Trade liberalization and credit constraints: Why "opening up" may fail to promote technology adoption

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VERY PRELIMINARY. COMMENTS WELCOME.

Abstract

Recent evidence suggests that despite "opening" up a country for for trade, the productivity gap often does not close between developed and emerging economies. This paper examines credit constraints as one channel held responsible for hampering convergence. Specifically, we extend a Melitz and Ottaviano (2008) type trade model with variable mark-ups to allow for endogenous technology adoption. We consider a framework with two countries that differ with respect to credit market development. Firms have the option to adopt a more efficient technology by paying some fixed cost that are more difficult to finance for financially constrained firms. A reduction in trade costs raises demand abroad (pro-technology adoption effect) but reduces mark-ups at home because of import competition (anti-technology adoption effect). Technology adoption increases (i) in both countries if the costs of external finance are low (ii) in the developed country only, if firms in the emerging country are credit constrained. Trade liberalization - through the usual selection effect and the additional technology adoption effect described above- makes the financially developed country better off but may reduce welfare in the emerging country. "Opening up" without sufficient access to external funding thus fails to promote convergence.

Keywords: Trade, Technology adoption, Financing constraints, Economic Growth
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1. Introduction

Trade liberalization is one of the most common policy reforms recommended to developing countries in order to enhance economic welfare (Rodrik, 2006). First, "opening up" to trade increases the market size for exporters. Second, incoming foreign firms foster competition and contribute to a more efficient allocation of resources across firms. Moreover, their presence increases the access to more advanced foreign technologies. However, trade liberalization often does not entail the desired effects. A prominent example is the situation of the Eastern European countries in the 1990s. Following the recommendations of the well-known Washington consensus, these countries opened their markets, but the economic performance did not improve. On the contrary, the per capita income gap with respect to the Western European countries widened during the following decade (Peter, Svejnar, and Terrell, 2009, Svejnar, 2002, World Bank, 2005). Another example is the adverse effect of trade liberalization on the economic performance of Argentina and Chile in the 1980s (World Bank, 2005). Moreover, Balat and Porto (2007) show for Zambia that trade results in higher income only if it accompagnied by complementary policies like the provision of infrastructure, credit, and extension services.

This paper develops a theoretical model to explore one channel held responsible for impeding convergence in the literature: credit constraints. In emerging countries, the credit market is generally less developed than in more advanced countries. As access to external funds is costly, firms are prevented from taking advantage of the larger market after trade liberalization but face import competition. They are thus less willing to invest in technology upgrading. As a consequence, aggregate productivity is lower than in a country with a developed credit market. When credit constraints are severe, aggregate productivity even declines leading to a decrease in welfare.

Our analysis builds and contributes to several strands of literature. First, it is related to a large literature that examines the impact of trade liberalization when firms are heterogeneous. Melitz (2003) shows that competition of, on average, more productive foreign firms forces the least productive domestic producers to shut down. Resources are reallocated towards the most productive domestic firms leading to a lower average price and higher real consumption. This is the well known selection effect of trade. Bustos (2010) and Navas-Ruiz and Sala (2007) introduce an endogenous technology adoption decision where firms have the option to invest in a more expensive but more efficient technology. A reduction in trading costs increases the market abroad and boosts technology adoption. This is the pro-technology adoption effect. However, import competition reduces demand at home and

thereby investment in technology upgrading. This is the anti-technology adoption effect. Both papers show that with Pareto distributed productivity the pro-technology adoption effect dominates. Technology adoption thus increases after trade liberalization leading to an increase in average productivity, in addition to the selection effect.

We incorporate such a technology adoption decision into the Melitz and Ottaviano (2008) framework where mark-ups decrease in the number of competitors. A reduction in trading costs increases the number of firms in the market and therewith lowers mark-ups (in addition to lower market shares). The least productive firms make losses and exit the market. In contrast to the above Melitz (2003)-type models, the selection effect of trade liberalization does not work through higher real wages but, as we observe it in the real world, through increased product market competition.

Moreover, and more importantly, we link the technology adoption decision to the level of credit market development by assuming that a fraction of the technology adoption cost needs to be financed externally. In a less developed credit market, using external finance is more expensive and increases the total costs of technology adoption. Hence, there is a range of firms that would upgrade technology in a developed credit market but are prevented from doing so if they are credit constrained. We provide a simple microfoundation for this result. In the tradition of Manova (2010) and Aghion, Howitt, and Mayer-Foulkes (2005), weak creditor protection increases the collateral required by banks. Only the more productive firms offer a high enough collateral to obtain credit.

Our paper thus contributes to a strand of literature that documents the negative impact of financial constraints on firms' ability to invest in productivity enhancing activities. In line with empirical studies reporting that exporters are on average financially more healthy than non-exporters (e.g. Greenaway, Guariglia, and Kneller, 2007, Bellone, Musso, Nesta, and Schiavo, 2010), Chaney (2005) and Manova (2010) show in theoretical models that financially unconstrained firms are more likely to cover the fixed costs of exporting. Information asymmetry between firm and creditor, moral hazard problems and lack of collateral reduce the access to external finance for investments in innovative activities (e.g. Hall and Lerner, 2009). The limited access to external finance is likely to result in credit constraints if the credit market is not sufficiently developed. Potential credit market frictions in emerging countries are manifold (Levine, 2005). First, the credit market is often not sufficiently competitive allowing creditors to charge lending rates that largely exceed marginal costs of financing credit. Second, employees without adequate managerial skills and business ethics might increase monitoring costs and lay the foundation for rent-seeking

behavior. Moreover, a lack of "Basel Accords" -type recommendations reduces transpareny and increases information and transaction costs. Finally, the legal environment in emerging countries often hampers financial contractibility and thereby increases the costs of external finance (e.g., Manova, 2010). Alleviating financing constraints of innovators therefore significantly boosts investment in more advanced technologies (e.g. Hajivassiliou and Savignac, 2007). Gorodnichenko and Schnitzer (2010) analyze the effect of financial constraints on the relation between exporting and innovation, theoretically and empirically using BEEPS. Without financial constraints, exporting increases the market size and stimulates investment in advanced technologies. More efficient production technologies on the other hand increase firms' competitiveness abroad. Hence, exporting and technology adoption are natural complements. However, when internal funds are limited and external finance is costly, engaging in one activity increases the costs of financing the other.

We explore how credit constraints influence the effect of trade liberalization on technology adoption and aggregate productivity in a two-country setting where countries potentially differ with respect to credit market development. A reduction in trading costs increases demand abroad but reduces market shares at home due to increased competition from foreign firms. If both countries have a developed credit market, overall demand and thereby the fraction of firms adopting the advanced technology increases. The selection effect of trade and technology upgrading lead to higher average productivity and welfare. This is the result obtained by Bustos (2010) and Navas-Ruiz and Sala (2007) who consider symmetric countries. In addition, we show that, if firms in one country face credit constraints, technology adoption in this country decreases after trade liberalization. Welfare in the less developed country increases thus less than in the symmetric case and might even decrease if credit constraints are severe. The reason is the following: higher costs of external finance reduce the fraction of technology adopters. Hence, firms are on average less productive and thus less competitive abroad. The number of new exporters after trade liberalization is lower than in the symmetric case. The number of new foreign competitors on the other hand is higher as foreign firms are now more competitive on the home market. While import competition increases, credit constraints thus prevent potential new exporters from taking advantage of the larger market and reduce investment in more advanced technologies. When credit constraints are severe, the import competition effect is so strong compared to the larger market effect that ex-ante expected profits and therefore the number of entrants decrease. As a consequence, competition is weaker leading to a decrease in welfare.

In a second step, we parameterize the model for a comparative statics exercise. In particular,

we explore how the results change if countries are initially more closed, if the differentiated good industry is less cost effective and more differentiated, and if the return to technology adoption is larger.

To our knowledge, we are the first to analyze how credit constraints change the effect of "opening up" to trade on technology upgrading and welfare in a theoretical model. In contrast to the common result that trade liberalization is ultimately beneficial for aggregate welfare, our model shows that welfare may decrease if firms do not have equal access to external finance. Moreover, we are able to do so in a heterogeneous-firm framework with endogenous mark-ups without reducing tractability compared to the standard constant-markup setup à la Melitz (2003). Endogenous mark-ups allow us to model the selection effect of trade liberalization through increased import competition. Consistent with empirical evidence (e.g. Feenstra and Weinstein, 2010, Tybout, 2003), trade liberalization reduces the average markup. Lower mark-ups, in addition to lower market shares, force the least productive firms to exit.

Our paper is closely related to Unel (2010) who extends Bustos (2010) and Navas-Ruiz and Sala (2007) to asymmetric countries that differ with respect to technology adoption cost. He finds that trade liberalization unambiguously increases welfare, the fraction of high-technology firms and the fraction of exporters in the country with lower technology adoption costs while the effect is ambiguous in the country where technology adoption is more expensive. Whenever a reduction in trade barriers increases (decreases) revenues from export sales, the fraction of exporters and the fraction of high-technology firms in the latter country increases (decreases). Hence, the effect of trade liberalization on exporting and technology adoption always works in the same direction. In our Melitz and Ottaviano-type framework, on the other hand, the fraction of high-technology firms may decrease even if revenues from exporting increase. The reason in the import competition effect of trade liberalization that is absent in the Melitz (2003) model. If external finance is very costly, higher import competition after "opening up" reduces domestic sales to such an extent that overall sales and therewith the incentive to invest in technology upgrading decrease.
Moreover, we endogenize the cost of technology adoption. In particular, we link higher technology adoption costs to credit market imperfections. Weak institutions and high information and transaction costs increase the cost of external finance and thus prevent a range of potential high-technology firms from adopting the advanced technology. Finally, we show how the effect on technology adoption and welfare that is a priori ambiguous depends on the main parameters of the model.

Atkeson and Burstein (2010) develop a dynamic model with two symmetric countries where heterogeneous firms, as in our model, endogenously decide about production, exporting and investment in process innovation. The authors show that the effect of trade liberalization on firm decisions is entirely compensated by the entry of new firms. They conclude that firm heterogeneity does not affect the impact of a reduction in trading costs on aggregate productivity and welfare. In our model, firm heterogeneity has an impact on the welfare implication of trade: if firms were homogenous, all firms or no firm would invest in technology upgrading. The model then reduces to the Melitz (2003) model where "opening up" entails a selection effect but no increase in plant-level productivity. Moreover, Atkeson and Burstein do not consider all three firm decision simultaneously but analyze three special cases that abstract from one decision respectively.

Another paper that studies the interaction between exporting and innovation in a dynamic model is Costantini and Melitz (2008) . The aim is to show that that adoption of new technologies is more likely to occur after trade liberalization. Like Atkeson and Burstein (2010), they do not consider credit market imperfections.

