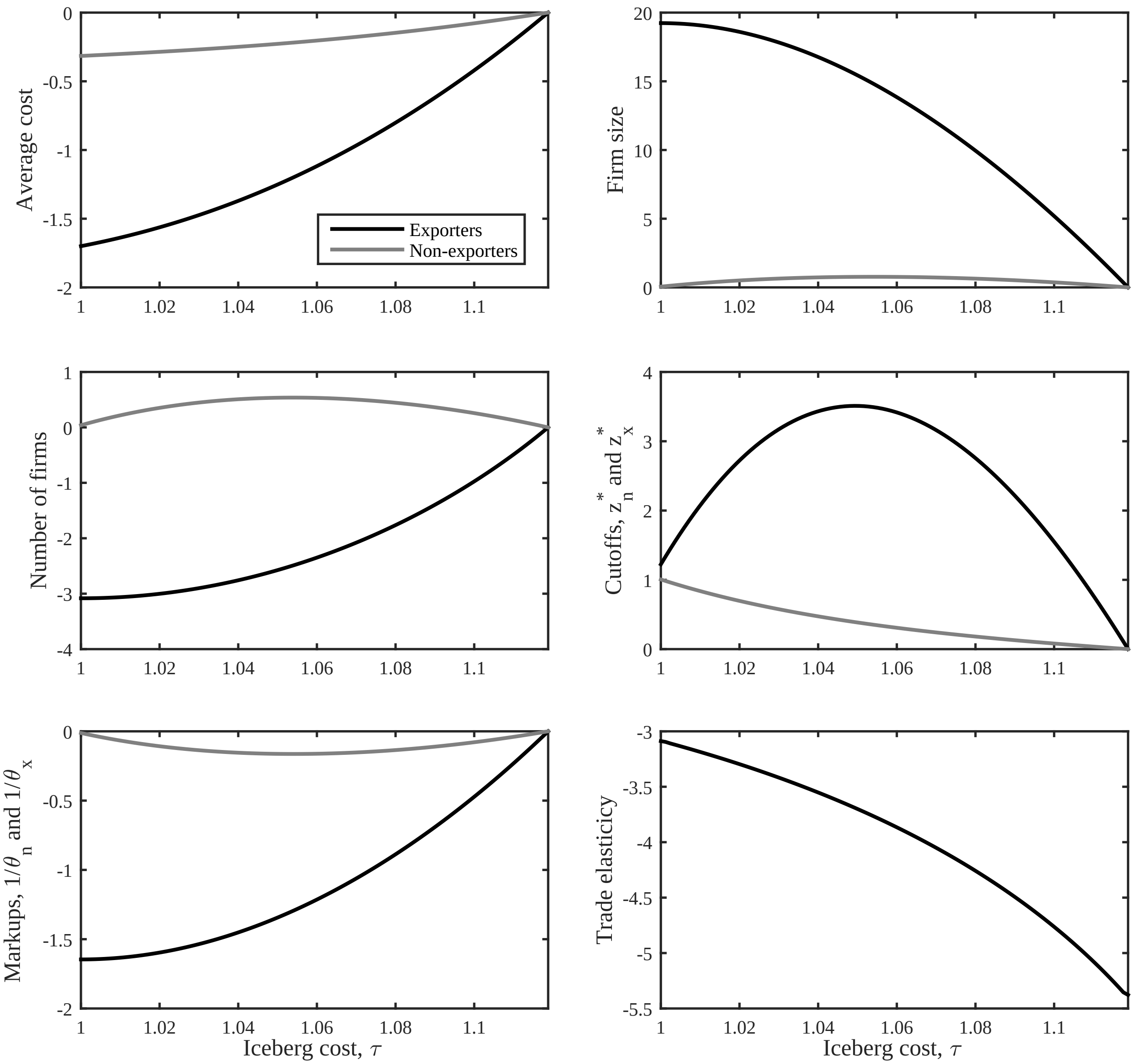


Figure 4: Trade liberalization: aggregate outcomes

*Notes.* All graphs, except for the elasticities, illustrate the percentage change in each variable relative to the benchmark.

The domestic and the export cutoffs shows similar changes, roughly about a one percent increase when comparing the benchmark outcome with that of free trade. It is interesting to notice though that the export cutoff displays an inverted U-shape. This feature is related to a classic result in trade models under oligopoly and was first highlighted in Brander and Krugman (1983). Their story goes as follows: 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 *declines*. 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 modern equivalent of this mechanisms affects selection into the export market in our heterogeneous firms economy. In particular, declining profits off-equilibrium implies that there is little scope for unproductive firms to survive in the market and the cutoff in equilibrium, $z_x^*$, increases with trade liberalization. This explain the downward sloping part of the graph. Conversely, increase profits off-equilibrium implies a larger scope for unproductive firms to survive in the market, and $z_x^*$ in equilibrium decreases with trade liberalization. This explain the downward sloping part of the graph. Together, these two forces lays the foundation for a U-shaped relationship between trade liberalization and the export market cutoff.

