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 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 demand at home because of import competition (anti-technology adoption effect). If firms in the emerging country are credit constrained, technology adoption may increase in the developed country only. 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
JEL: F1, O33, O16, G3

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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). "Opening up" to trade increases the market size for exporters. Furthermore, incoming foreign firms foster competition and contribute to a more efficient allocation of resources across firms. 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 is accompagnied by complementary policies like the provision of infrastructure, credit, and extension services.

This paper explores one channel through which trade liberalization might impede convergence between countries: credit constraints. We develop a heterogeneous-firm model of international trade where firms decide whether to invest in a more efficient production technology. In particular, we introduce technology adoption into the Melitz and Ottaviano (2008) framework. A fraction of the cost of purchasing/renting the advanced technology has to be financed externally. Therefore, the technology adoption decision is related to credit market development. We then analyze the effect of trade liberalization on technology adoption and on welfare in a two-country setting where the two countries potentially differ with respect to credit market development. We find that if both countries have a developed credit market, the fraction of firms adopting the advanced technology increases. Technology upgrading and the selection effect of trade lead to higher average productivity and welfare. Furthermore, we show that if firms in one country face credit constraints, technology adoption in this country decreases after trade liberalization. Therefore, the welfare increase in the country with a less developed credit market is lower and welfare might even decrease if credit constraints are severe.

The reason is the following: in less developed credit markets, access to external finance is more costly. These costs of external finance are likely to decrease in firm size. Thus, technology adoption is more expensive for smaller firms and as a consequence they are less willing to invest in more efficient technologies. Therefore, firms in the country with a less developed credit market 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 aggregate investment in more advanced technologies. When credit constraints are severe, aggregate productivity and therefore welfare decrease.

In a second step, we parameterize the model for a comparative statics exercise. We find a positive effect of higher initial trade barriers and higher average costs of production: "opening up" to trade increases technology adoption and welfare also in countries with a less developed credit market if these are initially more closed or firms have higher average costs. Moreover, a larger return to technology upgrading and a lower degree of product differentiation have a positive effect on technology adoption. The effect on welfare on the other hand is negative: trade liberalization decreases welfare also in countries with a more developed credit market if the return to technology adoption is larger or the industry is less differentiated.

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 that reduces the average markup. This is consistent with empirical evidence (e.g. Feenstra and Weinstein, 2010, Tybout, 2003).

Our analysis builds on and contributes to several strands of literature. First, it is related to previous research that examines the impact of trade liberalization when firms have the option to invest in a more efficient production technology. Bustos (2010) and Navas-Ruiz and Sala (2007) introduce an endogenous technology adoption decision into a Melitz (2003) framework with symmetric countries. Both papers show that technology adoption increases after trade liberalization leading to an increase in average productivity, in addition to the selection effect of trade. Unel (2010) extends Bustos (2010) and Navas-Ruiz and Sala (2007) to asymmetric countries that differ with respect to technology adoption costs. He finds that trade liberalization can hurt the country where technology adoption is more expensive.

In contrast to these papers, we explicitly consider firms to be financially constrained when financing technology adoption. Furthermore, we allow these financial constraints to depend endogenously on firm size. Finally, we use a Melitz and Ottaviano (2008) type framework with endogenous mark-ups. This leads to different predictions. While Unel (2010) finds for example that the effect of trade liberalization on exporting and technology adoption always works in the same direction, we find that the fraction of high-technology firms may decrease although revenues from exporting increase. The reason is the import competition effect of trade liberalization that is absent in the Melitz (2003) model. Furthermore, we find that for a given level of competition heterogeneous costs of technology adoption lead to less but more efficient technology adopters in equilibrium. Finally, we we can derive comparative statics results for the effect of trade liberalization on technology adoption and welfare.

The second strand of literature documents the negative impact of financial constraints on firms' ability to invest in innovation. 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).