The paper is organized as follows: section 2 lays out the model setup and describes the closed economy equilibrium. The equilibrium in the open economy is described in section 3. Section 4 analyzes the impact of trade liberalization and comparative statics results are given in section 5. Section 6 concludes.

2. Closed Economy

In this section, we introduce an endogenous technology adoption decision into a model a la Melitz and Ottaviano (2008).

2.1. Demand

The economy consists of L consumers who have identical preferences over a continuum of varieties indexed by $i \in \Omega$ and a homogeneous good chosen as numéraire ($p_0 = 1$). Preferences are decribed by the quasi-linear quadratic utility function developed by Ottaviano, Tabuchi, and Thisse (2002):

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

where $\alpha, \beta, \gamma > 0$. q_0^c and q_i^c denote the per capita consumption level of the homogeneous good and of each variety i. The parameters α and β characterize substitution between the

differentiated good and the numéraire good. Demand for differentiated varieties relative to the numéraire increases as α increases or β decreases. The degree of product differentiation is captured by the parameter γ. If $\gamma = 0$, varieties are perfectly substitutable and consumers only care about their overall consumption level $Q^c = \int_{i\in\Omega} q_i^c di$. As γ increases, consumers increasingly prefer to distribute consumption across varieties. A price increase entails thus a smaller drop in demand. Hence, higher product differentiation is reflected by a flatter slope of the demand curve.

Utility maximization is with respect to the budget constraint $E = \int_{i\in\Omega'} p_i q_i^c + q_0^c$ where $\Omega' \subset \Omega$ denotes the subset of varieties that are consumed in the economy. Assuming that the demand for the numéraire good is positive ($q_0^c > 0$), demand for variety i is given by

$$q_i = Lq_i^c = \frac{\alpha L}{\gamma + \beta N} - \frac{L}{\gamma} p_i + \frac{\beta N}{\gamma + \beta N} \frac{L}{\gamma} \bar{p}. \tag{2}$$

$\bar{p} = \frac{1}{N} \int_{i\in\Omega} p_i di$ is the average price and N the number of consumed varieties.

Variety i is consumed whenever the price p_i is non-prohibitive:

$$p_i \leq p_{\max} \equiv \frac{\gamma\alpha}{\gamma + \beta N} + \frac{\beta N}{\gamma + \beta N} \bar{p}, \tag{3}$$

where $p_{\max}$ is the prohibitive price above which demand q_i is equal to zero.

Equations (2) and (3) then imply a price elasticity of demand equal to

$$\epsilon_i = \left(\frac{p_{\max}}{p_i} - 1 \right)^{-1}. \tag{4}$$

Given the price p_i, an increase in competition - a larger set of consumed varieties N or a lower average price $\bar{p}$ - raises the price elasticity ϵ_i and decreases the mark-up, $\mu_i = \frac{\epsilon_i}{\epsilon_i - 1}$. The mechanism behind this result is the following: an additional variety reduces overall per-variety consumption. Formally, the demand function shifts downwards resulting in a lower prohibitive price. Firms' market power, as reflected by a higher price elasticity, and therefore mark-ups decrease. Likewise, a lower price index $\bar{p}$, implying a higher relative price $\frac{p_i}{\bar{p}}$, reduces demand for variety i and thereby the mark-up μ_i.

Hence, in contrast to the case of CES demand, higher product market competition leads to lower mark-ups when using the linear demand system specified in (2).

2.2. Supply

The only factor of production, labor, is inelastically supplied in a competitive market. The market for the homogeneous good, the numéraire good, is perfectly competitive. Firms produce at constant returns to scale and require one unit of labor to produce one unit of output. From the quasi-linear utility in (1), the market for the numéraire good absorbs all labor imbalances. Assuming a positive demand for the numéraire, the nominal wage in the economy is equal to unity.

Firms in the differentiated good industry operate under monopolistic competition and take the average price $\bar{p}$ and the number of competitors N as given. Production is at constant returns to scale with firm-specific input requirement c_i. In order to satisy demand q_i, firms need to hire $l_i = c_i q_i$ units of labor[1].

2.2.1. Technology adoption

Extending the Melitz and Ottaviano (2008) framework, firms have the option to upgrade their technology by spending f units of labor. The cost of using the traditional technology is normalized to zero. The technology adoption cost f can be thought of as a per-period fixed costs that comes with adopting the more advanced technology as for example the rent for new machinery. Technology upgrading reduces production cost by a fixed amount t: firms adopt a process innovation that reduces labor input requirement to $l_i = (c_i - t)q_i$. We call t the "technological leap". The more advanced technology thus comes at a higher cost but allows for more efficient production[2].

Let p_i, μ_i, q_i, π_i and $p_i^A, \mu_i^A, q_i^A, \pi_i^A$ denote price, mark-up, quantity and profits when using the traditional and the advanced technology respectively. Profit maximization implies the following price and mark-up rules:

$$\begin{aligned} p_i &= \frac{1}{2}\left(p_{\max} + c_i\right), \quad p_i^A = \frac{1}{2}\left(p_{\max} + c_i - t\right) \\ \mu_i &= \frac{1}{2}\left(p_{\max} - c_i\right), \quad \mu_i^A = \frac{1}{2}\left(p_{\max} - c_i + t\right). \end{aligned} \tag{5}$$

[1]Following Melitz and Ottaviano (2008), we abstract from fixed overhead cost as these make the analysis cumbersome without adding new insights.

[2]Modelling a continuous investment decision, e.g. $\max \pi = i^{\beta}(p_i - c_i)q_i - i$, instead of a binary one makes the analysis cumbersome but leaves the results qualitatively unchanged: "opening up" reduces investment of purely domestic firms and has a positive larger market and a negative import competition effect on the investment of exporters.

The corresponding quantities are given by

$$q_i = \frac{1}{2}\left(p_{\max} - c_i\right)\frac{L}{\gamma}, \quad q_i^A = \frac{1}{2}\left(p_{\max} - c_i + t\right)\frac{L}{\gamma}. \tag{6}$$

Prices charged by firms using the advanced technology are lower, $p_i^A = p_i - \frac{t}{2}$. Accordingly, quantities sold are higher, $q_i^A = q_i + \frac{L}{2\gamma}t$, as are mark-ups, $\mu_i^A = \mu_i + \frac{t}{2}$. Technology adoption thus increases variable profits but involves higher fixed cost

$$\pi_i = \frac{L}{4\gamma}\left(p_{\max} - c_i\right)^2, \quad \pi_i^A = \frac{L}{4\gamma}\left(p_{\max} - c_i + t\right)^2 - f. \tag{7}$$

This trade-off between higher fixed cost and lower variable costs is depicted in Fig. 1.

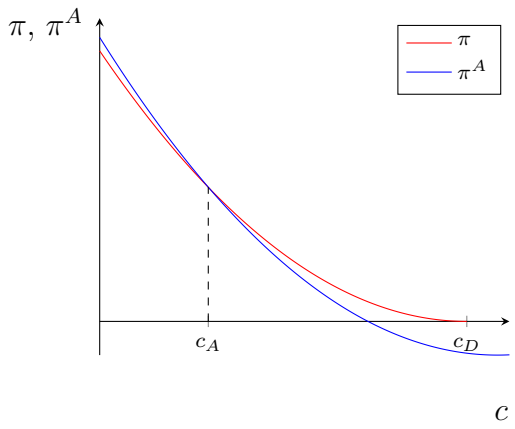


Figure 1: Technology adoption trade-off

c_D denotes the entry cutoff that corresponds to the production cost of the least productive firm in the market that just breaks even. c_A is the technology adoption cutoff: firms with cost of production below c_A realize higher profits when using the more advanced technology ($\pi_i^A > \pi_i$). Hence, these firms invest in technology upgrading. The contrary holds for firms with marginal costs above c_A.

The return to technology upgrading increases in the scale of production. From (6), firms with lower marginal cost c_i (that is with higher productivity $1/c_i$) satisfy a larger demand. Hence, the incentive to invest in technology upgrading increases in productivity. For $f = 0$, all firms adopt the more advanced technology. For f very large, on the other hand, no firms find it profitable to bear the higher fixed cost. To ensure that some but not all firms use the advanced technology, f is assumed to be sufficiently high to prevent only the least

productive firms from technology adoption ($0 < c_A < c_D$)[3].

2.2.2. Pareto distributed production costs

There is an unbounded mass of ex-ante identical firms who decide whether or not to enter the differentiated good industry. Entry requires a fixed investment f_E. This investment is thereafter sunk and captures start-up costs such as setting up a facility and buying equipment. Upon entry, firms draw their marginal cost c_i from a common distribution $F(c_i)$. In particular, we assume that productivity $1/c_i$ is Pareto distributed with lower bound $1/c_M$ and shape parameter $k \geq 1$. It follows that marginal cost c_i is also Pareto distributed with shape parameter $k \geq 1$ and support $[0, c_M]$

$$F(c_i) = \left(\frac{c_i}{c_M}\right)^k, \quad c_i \in [0, c_M]. \tag{8}$$

The Pareto distribution has been intensively used in the recent literature as several studies have suggested that it is a good fit of the firm size distribution (e.g., Axtell, 2001, Del Gatto, Ottaviano, and Mion, 2006, Helpman, Melitz, and Yeaple, 2004). Furthermore, it makes the analysis highly tractable and easily lends itself to interpretation. The upper bound on marginal cost c_M indicates how cost effective the economy is in producing the differentiated good. A higher c_M implies higher average cost of production. The shape parameter k governs the dispersion of the cost distribution. If $k = 1$, $F(c_i)$ corresponds to the uniform distribution. A higher k implies a higher cost concentration and thus higher average cost of production. Moreover, any truncation of the Pareto distribution is also a Pareto distribution with shape paramater k.

2.2.3. Firm decisions

The timing of the model is as follows: upon learning the marginal cost of production, a firm decides (i) whether to exit or to produce and if it produces (ii) whether to use the traditional or the advanced technology. Then, production takes place.

A firm decides to exit if it makes losses. The marginal producer uses the traditional technology and realizes zero profits. From (7), the entry cutoff c_D then corresponds to the prohibitive price:

$$\pi_i(c_D) = 0 \;\Leftrightarrow\; c_D = p_{\max}. \tag{9}$$

[3]A sufficient condition is $\frac{t}{2}\frac{Lt}{2\gamma} < f < \left(c_D + \frac{t}{2}\right)\frac{Lt}{2\gamma}$.