Table 3: Summary of aggregate effects.

| | | Av. cost | Size | # Firms | TFP | Cutoffs | Markups |
|---|---|---|---|---|---|---|---|
| Exporters | $\tau = 1.12$ | 1.48 | 3.69 | 1.13 | 2.47 | 1.70 | 1.18 |
| | $\tau = 1.00$ | 1.45 | 4.47 | 1.09 | 2.59 | 1.72 | 1.16 |
| Domestic | $\tau = 1.12$ | 1.65 | 1.51 | 1.12 | 1.29 | 1.16 | 1.38 |
| | $\tau = 1.00$ | 1.66 | 1.51 | 1.12 | 1.31 | 1.17 | 1.38 |

*Notes.* This table illustrates the effects *in levels* of reducing $\tau$ from 1.12 to 1 for the aggregate/average variables illustrated in Figure 4.

As a consequence of lower markups and the reduction of firms within each product line, the average firm size of exporters increases substantially, while non-exporting firms show only negligible changes. The average *size* for exporters, in fact, increases by 20% from the benchmark to free trade, while the average *number* of exporting firms shrinks by 3 percent. Reading these results in the light of the cross-sectional findings presented in Figure 2 suggests that the change in the market structure, and in average firm size, are driven by trade-induced adjustment of exporters, especially the most productive. Moreover, along with the increase in average size, we document a 1.7% decline in their average cost. The latter comes from two sources: first, average costs are slashed by the trade-induced increase in exporters productivity due to innovation. Second, in the presence of fixed operating costs, an increase in firm size generates a reduction in average costs via increasing returns. Table D.1 in the Appendix shows that these results are strongly robust across different parameter specifications.

Finally, we show that the trade elasticity – more precisely the elasticity of the average export to total sales ratio – varies substantially with the size of liberalization. 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 small decrease in the variable trade cost is substantially higher in more closed economies than in open ones. These fairly intuitive 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 liberalization 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 turn to the main goal of our paper and break down the different components of the welfare gains from trade.

## 4.2 Gains from trade structure

In this section we analyze gains from trade and decompose them into their different sources. More precisely, we reduce the trade cost from its benchmark level, which we here denote $\tau_0$, to one and compute the welfare gains of moving from each intermediate level of $\tau$ with respect to the benchmark, activating the relevant channels one-by-one. Since our global economy consists of countries that are symmetric in all features including the mass of varieties produced, there is no variety gains from trade as in the typical intra-industry trade model (e.g. Krugman, 1980). For this reason we set $\nu$ to $(\alpha-1)/\alpha$, which eliminates love for variety entirely.[20] We later perform robustness on this choice.

Without any love for variety welfare is given by

$$W(\theta(\tau), z(\tau), z^*(\tau)) = \bar{z}^{\frac{1-\alpha}{\alpha}} = \left( \int_{z_n^*}^{z_x^*} \theta_n(z)^{\frac{\alpha}{1-\alpha}} z dF_n(z) + \int_{z_x^*}^{\overline{\zeta}_x} \theta_x(z)^{\frac{\alpha}{1-\alpha}} z dF_x(z) \right)^{\frac{1-\alpha}{\alpha}}, \qquad (35)$$

where the dependence of $\theta_n(z)$, $\theta_x(z)$, $z$, $z_n^*$, $z_x^*$, and $\overline{\zeta}_x$, on $\tau$ is suppressed. In addition, and with a slight abuse of notation, the arguments $\theta(\tau)$, $z(\tau)$, $z^*(\tau)$ in $W$ indicate that welfare is a function of the distribution of markups; the distribution of productivity ; and the cutoffs. Let $\tau' \in [1, \tau_0)$ denote the value of $\tau$ after trade liberalization. The compensating variation of reducing $\tau$ from $\tau_0$ to $\tau'$ is straightforwardly given by

$$CV(\tau') = 100 \times \{\ln[W(\theta(\tau'), z(\tau'), z^*(\tau')] - \ln[W(\theta(\tau_0), z(\tau_0), z^*(\tau_0))]\}. \qquad (36)$$

A natural question arises, however, regarding the extent to which the measure of compensating variation can be accounted for by variations in markups ,$\theta$, selection, $z^*$, or innovation, $z$. One approach would be to, for instance, decompose welfare as

$$\begin{aligned} CV(\tau') = {} & 100 \times \{\ln[W(\theta(\tau'), z(\tau_0), z^*(\tau_0))] - \ln[W(\theta(\tau_0), z(\tau_0), z^*(\tau_0))]\} \\ & + 100 \times \{\ln[W(\theta(\tau'), z(\tau'), z^*(\tau_0))] - \ln[W(\theta(\tau'), z(\tau_0), z^*(\tau_0))]\} \\ & + 100 \times \{\ln[W(\theta(\tau'), z(\tau'), z^*(\tau'))] - \ln[W(\theta(\tau'), z(\tau'), z^*(\tau_0))]\}, \end{aligned}$$

where the first line captures the effects of changing the markups, the second the effect of innovation, and the third the effect of selection. However, while this decomposition is straightforward and relatively intuitive, it suffers from two major shortcomings. First, the order in which changes take place is

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

neither unique nor innocuous. Indeed, there are five additional permutations to this approach of decomposing effects, all of which contain different interactions of mechanisms possibly leading to large discrepancies in results. Second, it is not obvious that the welfare associated to, say, the very first term even corresponds to a possible equilibrium.