The third strand of literature analyzes the dynamic interaction between exporting and innovation. Atkeson and Burstein (2010) develop a dynamic model with two symmetric countries where heterogeneous firms decide about production, exporting and process innovation. They find that the effect of trade liberalization on welfare when firms are heterogeneous is the same as in the earlier homogeneous-firm literature. In our model, on the other hand, firm heterogeneity has an impact on the welfare implication of trade: if firms were homogeneous, all firms or no firm would invest in technology upgrading leading to a higher or lower increase in welfare. Costantini and Melitz (2008) show that the adoption of new technologies is more likely to occur after trade liberalization. Like Atkeson and Burstein (2010), they do not consider credit market imperfections.

Finally, our paper is related to Gorodnichenko and Schnitzer (2010) who analyze the effect of financial constraints on the relation between exporting and innovation using BEEPS data. They argue that exporting and technology adoption are natural complements because exporting increases the market size and hence stimulates investment in advanced technologies while more effcient production technologies on the other hand increase firms' competitiveness abroad. However, when internal funds are limited and external finance is costly, they find that engaging in one activity increases the costs of financing the other, and hence that the joint observation of both exporting and innovation becomes less likely. In our model, exporting and technology adoption are also complementary activities if firms do not face credit constraints. Furthermore, costly external finance reduces exporting and thus technology adoption after trade liberalization.

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. Utility maximization is with respect to the budget constraint $I^c = \int_{i\in\Omega'} p_i q_i^c + q_0^c$ where I^c is consumer's income. $\Omega' \subset \Omega$ 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 labor 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 laborThe technology adoption cost f can be thought of as a per-period fixed cost 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 $p_i, \mu_i, q_i, r_i, \pi_i$ and $p_i^A, \mu_i^A, q_i^A, r_i^A, \pi_i^A$ denote price, mark-up, quantity, revenues and profits when using the traditional and the advanced technology respectively. Profit maximization implies the following price and mark-up rules:

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

The corresponding quantities are given by

$$\begin{aligned} q_i &= \frac{L}{4\gamma}\left(p_{\max} - c_i\right), \quad q_i^A = \frac{L}{4\gamma}\left(p_{\max} - c_i + t\right) \\ r_i &= \frac{L}{4\gamma}\left(p_{\max}^2 - c_i^2\right), \quad r_i^A = \frac{L}{4\gamma}\left[p_{\max}^2 - (c_i - t)^2\right] \end{aligned} \tag{6}$$

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, $\mu_i^A = \mu_i + \frac{t}{2}$, and revenues,

[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.

$r_i^A = r_i + \frac{Lt}{4\gamma}(2-t)$, $t < 2$. 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.

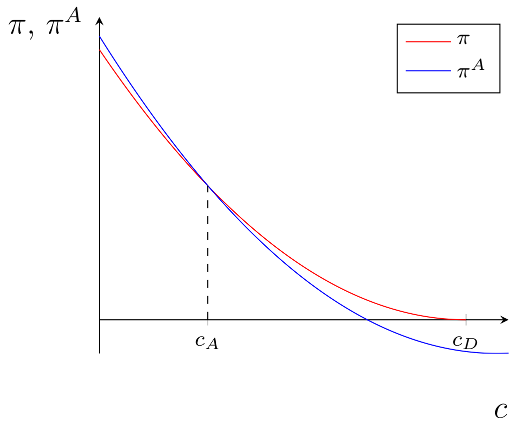

Figure 1: Technology adoption trade-off

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

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

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:

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

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

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

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 reduction in variable costs t and higher aggregate demand L raise the incentive to upgrade technology. It is dampened by higher investment cost f and lower firm scale brought about by a higher γ[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:

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

The free entry condition (12) uniquely determines the entry cutoff c_D. To see this, note that the left-hand side, the ex-post expected profits, is strictly increasing in c_D while the right-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 the entry cutoff c_D

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

[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.

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 $\frac{N_A}{N}$, where N_D and N_A denote the absolute number of low-technology and high-technology firms.