Firms with cost draws above c_D exit the market immediately. Using (9), profits can be rewritten as

$$\pi_i = \frac{L}{4\gamma}\left(c_D - c_i\right)^2, \quad \pi_i^A = \frac{L}{4\gamma}\left(c_D - c_i + t\right)^2 - f. \tag{10}$$

Surviving firms upgrade technology if profits are higher when using the advanced technology, that is if $\pi_i^A(c_i) \geq \pi_i(c_i)$. The technology adoption cutoff c_A corresponds to the production cost of the marginal technology adopter who is just indifferent between traditional and advanced technology:

$$\pi_i^A(c_A) = \pi_i(c_A) \;\Leftrightarrow\; c_A = c_D + \frac{t}{2} - \frac{2\gamma}{Lt}f. \tag{11}$$

The technology adoption cutoff increases in the technological leap t and in market size L and decreases in the technology adoption cost f and in product differentiation γ: a larger decrease in variable costs and a higher demand raise the incentive to upgrade technology. It is dampened by higher investment cost and lower firm scale[4].

Upon entry, there are thus three types of firms: firms with cost draw above c_D immediately exit the market, firms with marginal cost between c_D and c_A produce using the traditional technology (low-technology firms) and firms with cost below c_A adopt the advanced technology (high-technology firms).

2.3. Closed economy equilibrium

Entry into the industry is unrestricted: firms enter until ex-post expected profits are equal to the fixed entry cost f_E. Hence, there are zero ex-ante expected profits in equilibrium:

$$\int_0^{c_A}\left[\frac{L}{4\gamma}\left(c_D - c_i + t\right)^2 - f\right]dF(c) + \int_{c_A}^{c_D}\frac{L}{4\gamma}\left(c_D - c_i\right)^2 dF(c) = f_E. \tag{12}$$

The free entry condition (12) uniquely determines the entry cutoff c_D. To see this, note that the right-hand side, the ex-post expected profits, are strictly increasing in c_D while the left-hand side is a constant. Hence, there is one intersection and thus a unique equilibrium. As c_A is completely determined by c_D, all performance measures can be expressed as a function of the entry cutoff c_D only.

The ex-ante distribution of successful entrants is the Pareto distribution in (8) truncated at

[4] A higher degree of product differentiation lowers the price elasticity of demand. Therefore, it is optimal for firms to set higher prices that imply lower quantities.

the entry cutoff c_D

$$F_{c_D}(c_A)\left(\frac{c_i}{c_D}\right)^k, \quad c_i \in [0, c_D]. \tag{13}$$

From the law of large numbers (LLN), this is also the ex-post distribution of producers. Being a producer, the probability of using the traditional and the advanced technology is given by $\frac{F(c_D)-F(c_A)}{F(c_D)}$ and $\frac{F(c_A)}{F(c_D)}$ respectively. By the LLN, these expressions also represent the fraction of low-technology and high-technology firms, $\frac{N_D}{N}$ and $\frac{N_I}{N}$, where N_D and N_I denote the absolute number of low-technology and high-technology firms.
Average cost, price, sales, and profits are then given by

$$\begin{aligned}
\bar{c} &= \frac{k}{k+1}c_D \\
\bar{p} &= \frac{2k+1}{2k+2}c_D - (p_D - p_D^A)\frac{N_I}{N} \\
\bar{q} &= \frac{L}{2\gamma}\frac{1}{k+1}c_D + (q_D^A - q_D)\frac{N_I}{N} \\
\bar{\pi} &= f_E\left(\frac{c_M}{c_D}\right)^k + (\pi_D^A - \pi_D)\frac{N_I}{N}.
\end{aligned} \tag{14}$$

Comparing (14) to the Melitz and Ottaviano (2008) model without technology adoption (see Melitz and Ottaviano, 2008, pg. 301) reveals that the average price is lower while average output and profits are higher. To understand the intuition behind this result, we rewrite the free entry condition as

$$\int_0^{c_D} \frac{L}{4\gamma}\left(c_D - c_i\right)^2 dF(c) + \int_0^{c_A}\left\{\frac{L}{4\gamma}\left[2(c_D - c_i)t + t^2\right] - f\right\} dF(c) = f_E, \tag{15}$$

where the first term gives profits realized by all producers and the second the additional profits of high-technology firms. In contrast to the Melitz and Ottaviano (2008) model, the option to upgrade technology allows the most productive firms to increase profits. Ex-post expected profits are thus higher leading to more entry. A larger number of entrants drives down the entry cutoff c_D. Surviving firms are, on average, more efficient (lower average price) and larger (higher average sales). Average mark-ups and profits are higher.

The implications on welfare can be seen from the indirect utility function associated with (1)

$$W = 1 + \frac{1}{2\eta}(\alpha - c_D)\left(\alpha - \frac{k+1}{k+2}c_D\right). \tag{16}$$

The welfare level is a decreasing function of the entry cutoff c_D. A higher c_D implies less

entry and a higher pre-entry probability of survival $G(c_D)$. In other words, there is less competition and thus a higher average price $\bar{p}$ and a smaller range of varieties. From our analysis above follows that the option to upgrade technology increases competition (lower c_D). Welfare in our economy thus is higher than in the Melitz and Ottaviano (2008) model without technology adoption:

Proposition 1. *Suppose that $0 < c_A < c_D$. The possibility to adopt a more advanced technology increases average productivity and welfare.*

3. Open Economy

We now extend our model to two countries, L and H.
The assumption of a positive demand for the homogenous good ensures that the wage is equal to unity in both countries. Furthermore, from the quasi-linear utility in (1), trade is then balanced. Trade between the two countries is not free but involves trading costs that consist of a fixed and a variable component. Variable costs include transport costs and tariffs. Specifically, in order to deliver one unit abroad, $\tau > 1$ units must be shipped. This is the well-known iceberg formulation. The fixed component reflects entry costs: a firm has to gather information about the foreign market, adapt and advertise the product and build up a sales network. Following Ottaviano, Taglioni, and Di Mauro (2009), we collapse all trading costs into a single indicator, τ, that we call "freeness of trade". We assume that trading costs increase the marginal cost of production c_i but do no affect the return to innovation t. The idea here is that trading costs increase the delivered cost abroad but do not affect the extent to which an innovator can exploit the return from technology adoption.
Let $l = L, H$ denote a firm's home country (where it produces) and $h \neq l$ the foreign country. A low-technology exporter from country l charges $p_X^l = \frac{1}{2}\left(c_D^h + \tau c_i\right)$ abroad and a high-technology exporter $p_{XA}^l = \frac{1}{2}\left(c_D^h + \tau c_i - t\right)$. The respective profits in the foreign country h are then

$$\begin{aligned} \pi_X^l &= \frac{L}{4\gamma}\left(c_D^h - \tau c_i\right)^2 \\ \pi_{XA}^l &= \frac{L}{4\gamma}\left(c_D^h - \tau c_i + t\right)^2. \end{aligned} \tag{17}$$

Total profits are given by $\pi_T^l = \pi_D^l + \pi_X^l$ and $\pi_{TA}^l = \pi_{DA}^l + \pi_{XA}^l$. As in the home market, high-technology firms charge a lower price and realize higher profits in the foreign country than low-technology firms. Price, quantity sold and profits abroad depend on the entry

cutoff in the foreign country that is different from the entry cutoff in the home country. This is because the two countries differ along one dimesion: credit market development. The cost of purchasing/renting the more advanced technology is the same in both countries. In country H, however, credit constraints increase the cost of external finance and therefore the *total* costs of technology adoption.

3.1. Credit constraints

We assume that the fixed cost of purchasing/renting the more advanced technology is paid upfront and cannot be covered by future revenues. Internal funds are not sufficient to finance the investment and firms need to raise outside finance for a fraction d, $d \in (0,1)$, of the purchasing/renting cost f. We follow Rajan and Zingales (1998) in that the need for outside capital arises from technological reasons and is thus industry specific. The measure of external dependance d is thus the same for all firms within an industry.

For simplicity, we assume that firms in country L face a perfect capital market. Normalizing the outside option of creditors to zero, there are no additional costs of external finance, that is $f_L = f$[5]. Country H, on the other hand, has a less developed credit market. In particular, it lacks a market-oriented legal system (a set of legal rules and institutions that enforce these rules) that ensures the enforcement of contracts. Limited contract enforcement makes lending more risky: only firms which offer creditors enough securities obtain credit[6]. Following Manova (2010), we assume that creditors are repaid with some probability strictly lower than one. Hence, with positive probability the firm defaults. Creditors thus require a collateral that they can seize in case of default. We assume that the equipment financed out of the credit serves as collateral. In our framework, firms use credit to finance the investment in a more advanced production technology, for example in more sophisticated machinery. We proxy the investment in high-technology equipment by the additional net revenues from technology upgrading. Hence, the collateral is given by $C_i = \pi_{TA}^H(c_i) - \pi_T^H(c_i)$[7]. Note that C_i increases in firm productivity. More productive firms are larger and offer thus more collateral.

Creditors recover only a fraction θ, $\theta \in (0,1)$ of the collateral as they incur liquidation costs (e.g. Schnitzer, Buch, Kesternich, and Lipponer, 2009). The more advanced machinery is

[5]If creditors earn a world-market net interest rate r on their investment instead, technology adoption costs are $f_L = [1 + d(r-1)]f$ and the results qualitatively unchanged (cf. Manova, 2010).

[6]See Appendix for alternative microfundations for credit constraints.

[7]Investment theory tells us that the return to investment must be equal to the cost of equipment at the margin. Therefore, our assumption seems quite reasonable.

specific to the production of the respective variety and cannot be sold at the original price. Alternatively, creditors might need to invest time and effort in order to sell the equipment because they do not have sufficient knowledge of the industry.
Only firms which offer a high enough collateral to allow creditors to recover their money get credit:

$$\theta C_i = \theta \left[\pi_{TA}^H(c_i) - \pi_T^H(c_i)\right] = \theta \frac{Lt}{2\gamma} \left[c_D^L + c_D^H + t - (1+\tau)c_i\right] \geq df. \tag{18}$$

The most productive firms provide creditors with a large collateral and are not credit constrained. However, there is a range of firms that want to invest in technology upgrading but do not generate enough additional revenues to get credit. This can be seen from the technology adoption cutoff, that is the production cost of the marginal technology adopter, that directly follows from (18)

$$\frac{1}{1+\tau}\left(c_D^L + c_D^H + t - \frac{2\gamma}{Lt} f_H\right) = c_A, \tag{19}$$

where $f_H = \frac{d}{\theta} f$. As long as there is a strong dependence on external finance d (Rajan and Zingales (1998) report an external depence of close to one for several sectors) and some liquidation costs due to inefficient markets, the cutoff is lower: weak institutions reduce the fraction of high-technology firms in the economy[8].