Thus, to circumvent these shortcomings, we propose to decompose welfare as follows: For any $\tau'$ the compensating variation in equation (36) can be written as the derivative of itself with respect to $\tau$, integrated from $\tau_0$ to $\tau'$.[21] However, the chain rule allows us to decompose the derivative of the compensating variation into three component, pertaining to the particular effects of markups, selection, and innovation. In particular, our decomposition is given by

$$\begin{aligned} CV(\tau') &= \int_{\tau'}^{\tau_0} \frac{\partial CV(\tau)}{\partial \tau} d\tau + CV(\tau_0) \\ &= \frac{100}{W(\tau)} \times \left\{ \underbrace{\int_{\tau'}^{\tau_0} \frac{\partial W(\tau)}{\partial \theta} \frac{\partial \theta}{\partial \tau} d\tau}_{\text{Markups}} + \underbrace{\int_{\tau'}^{\tau_0} \frac{\partial W(\tau)}{\partial z} \frac{\partial z}{\partial \tau} d\tau}_{\text{Innovation}} + \underbrace{\int_{\tau'}^{\tau_0} \frac{\partial W(\tau)}{\partial z^*} \frac{\partial z^*}{\partial \tau} d\tau}_{\text{Selection}} \right\} + CV(\tau_0), \end{aligned} \tag{37}$$

which provides a unique decomposition along the equilibrium manifold. Figure 5 reports the results.

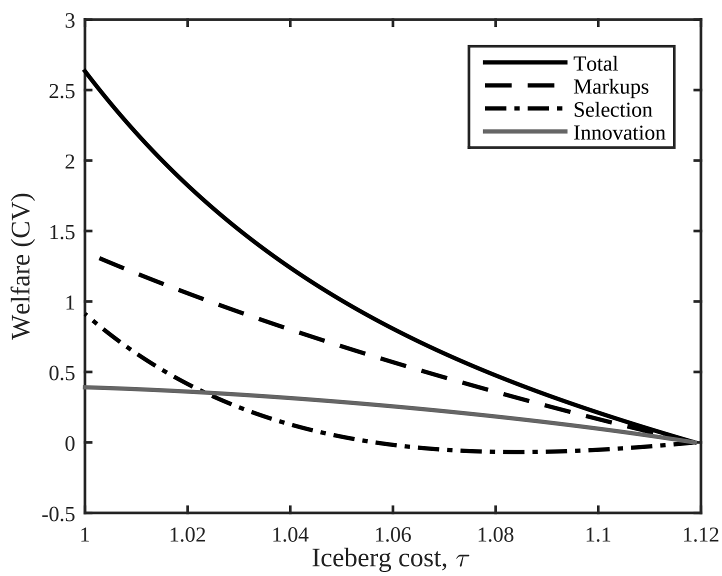


Figure 5: Gains from trade: decomposition

Going from the benchmark trade cost to free trade increases welfare equivalently to raising consumption by about 2.6%. Roughly half of this total gain can be attributed to the reduction in markups. This result should be interpreted as an increase in efficiency generated solely by the reduction in the firms' market power, and is primarily driven by the reduction in the markups of exporters on their domestic sales, as shown in Figure 2 and 4. Although more open markets are populated by a smaller number of larger firms, these firms have a lower market power and thus charge lower prices, which

[21] In addition to the constant $CV(\tau_0)$.

leads to substantial gains for consumers. In line with the discussion above, the competition effect operates through an intensive and an extensive margin: the first is generated by the stronger competitive pressure produced by a given number of foreign firms when trade costs drop. The extensive margin is due to vertical entry within each product lines regulated by the free-entry condition: trade-induced increases in competition make each product line harder to enter. These two forces have opposite effects on the markup but the intensive margin dominates thereby driving *pro-competitve* gains from trade.

The pure welfare gains deriving directly from *innovation* are not large, and about 10% of the total gains. While the gains arising from *selection* are large once we go all the way to free trade, they are not monotone. Indeed, starting from the benchmark level, small reductions in trade costs generate welfare losses, albeit small in size. As we consider wider liberalization scenarios we find gains which increase progressively with the size of the liberalization. This path of welfare gains 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 (Brander and Krugman, 1983). 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 some losses. When the trade cost reaches a certain threshold, however, the export cutoff starts dropping and the economy features more exporters, which are larger and more efficient. As a consequence, increasing selection into exports delivers extra gains from trade, as the economy has more of the firms that are the main drivers of the total welfare gains. Notice that Brander and Krugman (1983) obtain a similar U-shape effect of trade on welfare in the version of their model without free entry, where the economy features positive profits and the non-monotone welfare effect is due to the behavior of the producer surplus. When they introduce free entry, the producer surplus becomes zero and the gains from trade are generated by the consumer surplus which increases monotonically with the reduction in markups. Interestingly, in our heterogeneous firms economy, the producer surplus is indeed zero, but the U-shape welfare effect of trade is still present through selection into the export market.

**Robustness.** Table 4 shows that the decomposition results are robust to local parameter changes. In order for the restrictions in Assumption 1 to hold for all parametrizations, we compute the gains from a slightly smaller liberalization, moving $\tau$ from 1.08 to free trade. In most parametrizations the pro-competitive and the selection gains each account for about 45% of the total gains, with the remaining 10% attributable to innovation. Higher substitutability across goods (i.e. a higher value of $\alpha$) implies a more pronounced role of markups and innovation 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. Moreover, a better technology, and therefore a lower price, commands a higher market size premium when goods are more substitutable – hence the welfare gains attributable to innovation are larger. The role of innovation is, perhaps unsurprisingly, also further 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 substantially when the love for variety externality is positive and strong. In particular we set the externality in $\nu+(1-\alpha)/\alpha$ in equation (25) to 0.5, which is slightly stronger than the standard Dixit and Stiglitz (1977) value of $(1-\alpha)/\alpha$ which would imply 0.44 in our benchmark calibration. Not surprisingly, with a strong love for variety, the loss of product lines due to selection almost completely offsets the benefits from reallocating market shares from less to more productive firms. In this case, the bulk of the gains from trade comes from markups with a marginally improved role of innovation.