3.2. Production, export, and technology decision

In addition to the production and technology adoption decision, firms in the open economy decide whether to serve the foreign market. Since the markets are segmented and production is at constant returns to scale, they independently maximize profits earned in each country.
Consistent with empirical evidence (e.g. Bernard, Jensen, Redding, and Schott, 2007), Melitz and Ottaviano (2008) show that in a non-specialized equilibrium in which both countries produce the differentiated good only a subset of domestic producers serves the foreign market. Moreover, only the more productive firms upgrade technology. The least productive firms are thus purely domestic producers which use the traditional technology. Hence, the

[8]An alternative approach to model weak creditor protection, with similar implications for our analysis, has been suggested by Aghion et al. (2005) and adopted by Chor, Foley, and Manova (2008). The idea here is that defaulting is costly and the more so the better financial instutions are.

production decision is the same as in autarky and given by

$$\pi_D^l(c_D^l) = 0 \Leftrightarrow c_D^l = p_{\max}^l = \frac{\gamma\alpha}{\gamma + \beta N^l} + \frac{\beta N^l}{\gamma + \beta N^l}\bar{p}^l. \tag{20}$$

Further, there are two possible selections: the marginal technology adopter is a purely domestic firm or an exporter.

The first case, which we call selection XI, results if technology adoption is relatively cheaper than exporting. The technology adoption cutoff is analogous to the one in autarky (11), that is all exporters use the advanced technology. However, it is now country specific as the two countries differ with respect to the technology adoption cost

$$c_A^l = c_D^l + \frac{t}{2} - \frac{2\gamma}{Lt} f_l, \tag{21}$$

where $f_L = f$ and $f_H = \frac{d}{\theta} f$ with $d > \theta$ by assumption.

The marginal exporter just breaks even on the foreign market:

$$\pi_{XA}^l(c_X^l) = 0 \Leftrightarrow c_X^l = \frac{c_D^h + t}{\tau}, \tag{22}$$

where c_X^l is the export cost cutoff in country l. Firms with marginal costs of production below c_X^l also serve the foreign market.

If exporting is relatively cheaper than technology adoption, the marginal innovator is an exporting firm (selection IX)[9]. The marginal exporter uses the traditional technology and has marginal costs of production equal to

$$\pi_X^l(c_X^l) = 0 \Leftrightarrow c_X^l = \frac{c_D^h}{\tau}. \tag{23}$$

There are now two conditions for technology upgrading. As in the closed economy case, *total* profits must be higher when using the advanced technology, that is firms must have an incentive to upgrade technology. This incentive constraint corresponds to the technology adoption cutoff in the country with a developed credit market and is given by

$$\pi_{TA}^l\left(c_A^l\right) \geq \pi_T^l\left(c_A^l\right) \Leftrightarrow c_A^L \leq \frac{1}{1+\tau}\left(c_D^L + c_D^H + t - \frac{2\gamma}{Lt} f\right). \tag{24}$$

[9]Selection XI and IX obtain if $f^l < \left(c_D^l - \frac{c_D^h}{\tau} - \frac{2-\tau}{2\tau} t\right) \frac{Lt}{2\gamma}$ and $(c_D^l + t - \frac{c_D^h}{\tau}) \frac{Lt}{2\gamma} < f^l < \left(c_D^l + c_D^h + t\right) \frac{Lt}{2\gamma}$.

Moreover, credit constraints restrict the access to external finance in country H: potential high-technology firms must be able to finance the investment. From (18), this financing constraint is

$$\theta C_i \geq df \Leftrightarrow c_A^H \leq \frac{1}{1+\tau}\left(c_D^L + c_D^H + t - \frac{2\gamma}{Lt}\frac{d}{\theta}f\right). \tag{25}$$

Comparing (24) and (25) reveals that the technology adoption cutoff is lower in the high-cost country[10]. Credit constraints thus prevent the firms with marginal cost $c_i \in [c_A^H, c_A^L)$ from technology upgrading. These are the firms that sell a large enough quantity to have an incentive to upgrade technology but are not large enough to get credit. A larger dependance on external finance (higher d) or higher liquidation costs (lower θ) increase the collateral required by creditors. Firms must then be larger, that is more productive, to get credit. This is reflected by a lower technology adoption cutoff c_A^H: the marginal high-technology firm is more productive and thus larger. As a consequence, the fraction of high-technology firms is lower.

As the marginal technology adopter in selection IX is an exporting firm, the upgrading decision is directly affected by trade liberalization. In selection XI, on the other hand, "opening up" to trade affects this decision only indirectly through its impact on domestic profits. Given the aim of the paper, we therefore focus on selection IX and assume that only the most productive firms adopt the advanced technology, that is $c_A^l < c_X^l < c_D^l$. Bustos (2010) lends empirical support to this assumption by showing that in a panel of Argentinean firms only the most productive exporters use advanced technologies.

3.3. Open economy equilibrium

Free entry into the industry ensures that ex-ante expected profits are zero in equilibrium: firms enter until ex-post expected profits correspond to the fixed entry costs. The free entry conditions for both countries, L and H, are

$$\begin{aligned}
&\frac{(c_D^L)^{k+2} + \tau^{-k}(c_D^H)^{k+2}}{k+2} + t(1+\tau)^{-k}(c_D^L + c_D^H + t - \frac{2\gamma}{Lt}f)^{k+1} - \frac{f_E 2\gamma c_M^k (k+1)}{L} \\
&\frac{(c_D^H)^{k+2} + \tau^{-k}(c_D^L)^{k+2}}{k+2} + t(1+\tau)^{-k}(c_D^L + c_D^H + t - \frac{2\gamma}{Lt}\frac{d}{\theta}f)^{k+1} - \frac{f_E 2\gamma c_M^k (k+1)}{L}.
\end{aligned} \tag{26}$$

Note that the free entry conditions are symmetric but for the total costs of technology adoption $f^L = f$ and $f^H = \frac{d}{\theta}f$. In the following, we call country L low-cost country and country H high-cost country.

[10] In Selection XI, the incentive and financing constraints coincide.

(26) is a system of two equations with two unknowns (c_D^L and c_D^H). Due to the nonlinearity of the equations, c_D^L and c_D^H cannot explicitly be solved for. It is however possible to represent the two equations in the (c_D^L, c_D^H) space (Fig. 2). The equilibrium entry cutoffs are given

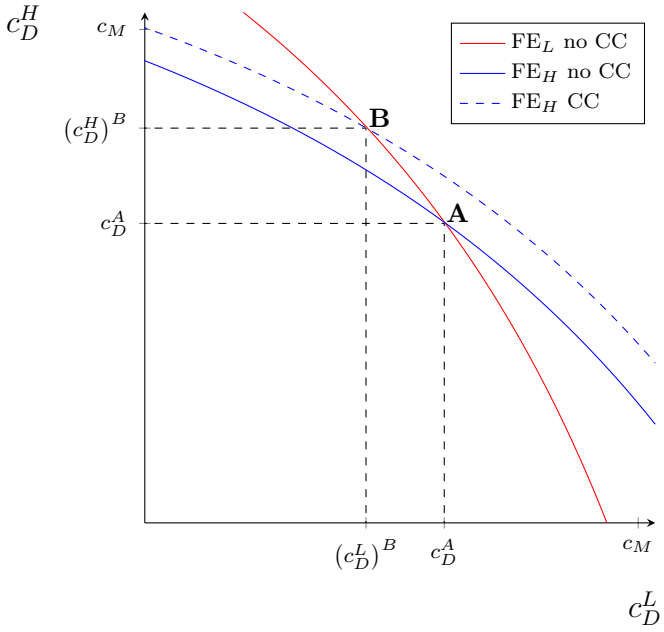


Figure 2: Open economy equilibrium

by the intersection of the two curves representing the free entry conditions. A denotes the symmetric equilibrium ($f^L = f^H = f$) and B the asymmetric equilibrium ($f^L \leq f^H$).
In the symmetric case, countries are identical and share the same entry cutoff which is given by $\left(c_D^L\right)^A = \left(c_D^H\right)^A = c_D^A$.
Higher total costs of technology adoption in country H, reflecting higher costs of external finance (higher d and/or lower θ), cause an outward shift of country H's free entry condition curve. For a given value of the entry cutoff in country L, c_D^L, the entry cutoff in country H, c_D^H, is now higher. Compared to the symmetric case, the resulting equilibrium entry cutoff is lower in country L and higher in country H, that is $\left(c_D^L\right)^B < c_D^A < \left(c_D^H\right)^B$. From (24) and (25) follows furthermore that the technology adoption cutoff and therefore the fraction of high-technology firms is higher in the low-cost country L. The intuition behind this result is as follows. Higher costs of external finance make technology upgrading in country H more expensive. Some exporters who use the advanced technology in the symmetric case now abstain from technology upgrading. Therefore, ex-post expected profits are lower leading to less entry, as reflected by a higher entry cutoff. Hence, the market in country H is less

competitive and consumers face a higher average price and less variety. The contrary holds for country L.

Proposition 2. *Suppose that $c_A < c_X < c_D$ and $f^L \leq f^H$. In the open economy, welfare, average productivity, and the fraction of high-technology firms are higher in the country with a developed credit market. The difference between the two countries increases in the severeness of credit constraints, i.e. in external financial dependance (higher d) and liquidation costs (lower θ).*

How does the open economy equilibrium compare to the closed economy equilibrium? In the open economy, the more productive firms choose to export. Serving the foreign market, in addition to the home market, increases total profits. The resulting higher expected profits induce more entry and lower the entry cutoff. From (16), welfare increases: compared to the closed economy, consumers benefit from a larger number of firms, that is of varieties, and from a lower average price due to higher average productivity.
There are two opposing effects on the incentive to upgrade technology. First, serving the foreign market increases sales abroad and thereby the benefit of using the advanced technology. This is the larger market or pro-technology adoption effect. In addition, exporting increases expected profits and, from above, the number of firms in the market. More competition reduces sales at home and and thus decreases the incentive to invest in technology upgrading. This is the import competition or anti-technology adoption effect. Note that while the pro-technology adoption effect is present in a scenario without entry, the anti-technology adoption effect works through entry and exit in general equilibrium.
The pro-technology adoption effect dominates and total output increases (if the total costs of technology adoption are not too large). Hence, in both countries more firms have an incentive to invest in technology upgrading. Moreover, as exporters become larger, more firms in country H offer creditors enough collateral to finance investment in technology adoption. Therefore, the fraction of high-technology firms increases in both countries in the open economy.
Moreover, we show that both welfare and technology adoption increase more in the low-cost country L[11].

Proposition 3. *Suppose that $c_A < c_X < c_D$ and $f^L \leq f^H$. In the open economy,*

[11] As explained in more detail in section (4.2), the reason is the Pareto distribution of production cost .

welfare, average productivity, and the fraction of high-technology firms are higher than in the closed economy.

4. Trade liberalization

In the following, we study the effect of trade liberalization through a decrease in trade barriers τ[12]. Before analyzing the asymmetric case, we consider the symmetric case as a benchmark. Here, we do not make any assumption about the level of credit constraints except that it is identical in both countries.