Table 4: Robustness of welfare gains.

| | Benchmark | $\bar{\alpha}$ | $\underline{\alpha}$ | $\bar{\eta}$ | $\underline{\eta}$ | $\bar{\kappa}$ | $\underline{\kappa}$ | $\underline{\nu}$ |
|---|---|---|---|---|---|---|---|---|
| Total | 2.15 | 2.21 | 1.95 | 2.03 | 2.27 | 1.83 | 2.53 | 1.26 |
| Markups | 46% | 47% | 45% | 45% | 46% | 46% | 46% | 78% |
| Selection | 45% | 41% | 47% | 44% | 46% | 45% | 45% | 6% |
| Innovation | 9% | 12% | 8% | 11% | 8% | 9% | 9% | 16% |

*Notes.* This table illustrates the welfare gains from reducing the iceberg cost, $\tau$, from 1.08 to 1 under eight different parameterizations. The total gains are calculated according to equation (35), and the decomposition according to equation (37). 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. An exception is the parameter $\underline{\nu}$ which is set such that $\underline{\nu}+(1-\alpha)/\alpha=0.5$.

### 4.2.1 Discussion

Next, we discuss our results and relate them to some key papers in the literature. 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 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. Among other things, they show that the standard Melitz (2003) model with an unbounded Pareto distribution meets these restrictions, and, consequently, that the welfare gains generated by the same increase in the domestic trade share produces the same gains in models with and without firm heterogeneity. Our oligopolistic model exists outside the realm of ACR's class since it violates restriction $(iii)$. In particular, while we do operate in a CES demand system, the elasticity of trade to trade cost is not constant, as shown in Figure 4. Indeed, Melitz and Redding (2015) show that with bounded Pareto the trade elasticity is not constant even in monopolistic competition, and similarly to us find that firm heterogeneity generates additional welfare gains that are otherwise not present. However in the presence of oligopolistic Cournot competition – in marked contrast to standard monopolistic competition – a bounded Pareto productivity distribution is not necessary, albeit sufficient, to violate ACR's restriction $(iii)$. More precisely, in a related model with unbounded Pareto but with undirected entry – i.e. firms draw productivity, and therefore the product line, randomly – Impullitti and Licandro

(2017) shows that the trade elasticity is not constant and selection contributes to the gains from trade.[22]

Arkolakis et al. (2017) (ACDR) compute the pro-competitive effect of trade for 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; the gains are due to the reduction in domestic markups and the welfare losses are due to the incomplete pass-through. But differently from the monopolistically competitive class of models considered in ACDR, the incomplete pass-through never dominates and the pro-competitive effect is always positive. As shown in Proposition 1, we prove analytically that the reduction in the trade cost reduces the average markup of exporters, $1/\theta_x$. This is a robust prediction of the standard symmetric country model of trade under Cournot oligopoly by Brander and Krugman (1983). Our more sophisticated framework, with heterogenous firms and in which directed entry generates variable and heterogeneous markups, features an additional force potentially offsetting the pro-competitive effect of trade. In particular, the numerical exercise shows that trade may reduce the number of exporting firms within each exported product lines, a change that can potentially lead to an increase in markups, and thereby reverting the pro-competitive effect. Interestingly, in our benchmark simulations and in all other parametrizations explored, the entry/exit margin tames, but never offsets, the welfare gains generated by trade-induced reductions in domestic markups; indeed the welfare gain from trade always stays positive and substantial.

# 5 Conclusion

This paper proposes an exploration of the gains from trade in an economy where the market structure and the technology 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. In order to properly assess this pro-competitive effect of trade it is crucial to consider the reaction of both

[22] As mentioned before, in our model bounded Pareto is assumed simply to avoid a restrictively low prohibitive trade cost for highly productive exporters.

domestic and foreign firms present in a market. When a country reduces its trade barriers foreign firms obtain a cost advantage over their competitors which they do not entirely pass onto their consumers. The trade model with Cournot oligopoly considered here suggests that although foreign firms cash in some of the cost advantage produced by the fall in trade costs and increase their markups, this change is not strong enough to offset the pro-competitive effect on domestic markups. This trade-induced increase in competition discourages entry, leading to a reduction of the number of active firms and an increase in market concentration. Crucially, even this second offsetting force is not enough to undo the pro-competitive effect of trade.

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 forces low-productivity firms out of both domestic and export markets, 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 competition and selection play an equally large part, whereas innovation plays a smaller but non-negligible role.

# A Proofs

**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 (19), (20) and (21) 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 (19) and (20) 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 (21)
$$\frac{\partial z}{\partial \tilde{z}} = \frac{1}{1-\eta}\,\frac{z}{\tilde{z}} > 0,$$
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.