4.1. Benchmark: Symmetric countries

The impact of trade liberalization on the symmetric equilibrium is depicted in Fig. 3. A reduction in trading costs τ causes an inward shift of the free entry condition curves. For a given entry cutoff in the foreign country, the entry cutoff in the home country is now lower. The intersection of the two curves moves along the 45-degree line towards the origin. Hence, in the new equilibrium, both entry cutoffs are lower. From the free entry conditions in (26), lower trade barriers τ imply higher expected profits and therefore more entry and a lower entry cutoff. A reduction in trading costs lowers the delivered costs abroad and increases the foreign demand for imports. Exporters thus serve a larger market abroad and realize higher profits. However, import competition at home increases as lower trading costs simultaneously increase the competitiveness of foreign exporters. The least productive domestic producers start making losses and exit the market. This is the well-known selection effect pointed out by Melitz (2003): trade liberalization reallocates production to the most productive firms and therewith increases average productivity.
Differentiating the export cost cutoff (23) with respect to trade barriers τ, we obtain

$$\frac{dc_X}{d\tau} = \frac{1}{\tau}\left(\frac{dc_D}{d\tau} - \frac{c_D}{\tau}\right). \tag{27}$$

Trade liberalization has two opposing effects on the export cost cutoff given by the two terms in the brackets. Lower trade barriers allow the most productive domestic firms to start exporting (second term). On the other hand, liberalization increases competition abroad and makes it more difficult to profitably export (first term). It can be shown that the first

[12]This paper develops a static model. Trade liberalization is thus the comparative statics analysis of how a situation with high trade barriers compares to a situation with lower trade barriers. However, as in Melitz and Ottaviano (2008), the different situations can be interpreted as steady state equilibria.

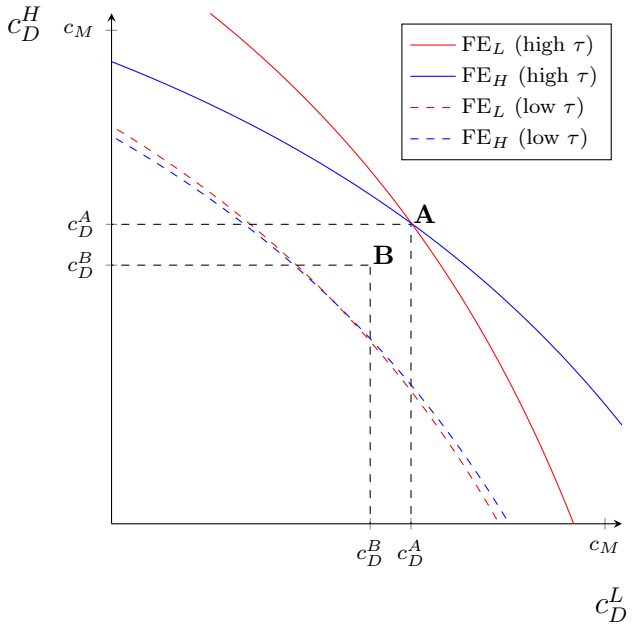


Figure 3: Trade liberalization: symmteric countries

effect dominates. Hence, as in standard heterogenous-firm trade models, the fraction of exporters increases after trade liberalization.

The novelty here is that we can also analyze the effect on the incentive to upgrade technology. From the expressions for the technology adoption cutoff (24) and (25), the impact of trade liberalization on technology upgrading is given by

$$\frac{dc_A}{d\tau} = \frac{1}{1+\tau}\left(2\frac{dc_D}{d\tau} - c_A\right). \tag{28}$$

A reduction in trade barriers increases the market abroad and induces the most productive low-technology firms to upgrade technology. This larger market effect is reflected by the second term in the brackets. From our analysis above, trade liberalization increases import competition and reduces market shares at home. The first term represents this anti-technology adoption effect. The net effect of lower trade barriers is pro-technology adoption if technology adoption is not too costly.

We summarize in

Proposition 4. *Suppose that $c_A < c_X < c_D$ and that countries are identical. A reduction in trade costs τ increases welfare, average productivity, and the fraction of exporters. Fur-*

thermore, the fraction of high-technology firms increases if technology adoption is not too costly.[13]

4.2. Asymmetric countries

How do the above results change if country H has a less developed credit market and therefore higher costs of external finance? Fig. 4 and Fig. 5 depict the new equilibrium.

A reduction in trade barriers still causes an inward shift of both free entry condition curves.

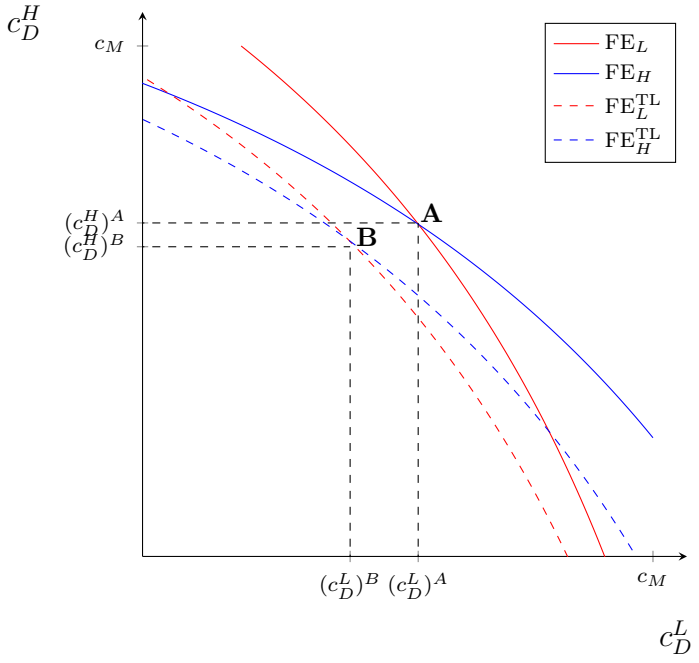


Figure 4: Trade liberalization: asymmteric countries and weak credit constraints

However, in contrast to the symmetric case, the entry cutoff in the high-cost country H decreases less (Fig. 4) and even increases if external finance is very costly (Fig. 5). In the first case, we speak of "weak" credit constraints and in the second of "severe" credit constraints. The entry cutoff in the low-cost country L, on the other hand, unambigously decreases and the more so the stronger the credit constraints in the high-cost country are. Hence, because of costly external finance, welfare increases less in the high-cost country. In other words, the welfare gap between the two countries widens. This divergence is stronger

[13]In selection XI, the marginal technology adopter is a purely domestic firm. As trade liberalization reduces domestic production, only the anti-technology adoption effect is at work and the fraction of high-technology firms unambigously decreases.

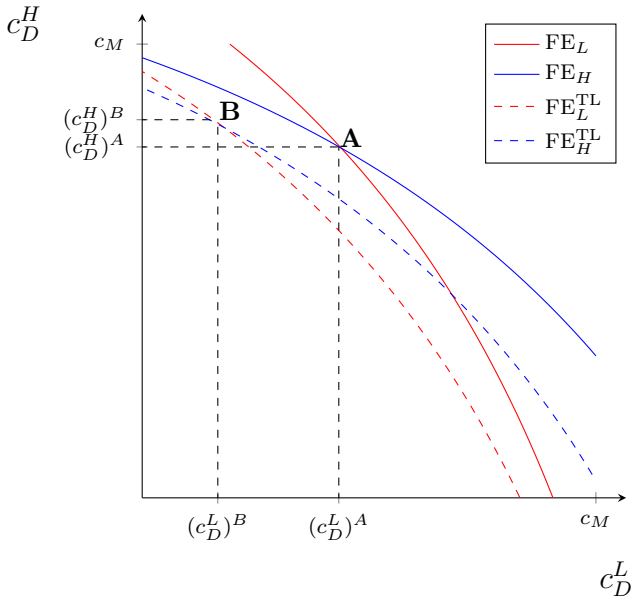


Figure 5: Trade liberalization: asymmteric countries and severe credit constraints

the more costly external finance in the high-cost country is. This is the central result of our analysis. The intuition is the following: as will be shown below, the number of new exporters and high-technology firms is higher in the low-cost country. Hence, ex-post expected profits increase more after trade liberalization: more entry leads to a larger increase in competition and thus in welfare.

Higher costs of external finance prevent a range of exporters (those with production cost $c_i \in [c_A^H, c_A^H)$) in country H from adopting the advanced technology. The average exporter from country H is thus less efficient. Put differently, firms from L are thus relatively more competitive in H than firms from H in L, that is the fraction of exporters is higher in the low-cost country L, $c_X^L = \frac{c_D^H}{\tau} \geq c_X^H = \frac{c_D^L}{\tau}$. The effect of trade liberalization on the export cost cutoff is positive and given by

$$\frac{dc_X^l}{d\tau} = \frac{1}{\tau}\left(\frac{dc_D^h}{d\tau} - \frac{c_D^h}{\tau}\right) < 0. \tag{29}$$

From the free entry conditions (26), the initial level of competition is lower in the high-cost country: $c_D^H \geq c_D^L$. Moreover, our analysis above showed that the increase in the level of competition is also lower in country H, that is $\frac{dc_D^L}{d\tau} \geq \frac{dc_D^H}{d\tau}$. In the high-cost country, the pro-exporting effect (second term) is thus weaker and the anti-exporting effect (first term)

is stronger. Hence, the export cost cutoff, that is the fraction of exporters, increases more in the low-cost country. The reason is the Pareto distribution of production costs that has a high mass of firms at high cost levels: a higher export cutoff implies a larger number of firms that start exporting after (an increase in sales abroad due to) trade liberalization. Hence, in the low-cost coutry, more firms can take advantage of the larger market.
Analogous to (28) the effect on the technology adoption cutoff is

$$\frac{dc_A^l}{d\tau} = \frac{1}{1+\tau}\left(\frac{dc_D^L}{d\tau} + \frac{dc_D^H}{d\tau} - c_A^l\right) \gtrless 0. \tag{30}$$

The first term in the brackets gives again the import competition or anti-technology adoption effect and the second term the larger market or pro-technology adoption effect. From above, the larger market effect is stronger in the low-cost country. More formally, note that the pro-technology adoption effect increases in the technology adoption cutoff c_A and the anti-technology adoption effect decreases in the entry cutoffs c_D^L and c_D^H. Hence, the strength of the two effects depend on the initial (before trade liberalization) level of these cutoffs. This is also due to the assumption of Pareto distributed production costs: a higher technology adoption cutoff implies a larger number of firms that start using the new technology after trade liberalization. The same argumentation applies to the anti-technology adoption effect: for a given increase in ex-post expected profits, the entry cutoff c_D has to decrease more the lower it initially is in order to satisfy the free entry condition. Here, the anti-technology adoption effect is the same for both countries. The pro-technology adoption effect, on the other hand, is stronger in the low-cost country as low costs of external finance imply a higher initial technology adoption cutoff. The net effect on the technology adoption cutoff is ambiguous and depends on the level of total technology adoption costs. Eq. (30) is, however, unambigously smaller for country L, that is technology upgrading increases more in the low-cost country if the net effect is pro-technology adoption and increases less if it is anti-technology adoption.
We summarize in:

Proposition 5. *Suppose that $c_A < c_X < c_D$ and $f_L \leq f_H$. A reduction in trade costs τ increases welfare in the country with a developed credit market whereas the effect is ambiguous in the less developed country. Moreover, divergence between the two countries increases and the more so the stronger the credit constraints, i.e. the higher the dependance on external finance (higher d) and the liquidation costs (lower θ).*

5. Comparative statics

In the following, we parameterize the model to (i) illustrate the impact of trade liberalization on technology upgrading and welfare and to (ii) perform simulations in order to derive comparative statics.