**Proposition 2.** When $n=1$, $\theta_n = \alpha$, which implies that $1-(1+\hat{\eta})\alpha > 0$ since $\eta \in (0,1)$. Since $\underline{\zeta}$ is assumed to be small enough, $z_n^* > \underline{\zeta}$ exists and is unique. For any $z > z_n^*$, the number of firms $n_n(z) > 1$ producing a non-traded variety requires $(1+\hat{\eta})\theta_n > 1$, otherwise profits will be strictly negative.
Let us now prove that an increase in $z$ requires an increase in $n_n(z)$ in order to the zero-profit entry condition (23) hold. An increase in $z$ raises the right-hand-side of (23). Concerning the left-hand-side, notice that
$$\text{sign}\ \frac{\partial\left(\frac{\theta_n^{\frac{\alpha}{\alpha-1}}}{1-(1+\hat{\eta})\theta_n}\right)}{\partial \theta_n} = \text{sign}\ (1+\hat{\eta})\theta_n - \alpha,$$
which is strictly positive since, as stated just above, $(1+\hat{\eta})\theta_n > 1$. To complete the proof, notice that
$$\frac{\partial \theta_n}{\partial n} = \frac{1-\alpha}{n^2} > 0,$$
which implies that an increase in $z$ raises the number of firms $n(z)$.

**Proposition 3.** Let us first prove that exporters are more productive than non-exporters, i.e., $z_x^* > z_n^*$. Recall that $0 < \alpha < \theta_d^* < \theta_x^* < 1/(1+\hat{\eta}) < 1$. Since $\theta_d^* < \theta_x^*$, then

$$\big(1-(1+\hat{\eta})\theta_x\big)\theta_d^{\frac{\alpha}{1-\alpha}} < \big(1-(1+\hat{\eta})\theta_d\big)\theta_d^{\frac{\alpha}{1-\alpha}}.$$

Let us define the function

$$f(x) = \big(1-(1+\hat{\eta})x\big)\, x^{\frac{\alpha}{1-\alpha}}.$$

Its first derivative

$$f'(x) = -(1+\hat{\eta})\, x^{\frac{\alpha}{1-\alpha}} + \frac{\alpha}{1-\alpha}\big(1-(1+\hat{\eta})x\big)\, x^{\frac{\alpha}{1-\alpha}-1} = (\alpha-(1+\hat{\eta})x)\frac{x^{\frac{\alpha}{1-\alpha}-1}}{1-\alpha},$$

which is strictly negative for $\alpha < x < (1+\hat{\eta})x$. Consequently, since $0 < \alpha < \theta_d^* < 1/(1+\hat{\eta})$ and $\hat{\eta} > 0$,

$$\big(1-(1+\hat{\eta})\theta_d\big)\theta_d^{\frac{\alpha}{1-\alpha}} < \big(1-(1+\hat{\eta})\alpha\big)\alpha^{\frac{\alpha}{1-\alpha}},$$

which completes the proof that $z_x^* > z_n^*$.

# B Computational details

The key equations used to solve the model are

$$
\begin{aligned}
z_n(n,\tilde{z};\Delta) &= A^{\frac{1}{1-\eta}}\left[\frac{\hat{\eta}}{n}(\theta_n\Delta)^{\frac{1}{1-\alpha}}\right]^{\frac{\eta}{1-\eta}}\tilde{z}^{\frac{\eta}{1-\eta}},\\
z_x(n,\tilde{z};\Delta) &= A^{\frac{1}{1-\eta}}\left[\frac{\hat{\eta}}{n}\mathscr{A}(\theta_d\Delta)^{\frac{1}{1-\alpha}}\right]^{\frac{\eta}{1-\eta}}\tilde{z}^{\frac{\eta}{1-\eta}},\\
\pi_n(n,\tilde{z};\Delta) &= (1-(1+\hat{\eta})\theta_n)\theta_n^{\frac{\alpha}{1-\alpha}}\frac{1}{n}\Delta^{\frac{1}{1-\alpha}}z_n(n,\tilde{z};\Delta)-\lambda,\\
\pi_x(n,\tilde{z};\Delta) &= (1-(1+\hat{\eta})\theta_x)\theta_d^{\frac{\alpha}{1-\alpha}}\frac{1}{n}\Delta^{\frac{1}{1-\alpha}}z_x(n,\tilde{z};\Delta)-\lambda,\\
L_n(n,\tilde{z};\Delta) &= (1+\hat{\eta})\left[(\theta_n\Delta)^{\frac{1}{1-\alpha}}z_n(n,\tilde{z};\Delta)\right]+n\lambda,\\
L_x(n,\tilde{z};\Delta) &= (1+\hat{\eta})\left[\mathscr{A}(\theta_d\Delta)^{\frac{1}{1-\alpha}}z_n(n,\tilde{z};\Delta)\right]+n\lambda,
\end{aligned}
$$

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

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

ii. Obtain the cut-offs $\tilde{z}_n^*$ and $\tilde{z}_x^*$ by solving the equations

$$
\begin{aligned}
\pi_n(1,\tilde{z}_n^*;\Delta) &= 0,\\
\pi_x(1,\tilde{z}_x^*;\Delta) &= 0.
\end{aligned}
$$

iii. Given these cut-offs we create two grids: $\vec{z}_n = \{\tilde{z}_n^*,\ldots,\tilde{z}_x^* - \varepsilon\}$ and $\vec{z}_x = \{\tilde{z}_x^*,\ldots,\bar{\omega}\}$. We find the vectors $\vec{n}_n(\tilde{z};\Delta)$ and $\vec{n}_x(\tilde{z};\Delta)$ to satisfy the free entry conditions. That is,

$$
\begin{aligned}
\pi_n(\vec{n}_n(\tilde{z};\Delta),\tilde{z};\Delta) &= 0,\\
\pi_x(\vec{n}_x(\tilde{z};\Delta),\tilde{z};\Delta) &= 0,
\end{aligned}
$$

for all $\tilde{z} \in \vec{z}_n$ and $\tilde{z} \in \vec{z}_x$.