5.1. Parameterization

The parameters representing trade costs (τ), industry cost effectiveness (k), technological leap (t) and product differentiation (γ) are taken from empirical studies and calibrations to connect the model to real data (see below). We allow for $\tau \in [1.05, 1.35]$ as this reduction of 30% corresponds to the typical reduction in trade costs in industries most affected by trade liberalization (Costantini and Melitz, 2008). Del Gatto et al. (2006) estimate $k = 2$ across 18 industries in 11 Western European countries. In line with Bernard, Eaton, Jensen, and Kortum (2003), Kristian Behrens and Ottaviano (2007) calibrate $k = 3.6$. Balistreri et al. (2008), obtain $k = 4.5$ by dividing the world in 12 regions. We consider $k = \{2, 3.6, 4.5, 6\}$ to examine how higher average cost affect the impact of trade liberalization on technology upgrading. Following Costantini and Melitz (2008), the return to technology upgrading, the technological leap, is set to 10% of average productivity. Finally, Ottaviano et al. (2009) estimate the degree of product differentiation in 12 industries using data on 12 EU countries for the years 2001-2003. Calculating the average across all industries, we use $\gamma = 0.25$.
Entry costs (f_E), the upper bound on marginal costs (c_M) and market size (L) are scale parameters that are chosen to be in line with our assumption about the cutoff ranking, namely

$$0 < c_A < c_X < c_D < c_M. \tag{31}$$

The range of parameter values for the total costs of technology adoption (f^l, f^h) is selected to satisfy (31) and to allow for a large enough cost difference between the two countries. A larger dependance on external finance (d) and higher liquidation costs (lower θ) are captured by a higher f^l and f^h respectively. In particular, $f_E = 10; c_M = 10; L = 1; f^l, f^h \in [10, 20]$. Our preferred specification ("basic specification") is given by

- $\tau = 1.1$
- $k = 3.6$
- $t = 0.75 \equiv 10\%$ of average productivity
- $\gamma = 0.25$

5.2. Impact of trade liberalization: How does it depend on credit constraints?

The basic specification is used to illustrate the impact of trade liberalization on technology upgrading and welfare. Fig. 6 shows the impact of a marginal reduction in trade

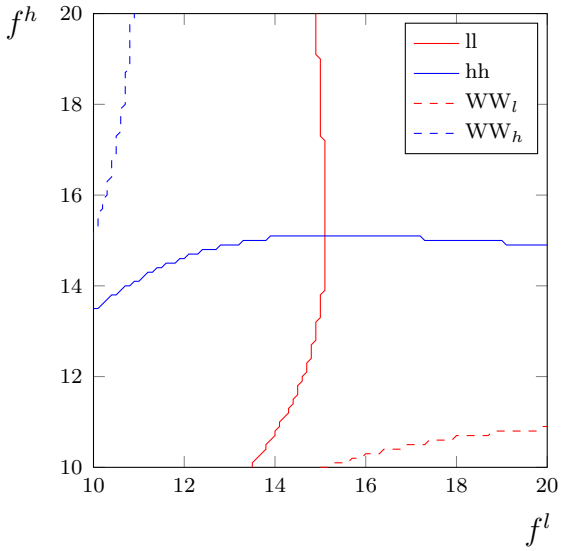


Figure 6: Illustration: Impact of trade liberalization on technology adoption and welfare

costs on technology upgrading ($\frac{dc_A}{d\tau}$) and welfare ($\frac{dc_D}{d\tau}$) for different combinations of total technology adoption costs (f^l, f^h). The ll-line represents cost combinations for which "opening up" to trade has no effect on technology upgrading in country l. Technology upgrading decreases for cost combinations on the right-hand side and increases for combinations on the left-hand side. Analogously, the hh-line represents cost combinations for which technology upgrading is unchanged in country h. Technology upgrading in country h decreases for cost combinations above the hh-line and increases for combinations below the hh-line. The two lines divide the (f^l, f^h)-space in four areas. Technology upgrading, that is the fraction of high-technology firms, increases (i) in both countries if f^l, f^h are both low (lower-left area), (ii) only in the low-cost country if the cost difference is large (upper-left area and lower-right area) and (iii) in neither country if f^l, f^h are both high (upper-right area).

Larger credit constraints in one country, as reflected by a higher d or a lower θ, shift the respective line inwards and reduce the area for which technology adoption increases in that country.

The WW-lines represent cost combinations for which welfare is unchanged after trade liberalization: welfare decreases in country l (country h) for cost combinations below the

WW_l-line (on the left-hand side of the WW_h-line). Following our previous analyis, welfare decreases in the high-cost country if the difference in technology adoption costs and thus in competitiveness between the two countries is large.

5.3. Comparative statics analysis: Do more credit constrained conuntries gain or lose?

This section examines how changes in parameters (τ, k, t, γ) affect the impact of trade liberalization on technology adoption and welfare in more credit constrained countries.

5.3.1. Change in the trade costs parameter τ

Fig. (C.7) shows how the impact of trade liberalization changes if countries are initially more closed. Higher (initial) trade barriers shift the *ll*-line and the *hh*-line outwards and thus increase the area of cost combinations for which technology adoption increases. Hence, technology adoption increases also in countries with a less developed credit market if these are initially more closed. The impact on welfare is analogous. Higher initial trade barriers shift the WW-lines outwards: if countries are initially more integrated, welfare in the high-cost country increases also if the difference in total technology adoption costs is larger. For $\tau > 1.1$, welfare increases for every level of f^l, f^h.
Higher initial trade barriers imply a lower initial level of competition in both countries. Because of Pareto distributed production cost, the increase in import competition after trade liberalization is thus also lower (see section (4.2)). Put differently, high-cost countries with severe credit constraints now face less import competition and start to gain from liberalizing trade. Moreover, while higher initial trade barriers reduce sales abroad, lower import competition increases sales at home and also total sales. Therefore, the fraction of high-technology firms increases now also in less developed countries with stronger credit constraints.

5.3.2. Change in the cost effectiveness parameter k

k determines the shape of the distribution of production cost. A higher k implies more mass at higher cost levels and therefore higher average cost of production. The effect of a higher k on the impact of trade liberalization is shown in Fig. (C.8). Higher average costs of production lead to an outward shift of the *ll*- and the *hh*-lines. The WW-lines also shift outwards. For $k > 3.6$, welfare increases for every level of f^l, f^h. Welfare and technology adoption increase now also in less developed countries with higher costs of technology adoption. The reason is the following: higher average costs of production imply lower expected profits and thus less entry and a lower initial level of competition. Hence, less developed

countries face now less import competition after trade liberalization and gain from trade (see above).

5.3.3. Change in the return to innovation parameter t

t represents the return to technology upgrading: spending a given amount f^l, f^h decreases production cost by t. In the comparative statics exercise, we consider $t \in [0.5, 1] \equiv [5\%, 20\%]$ of average productivity (Fig. (C.9)). A higher return to technology adoption leads to an outward shift of the ll- and the hh-lines. In addition, these lines are increasingly curved. The WW-lines shift inwards. As the return to technology adoption becomes larger, trade liberalization increases technology adoption also in countries with less developed credit markets. However, if t is large ($t > 0.65$), technology adoption and welfare increase only if the difference in the total costs of technology adoption between the two countries is not large.

A higher return to technology adoption makes technology upgrading profitable for a larger range of firms and leads to a higher fraction of high-technology firms. The resulting higher aggregate productivity increases welfare through increased competition. However, from above, a higher initial level of competition implies a larger increase in import competition after trade liberalization. Increased import competition does not reduce technology adoption and welfare if the difference in development, and thereby in competitiveness, is small. In this case, both countries are able to take advantage of the larger market. However, if firms in the high-cost country are severely credit constrained, increased import competition prevents firms from technology upgrading and even reduces welfare.

5.3.4. Change in the product differentiation parameter γ

A lower γ implies less product differentiation. We allow for $\gamma \in [0.1, 0.4]$ in the comparative statics analysis. For any other value of γ the constraint (31) is no longer satisfied. The effect of a decrease in product differentiation is similar to the effect of an increase in the return to technology adoption t (Fig. (C.10)). In a less differentiated industry, technology adoption and welfare increase also in less developed countries. However, as varieties become more and more substitutable, technology adoption and welfare decrease if the cost difference between the two countries is large.

Less differentiation increases the price elasticity of demand. Firms, which behave as (local) monopolists, thus choose to set lower prices and produce more. Hence the scale of production increases and therefore also technology upgrading. The resulting higher average efficiency increases welfare and the intensity of competition. From above follows that more intense

competition increases import competition and theferore welfare in countries with large costs of external finance.

Proposition 6. *Trade liberalization increases technology adoption and welfare also in countries with higher costs of external finance if (i) the countries are initially more closed, (ii) average costs in the industry are higher, (iii) the return to technology adoption is higher and countries are not too different, (iv) the industry is less differentiated and countries are not too different.*

6. Conclusion

Even though recommended to many developing countries, "opening up" to trade enhances economic performance only if certain conditions are met. This paper examines the role of credit market imperfections as a reason for a potentially detrimental effect of trade liberalization on economic welfare. In particular, we introduce the possibility to invest in a more efficient technology into a two-country heterogeneous-firm model with variable mark-ups. The two countries differ with respect to credit market development: in the less developed country, firms face credit constraints and therefore higher costs of technology upgrading. As a consequence, average productivity is lower than in the more developed country. A reduction in trading costs then causes only a small increase in the fraction of exporters but a large increase in number of foreign competitors. In other words, credit constrained firms cannot take advantage of the larger market but face increased import competition and a drop in overall demand. Therefore, investment in advanced technology decreases. If credit constraints are severe, aggregate productivity and welfare even decrease after trade liberalization. The contrary holds for the developed country: a less competitive trading partner implies a larger market abroad and less import competition at home. The fraction of high-technology firms and welfare thus unambiguously increase after a reduction in trade barriers. Hence, a necessary condition for "opening up" to foster economic convergence is that firms have sufficient access to external finance. Once, there was a functioning banking sector (mainly through the entry of foreign banks) at the end of the 1990s, the economic performance of the Eastern European countries improved and the income gap to the Western neighbors started to close (Svejnar, 2002).

References

Aghion, P., Howitt, P., Mayer-Foulkes, D., 2005. The Effect of Financial Development on Convergence: Theory and Evidence. Quarterly Journal of Economics 120 (1), 173–222.

Atkeson, A., Burstein, A., 2010. Innovation, Firm dynamics, and International Trade. Journal of Political Economy 118 (3), 433–484.

Axtell, R., 2001. Zipf distribution of US firm sizes. Science 293, 1818–1820.

Balat, J., Porto, G., 2007. Globalization and Complementary Policies: Poverty Impacts in Rural Zambia. Balat, J. and Porto, G.

Bellone, F., Musso, P., Nesta, L., Schiavo, S., 2010. Financial Constraints and Firm Export Behaviour. World Economy 33 (3), 347–373.

Bernard, A., Eaton, J., Jensen, J., Kortum, S., 2003. Plants and Productivity in International Trade. The American Economic Review 93 (4), 1268–1290.

Bernard, A., Jensen, J., Redding, S., Schott, P., 2007. Firms in International Trade. The Journal of Economic Perspectives 21 (3), 105–130.

Bustos, P., 2010. Trade Liberalization, Exports and Technology Upgrading: Evidence on the Impact of MERCOSUR on Argentinean Firms. American Economic Review forthcoming.

Chaney, T., 2005. Liquidity Constrained Exporters. University of Chicago, mimeo.

Chor, D., Foley, C., Manova, K., 2008. Host Country Financial Development and MNC Activity. Stanford University, Singapore Management University, HBS, mimeo.

Costantini, J., Melitz, M., 2008. The Dynamics of Firm-Level Adjustment to Trade Liberalization. The Organization of Firms in a Global Economy, Harvard University Press, Cambridge.

Del Gatto, M., Ottaviano, G., Mion, G., 2006. Trade Integration, Firm Selection and the Costs of Non-Europe. CEPR Discussion Paper No. 5730.

Feenstra, R., Weinstein, D., 2010. Globalization, Markups, and the US Price Level. NBER Working Paper No. 15749.

Gorodnichenko, Y., Schnitzer, M., 2010. Financial Constraints and Innovation: Why Poor Countries Don't Catch Up. NBER Working Paper No. 15792.

Greenaway, D., Guariglia, A., Kneller, R., 2007. Financial Factors and Exporting Decisions. Journal of International Economics 73 (2), 377–395.

Hajivassiliou, V., Savignac, F., 2007. Financing Constraints and a Firm's Decision and Ability to Innovate: Establishing Direct and Reverse Effects. London School of Economics Discussion Paper No. 594.

Hall, B., Lerner, J., 2009. The Financing of R&D and Innovation. NBER Working Paper.

Helpman, E., Melitz, M., Yeaple, S., 2004. Export versus FDI with Heterogeneous Firms. American Economic Review 94 (1), 300–316.

Holmstrom, B., Tirole, J., 1997. Financial Intermediation, Loanable Funds, and The Real Sector*. Quarterly Journal of Economics 112 (3), 663–691.

Kristian Behrens, C., Ottaviano, G., 2007. Industry Reallocation in a Globalizing Economy. CEPR Discussion Paper No. 6049.

Levine, R., 2005. Finance and growth: Theory and evidence. In: Aghion, P., Durlauf, S. (Eds.), Handbook of Economic Growth. Elsevier, Ch. 12, pp. 865–934.

Manova, K., 2010. Credit Constraints, Heterogeneous Firms, and International Trade. Stanford University, mimeo.

Melitz, M., 2003. The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity. Econometrica 71 (6), 1695–1725.

Melitz, M., Ottaviano, G., 2008. Market Size, Trade, and Productivity. Review of Economic Studies 75 (1), 295–316.

Navas-Ruiz, A., Sala, D., 2007. Technology Adoption and the Selection Effect of Trade. EUI Working Papers ECO 2007/58.

Ottaviano, G., Tabuchi, T., Thisse, J.-F., 2002. Agglomeration and Trade Revisited. International Economic Review 43 (2), 409–435.

Ottaviano, G., Taglioni, D., Di Mauro, F., 2009. The Euro and the Competitiveness of European Firms. Economic Policy 24 (57), 5–53.

Peter, K., Svejnar, J., Terrell, K., 2009. Foreign Investment, Corporate Ownership, and Development: Are Firms in Emerging Markets Catching Up to the World Standard? IZA Discussion Paper No. 1457.

Rajan, R., Zingales, L., 1998. Financial Dependence and Growth. American Economic Review 88 (3), 559–586.

Rodrik, D., 2006. Goodbye Washington Consensus, Hello Washington Confusion? A Review of the World Bank's "Economic Growth in the 1990s: Learning from a Decade of Reform". Journal of Economic Literature 44 (4), 973–987.

Schnitzer, M., Buch, C., Kesternich, I., Lipponer, A., 2009. Financial Constraints and the Margins of FDI. CEPR Discussion Papers No. 7444.

Svejnar, J., 2002. Transition Economies: Performance and Challenges. The Journal of Economic Perspectives 16 (1), 3–28.

Tybout, J., 2003. Plant-and Firm-Level Evidence on "New" Trade Theories. Handbook of International Trade 1, 388–415.

Unel, B., 2010. The Interaction Between Technology Adoption and Trade When Firms are Heterogeneous. Louisiana State University, mimeo.

World Bank, T., 2005. Economic Growth in the 1990s: Learning from a Decade of Reform.

Appendix A. Alternative microfoundations for credit constraints

Appendix A.0.5. High monitoring costs

Financial intermediaries screen credit applicants in order to avoid financing risky projects. Once the credit has been granted, close monitoring ensures that the firm adheres to the covenants specified in the contract. In developed credit markets, reporting rules reduce screening costs. Furthermore, skilled employees and long-term relationships between creditors and firms imply low monitoring costs. In emerging markets, however, disclosure requirements are low and often not properly enforced. Moreover, banks are young and do not have much monitoring capital. Therefore, screening and monitoring costs are high leading to high costs of external finance.

Following Holmstrom and Tirole (1997), we model monitoring costs m as being proportional to the amount of credit granted: $m = \mu df$, $\mu > 0$. In developed credit markets, operating costs of financial intermediaries are low and μ is close to zero. As outlined above, information costs are higher in emerging countries: this is reflected by a higher μ. Assuming that creditors operate under perfect competition, the required repayment just covers expenditures

$$F = df + m = (1 + \mu)df.$$

Total costs oftechnology adoption

$$f^H = (1 - d)f + (1 + \mu)df = (1 + \mu d)f \tag{A.1}$$

then imply a lower technology adoption cutoff

$$\frac{1}{1+\tau}\left[c_D^L + c_D^H + t - \frac{2\gamma}{Lt} f_H\right] = c_A, \tag{A.2}$$

where $f_H = (1 + \mu d)f$. Hence, financial intermediaries in developing credit markets require more monitoring capital and pass the resulting higher monitoring costs on to firms. Higher costs of external finance prevent a range of potential technology adopters from investing in high-technology equipment.

Appendix A.0.6. Pricing above marginal costs

A standard argument put forward to explain high lending rates in emerging economies in insufficient competition. Often, as for example in the case of the Eastern European countries or China, the credit market consists only of a small number of banks. Moreover, these are

often dependent on political power and tend to favor state-owned firms by charging higher lending rates to private firms.
If creditors source funds from an international capital market at some rate that we normalize to one, the costs of external finance are given by

$$f^H = (1-d)f + (1+r)df = (1+rd)f, \tag{A.3}$$

where r is the mark-up over marginal costs and thus an indicator of the market power of creditors. Higher costs of external finance lower the technology adoption cutoff, that is the fraction of high-technology firms in the economy.