iv. Given the pairs $(\vec{z}_n,\vec{n}_n)$ and $(\vec{z}_x,\vec{n}_x)$ we use numerical interpolation to approximate the values of $n_n$ and $n_x$ in between grid points, and subsequently use numerical integration to calculate

$$
L(\Delta) = \int_{\tilde{z}_n^*}^{\tilde{z}_x^*} L_n(n_n,\tilde{z};\Delta)d\Phi(\tilde{z}) + \int_{\tilde{z}_x^*}^{\bar{\omega}} L_x(n_x,\tilde{z};\Delta)d\Phi(\tilde{z}),
$$

where $n_n$ and $n_x$ are shorthand notation for the interpolated values of $n$.

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 both $\vec{z}_n$ and $\vec{z}_x$, and a quasi-Newton method to obtain the values of $\tilde{z}_n^*$, $\tilde{z}_x^*$, $\vec{n}_n(\tilde{z};\Delta)$ and $\vec{n}_x(\tilde{z};\Delta)$. We use linear interpolation to construct the functions $L_n(n_n,\tilde{z};\Delta)$ and $L_x(n_x,\tilde{z};\Delta)$ 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 $1e(-10)$.

# C Alternative equilibrium definition

Let us define $x = \frac{z}{M\bar{z}}$. For given point in the parameter set $\Psi = \{\alpha, \lambda, \eta, A, \tau, \kappa, \underline{\omega}, \bar{\omega}\}$ – notice that $\{\hat{\eta}, \theta_d^*, \theta_x^*, \mathscr{A}^*\}$ all depend on $\Psi$ – an equilibrium is

i. The (number of firms) function $n_n(x)$ is implicitly defined by,

for $x \in (x_n^*, x_{nx}^*)$,

$$\frac{\theta_n(n)^{\frac{\alpha}{\alpha-1}}}{1-\big(1+\hat{\eta}\big)\theta_n(n)}\, n = \frac{x}{\lambda}, \tag{C.1}$$

for $x \in (x_n^*, \bar{\chi}_x)$,

$$\frac{\theta_d(n)^{\frac{\alpha}{\alpha-1}}}{1-\big(1+\hat{\eta}\big)\theta_x(n)}\, n = \frac{x}{\lambda}, \tag{C.2}$$

where

$$\theta_n(n) = \frac{n+\alpha-1}{n}, \qquad \theta_d(n) = \frac{2n+\alpha-1}{n\,(1+\tau)}, \qquad \theta_x(n) = \mathscr{A}(n)\ \theta_d(n), \tag{C.3}$$

$$\mathscr{A}(n) = \frac{(1-n-\alpha)(1+\tau^2)+2n\tau}{(1-\alpha)(1+\tau)}. \tag{C.4}$$

Function $n(x)$, and then $\theta(n(x))$, only depends on parameters $\{\alpha, \lambda, \eta, \tau\}$. The boundaries $\{x_n^*, x_{nx}^*, x_x^*, \bar{\chi}_x\}$ are indeed endogenous and determined below.

ii. The (innovation factor) function $\mathscr{B}(x)$, such that $x = \mathscr{B}(x)\,\bar{z}^{\frac{1}{1-\eta}}$,

for $x \in (x_n^*, x_{nx}^*)$,

$$\mathscr{B}(x) = \hat{\eta}^{\frac{\eta}{1-\eta}} \left(\frac{\theta_n\big(n(x)\big)^{\frac{1}{1-\alpha}}}{n(x)}\right)^{\frac{\eta}{1-\eta}} \left(\frac{M\bar{z}}{A}\right)^{\frac{1}{\eta-1}}, \tag{C.5}$$

for $x \in (x_n^*, \bar{\chi}_x)$,

$$\mathscr{B}(x) = \hat{\eta}^{\frac{\eta}{1-\eta}} \left(\frac{\mathscr{A}\big(n(x)\big)\ \theta_d\big(n(x)\big)^{\frac{1}{1-\alpha}}}{n(x)}\right)^{\frac{\eta}{1-\eta}} \left(\frac{M\bar{z}}{A}\right)^{\frac{1}{\eta-1}}. \tag{C.6}$$

Function $\mathscr{B}(x)$ depends on the ration $\frac{M\bar{z}}{A}$, in top of parameters $\{\alpha, \lambda, \eta, \tau\}$.

iii. The cutoff values

$$x_n^* = \frac{\lambda\ \alpha^{\frac{\alpha}{\alpha-1}}}{1-(1+\hat{\eta})\alpha}, \tag{C.7}$$

$$x_x^* = \frac{\lambda\ \theta_d^{*\,\frac{\alpha}{\alpha-1}}}{1-(1+\hat{\eta})\theta_x^*}, \tag{C.8}$$

$$x_{nx}^{*}=\left(\frac{n(x_{nx}^{*})^{-1}\ \theta_n\big(n(x_{nx}^{*})\big)^{\frac{1}{1-\alpha}}}{\mathscr{A}^{*}\theta_d^{*\,\frac{1}{1-\alpha}}}\right)^{\frac{\eta}{1-\eta}} x_x^{*}, \tag{C.9}$$

$$\bar{\chi}_x=\mathscr{B}(\bar{\chi}_x)\ \bar{\omega}^{\frac{1}{1-\eta}}. \tag{C.10}$$