Appendix B. Proofs

to be completed

Appendix C. Tables

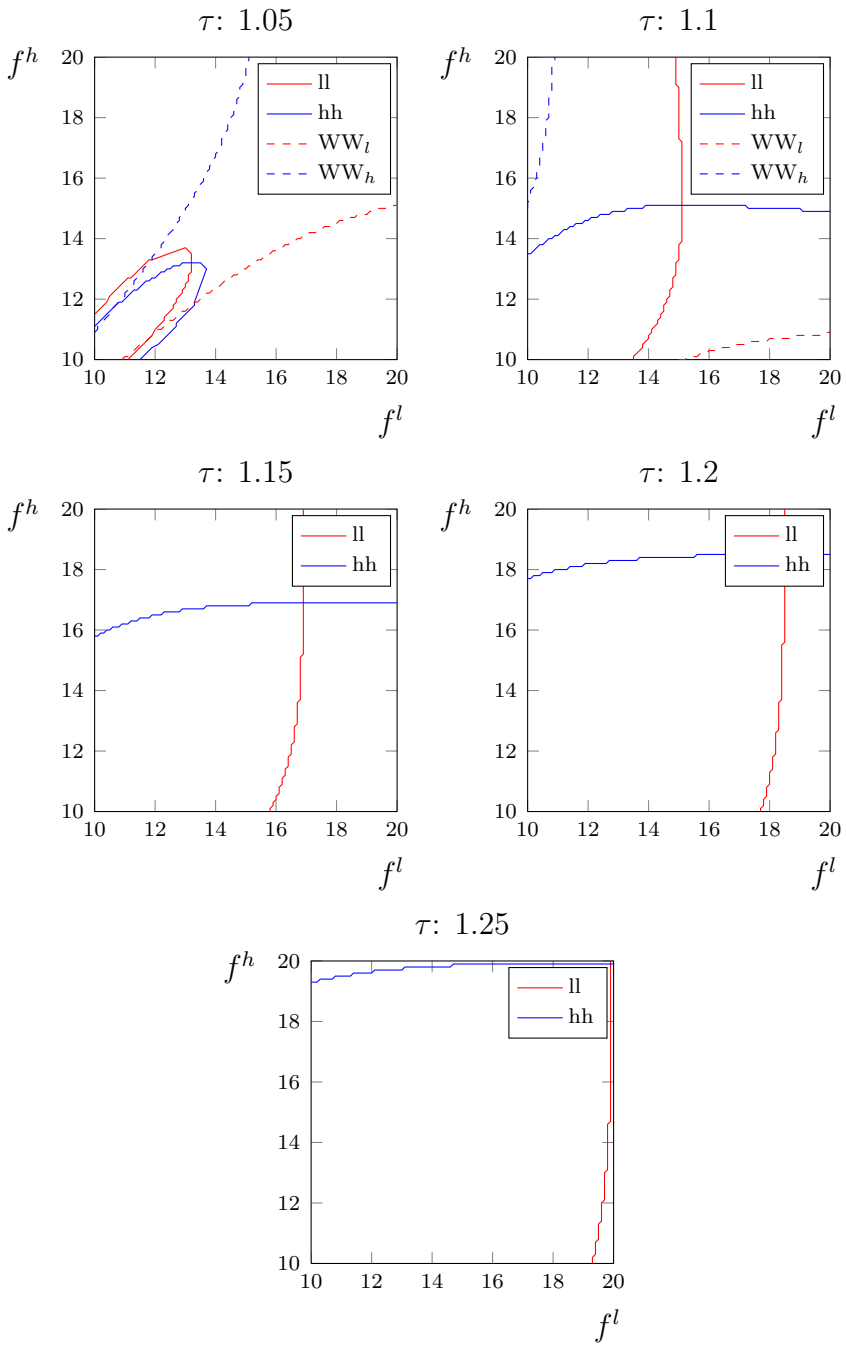


Figure C.7: Comparative statics: Trade barriers τ

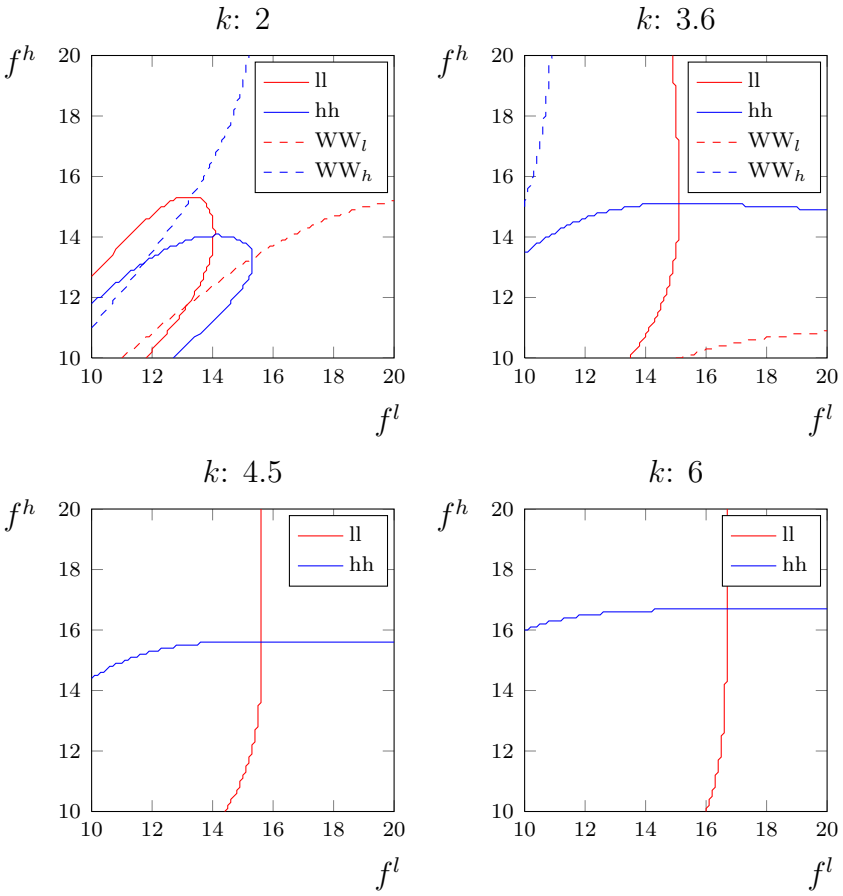


Figure C.8: Comparative statics: Cost effectiveness k

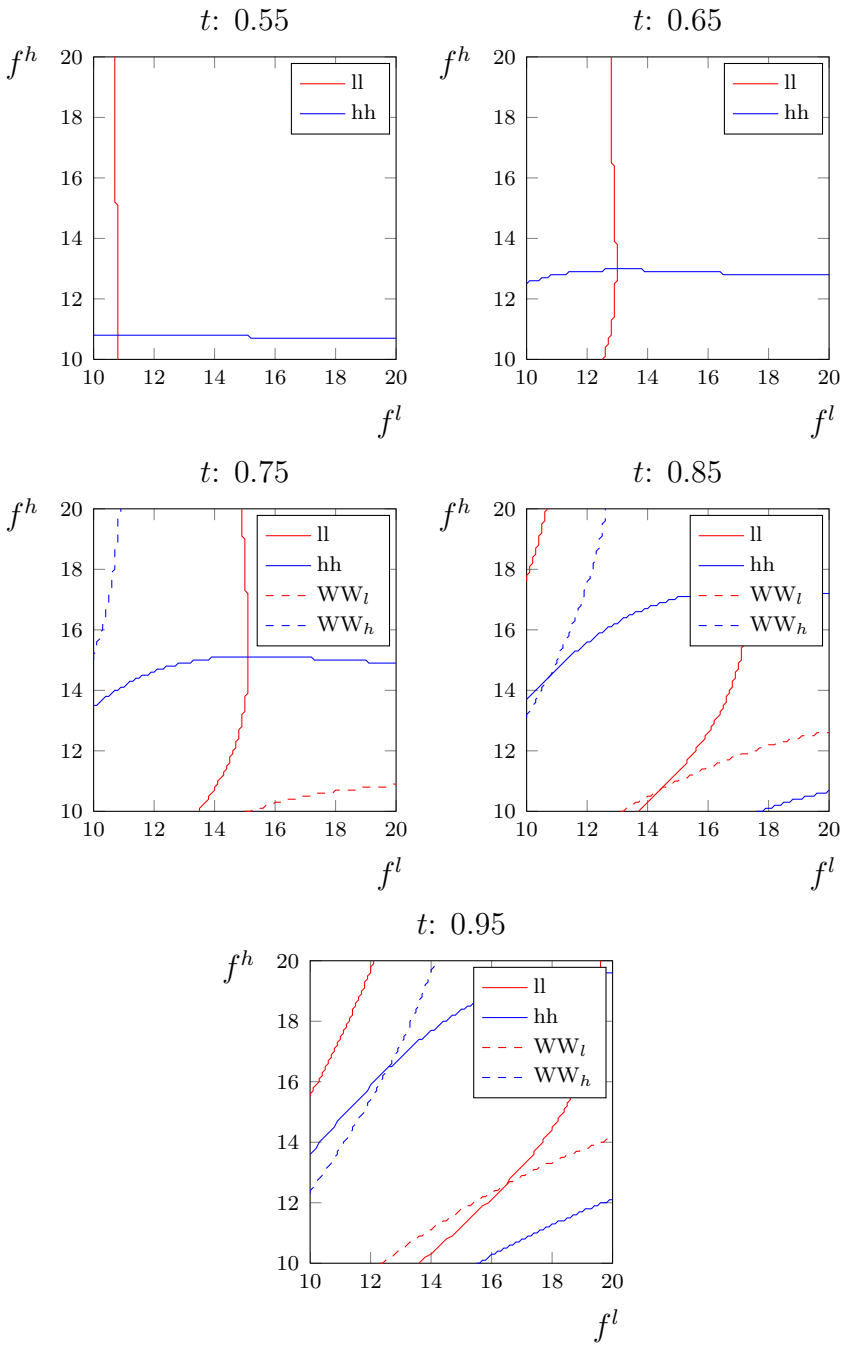


Figure C.9: Comparative statics: Technological leap t

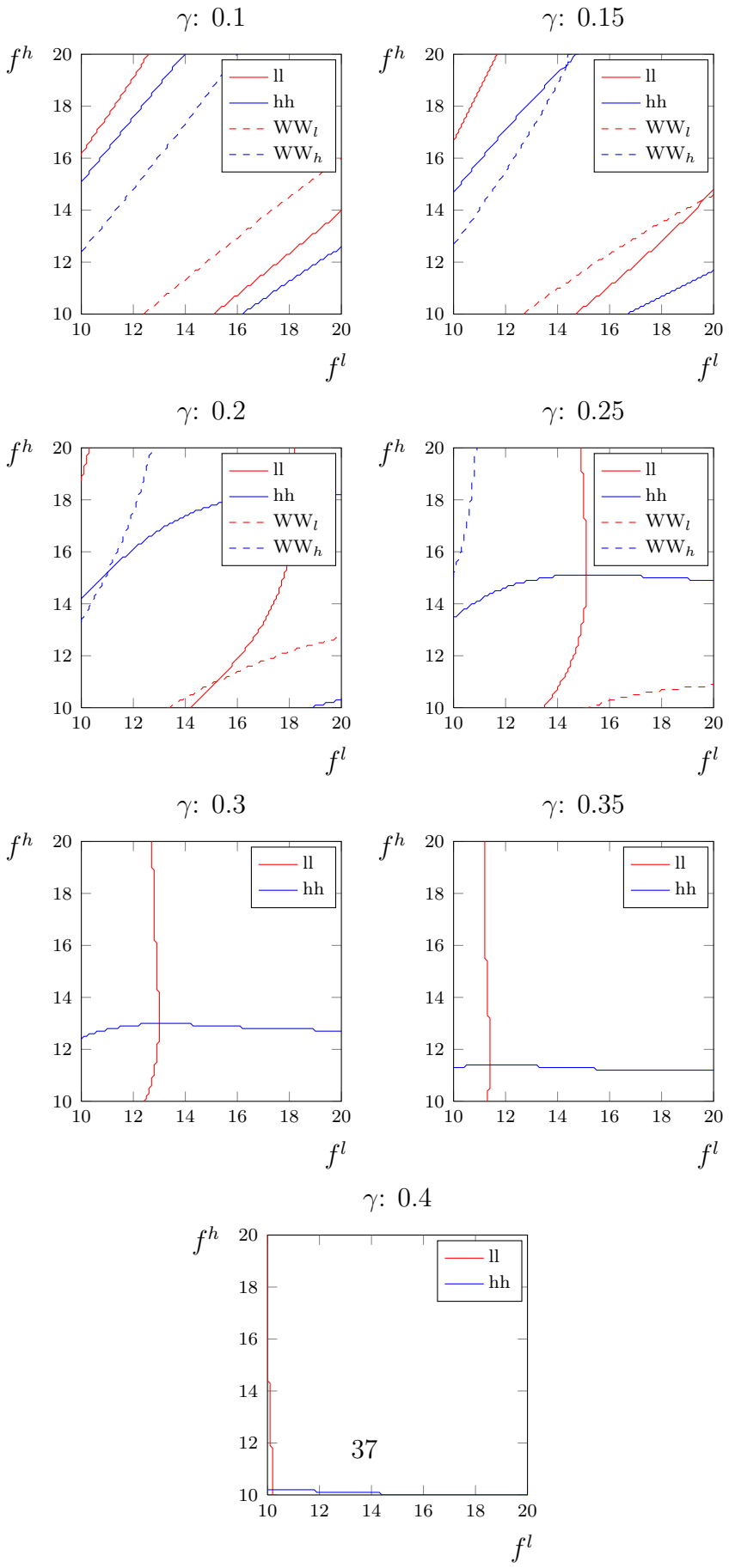


Figure C.10: Comparative statics: Product differentiation γ