The boundaries $x_n^*, x_x^*, x_{nx}^*$ only depend on parameters $\{\alpha,\lambda,\eta,\tau\}$. The $\bar{\chi}_x$ depends on $\frac{M\bar{z}}{A}$, in top of parameters $\{\alpha,\lambda,\eta,\tau\}$.

iv. The entry density $\varphi(x)$, defined in the support of $x$, is

$$\varphi(x)=\frac{\phi\left(\mathscr{B}(x)^{\eta-1}x^{1-\eta}\right)}{\mathscr{C}(x)}, \tag{C.11}$$

where

$$\mathscr{C}(x)=\frac{1}{1-\eta}\frac{\mathscr{B}(x)^{1-\eta}x^{\eta}}{1-\frac{\mathscr{B}'(x)x}{\mathscr{B}(x)}}.$$

The density $\varphi(x)$ only depends on $\frac{M\bar{z}}{A}$, through $\mathscr{B}(x)$, in top of parameters $\{\alpha,\lambda,\eta,\tau\}$.

v. Variable $\frac{M\bar{z}}{A}$ is determined by the definition of $\bar{z}$ multiplied by $M$, which after some algebra reads

$$1=\int_{x_n^*}^{x_{nx}^*}\theta_n\big(n(x)\big)^{\frac{\alpha}{1-\alpha}}\ x\ \varphi(x)\mathrm{d}x+\int_{z_x^*}^{\bar{\chi}_x}\theta_d\big(n(x)\big)^{\frac{\alpha}{1-\alpha}}\ x\ \varphi(x)\mathrm{d}x, \tag{C.12}$$

which for given parameters $\{\alpha,\lambda,\eta,\tau\}$ determines $\bar{\chi}_x$, which only depends on $\frac{M\bar{z}}{A}$.

**R&D Productivity scaler.** From the analyses above, it is clear that any change in $A$ makes $M\bar{z}$ to move proportionally. Since $M=1-\Phi(x_n^*)$, it has to remain unchanged after a change in $A$, $\bar{z}$ moving at the same rate as $A$. The implication is that the equilibrium does not depend on $A$, but on the equilibrium distribution of $z$. Consequently, there is always an $A$ that makes $z>\tilde{z}$, 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 $\bar{z}$.

# D Market concentration and robustness

**Globalization and market concentration** Figure D.1 illustrates the sale-shares of the most productive firms in the market for different degrees of trade liberalization; i.e. the *market concentration*. The first three panels illustrates the shares of the top 1%, 5%, and 10%, respectively, while the last panel shows the percent change. Full trade liberalization leads to an approximate 10% increase in market concentration for each quantile of productivity considered.

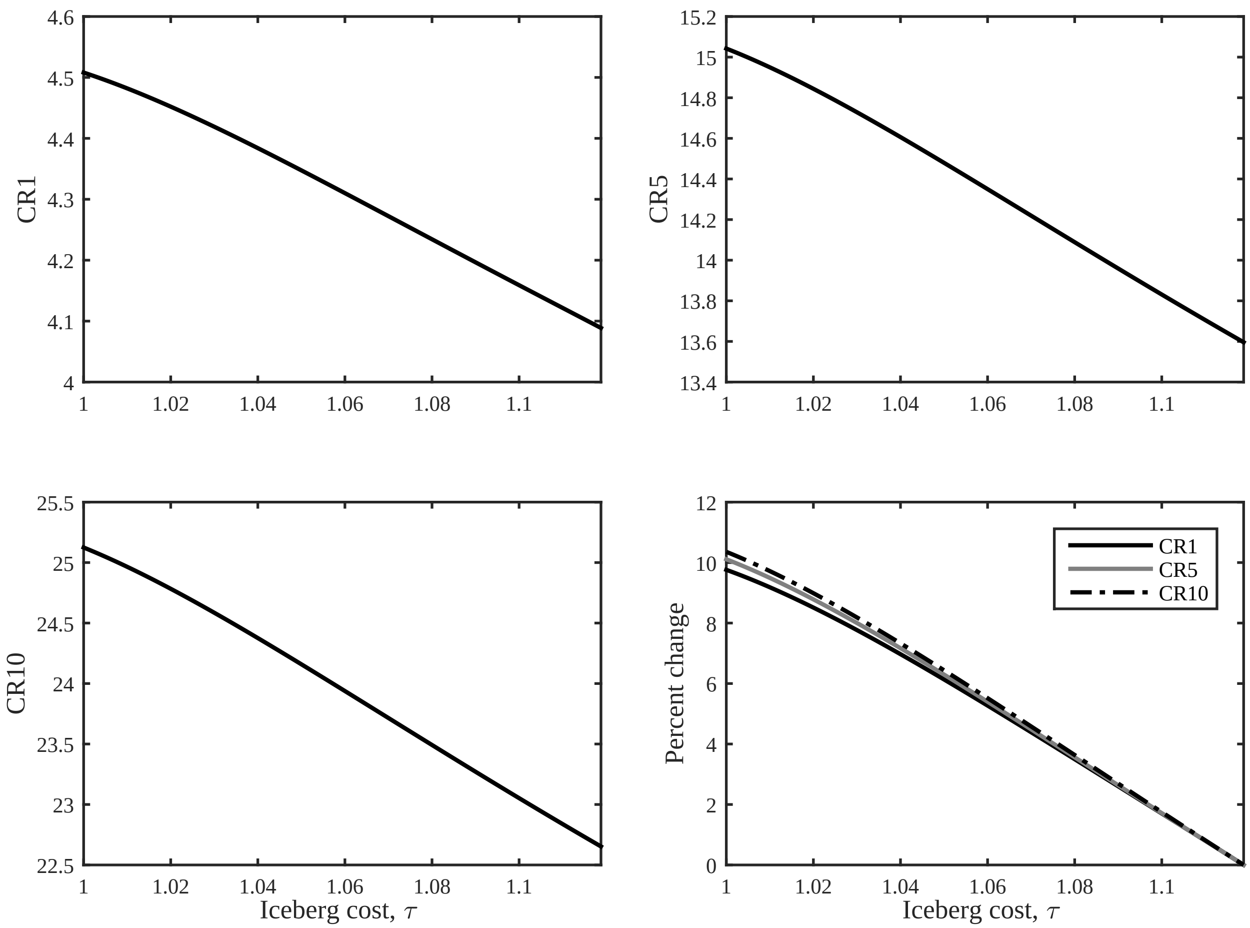


Figure D.1: Globalization and sales concentration ratios.

**Robustness** Table D.1 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 D.1: Robustness of aggregate effects.

| | | Bench. | $\bar{\alpha}$ | $\underline{\alpha}$ | $\bar{\eta}$ | $\underline{\eta}$ | $\bar{\kappa}$ | $\underline{\kappa}$ |
|---|---|---|---|---|---|---|---|---|
| *Average cost* | | | | | | | | |
| Exporters | $\tau = 1.08$ | 1.47 | 1.44 | 1.47 | 1.48 | 1.46 | 1.48 | 1.45 |
| | $\tau = 1.00$ | 1.46 | 1.42 | 1.46 | 1.47 | 1.44 | 1.47 | 1.44 |
| Domestic | $\tau = 1.08$ | 1.65 | 1.57 | 1.70 | 1.66 | 1.64 | 1.67 | 1.63 |
| | $\tau = 1.00$ | 1.65 | 1.57 | 1.70 | 1.66 | 1.64 | 1.66 | 1.63 |
| *Firm size* | | | | | | | | |
| Exporters | $\tau = 1.08$ | 4.07 | 4.75 | 3.61 | 4.4 | 3.79 | 4.0 | 4.16 |
| | $\tau = 1.00$ | 4.47 | 5.55 | 3.84 | 4.86 | 4.13 | 4.38 | 4.58 |
| Domestic | $\tau = 1.08$ | 1.52 | 1.94 | 1.26 | 1.57 | 1.48 | 1.51 | 1.53 |
| | $\tau = 1.00$ | 1.51 | 1.94 | 1.25 | 1.56 | 1.47 | 1.5 | 1.52 |
| *# Firms* | | | | | | | | |
| Exporters | $\tau = 1.08$ | 1.11 | 1.13 | 1.10 | 1.11 | 1.12 | 1.1 | 1.12 |
| | $\tau = 1.00$ | 1.10 | 1.10 | 1.09 | 1.09 | 1.10 | 1.09 | 1.11 |
| Domestic | $\tau = 1.08$ | 1.13 | 1.13 | 1.14 | 1.13 | 1.13 | 1.13 | 1.14 |
| | $\tau = 1.00$ | 1.13 | 1.12 | 1.13 | 1.13 | 1.12 | 1.12 | 1.13 |
| *TFP* | | | | | | | | |
| Exporters | $\tau = 1.08$ | 2.59 | 2.54 | 2.66 | 2.68 | 2.52 | 2.46 | 2.75 |
| | $\tau = 1.00$ | 2.59 | 2.6 | 2.64 | 2.7 | 2.51 | 2.46 | 2.77 |
| Domestic | $\tau = 1.08$ | 1.3 | 1.35 | 1.27 | 1.29 | 1.32 | 1.27 | 1.35 |
| | $\tau = 1.00$ | 1.31 | 1.36 | 1.27 | 1.3 | 1.32 | 1.27 | 1.36 |
| *Cutoffs* | | | | | | | | |
| Exporters | $\tau = 1.08$ | 1.75 | 1.77 | 1.75 | 1.79 | 1.71 | 1.71 | 1.8 |
| | $\tau = 1.00$ | 1.72 | 1.76 | 1.72 | 1.77 | 1.68 | 1.68 | 1.78 |
| Domestic | $\tau = 1.08$ | 1.16 | 1.23 | 1.12 | 1.17 | 1.16 | 1.14 | 1.2 |
| | $\tau = 1.00$ | 1.17 | 1.24 | 1.12 | 1.18 | 1.17 | 1.15 | 1.21 |
| *Markups* | | | | | | | | |
| Exporters | $\tau = 1.08$ | 1.17 | 1.13 | 1.22 | 1.17 | 1.17 | 1.17 | 1.17 |
| | $\tau = 1.00$ | 1.16 | 1.12 | 1.21 | 1.16 | 1.16 | 1.16 | 1.16 |
| Domestic | $\tau = 1.08$ | 1.38 | 1.27 | 1.5 | 1.37 | 1.38 | 1.38 | 1.37 |
| | $\tau = 1.00$ | 1.38 | 1.27 | 1.5 | 1.38 | 1.38 | 1.38 | 1.37 |

*Notes.* This table illustrates the effects of reducing the iceberg cost, $\tau$, from 1.08 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 4.1.2.

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