Average cost, price, mark-up, output, sales, and profits are then given by

$$\begin{aligned}
\bar{c} &= \frac{k}{k+1}c_D \\
\bar{p} &= \frac{2k+1}{2k+2}c_D - (p_i - p_i^A)\frac{N_A}{N} \\
\bar{\mu} &= \frac{1}{2(k+1)}c_D + \left(\mu_i^A - \mu_i\right)\frac{N_A}{N} \\
\bar{q} &= \frac{L}{2\gamma}\frac{1}{k+1}c_D + (q_i^A - q_i)\frac{N_A}{N} \\
\bar{r} &= \frac{L}{2\gamma}\frac{(c_D)^2}{k+2} + \left(r_i^A - r_i\right)\frac{N_A}{N} \\
\bar{\pi} &= \left(\frac{c_M}{c_D}\right)^k \left[f_E + \int_0^{c_A} \left(\pi^A - \pi\right) g(c)dc\right].
\end{aligned} \tag{14}$$

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 output and revenues). Average mark-ups and profits are higher.

We use the indirect utility function associated with (1) to analyze the implications on social welfare (see Melitz and Ottaviano (2008), p. 298):

$$W = I^c + \frac{N}{\gamma}\frac{\sigma_p^2}{2} + \frac{1}{2}\left(\frac{\gamma}{N} + \beta\right)^{-1}(\alpha - \bar{p})^2 . \tag{16}$$

The welfare level is a decreasing function of the entry cutoff c_D (see Appendix). 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 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 not 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 a high-technology firm 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

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

Total profits are given by $\pi_T^l = \pi_D^l + \pi_X^l$ and $\pi_{TA}^l = \pi_{DA}^l + \pi_{XA}^l$, where π_D and π_{DA} denote domestic profits. 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, revenues 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 of the purchasing/renting cost. We follow Rajan and Zingales (1998) in that the need for outside capital arises from technological reasons and is thus the same for all firms in the differentiated good 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: the total costs of technology adoption, TC^L, correspond to the purchasing/renting cost, that is $TC^L = f$ for all firms in country L[5].

Country H, on the other hand, has a less developed credit market. Therefore, firms' need for credit implies additional costs of external finance, f_{ext}. We assume that these additional costs are heterogeneous across firms. In particular, we assume that more productive (lower c_i) firms have lower costs of obtaining outside funds:

$$TC^H = f + f_{ext}\left(c_i\right),\ f'_{ext}(c_i) > 0. \quad (18)$$

The reason is that more productive firms are larger. Therefore, they offer creditors higher expected revenues and thus lower efficiency losses when it comes to repayment enforcing.

[5] If creditors earn a world-market net interest rate r on their investment instead, the results are qualitatively unchanged (cf. Manova, 2010).

We capture this notion in a very stylized way:

$$f_{ext}(c_i) = \max\left\{f - \mu\left[\pi^H_{TA,V}(c_i) - \pi^H_T(c_i)\right], 0\right\}, \tag{19}$$

where $\pi^H_{TA,V}(c_i) = \pi^H_{TA} - f$ are the variable profits of high-technology firms.
$\mu \in (0, 1]$ measures credit market development: a higher μ implies a lower overall level of credit constraints. $\mu = 1$ if the credit market is perfect and $\mu < 1$ otherwise. For μ close to zero, the costs of external finance are at their maximum of f. $\pi^H_{TA,V}(c_i) - \pi^H_T(c_i)$ is the net revenue from technology adoption that increases in firm size. Larger firms gain more from upgrading their production technology, that is their expected revenues are higher. This makes it easier for creditors to enforce repayment and hence lowers the cost of obtaining credit.
The expected revenues of the most productive firms are high enough for creditors not to require additional payments. These are the firms with marginal cost of production below c_{UC}, where c_{UC} is the production cost of the firm that is just large enough to be unconstrained:

$$\max\left\{f - \mu\left[\pi^H_{TA,V}(c_i) - \pi^H_T(c_i)\right], 0\right\} = 0 \Leftrightarrow c_i \leq c_{UC} = \frac{1}{1+\tau}\left[c^L_D + c^H_D + t - \frac{1}{\mu}\frac{2\gamma}{Lt}f\right]. \tag{20}$$

Smaller firms need to pay for obtaining outside finance. For these firms, adopting the more advanced technology is thus more expensive.

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 production decision is the same as in autarky and given by

$$\pi^l_D(c^l_D) = 0 \Leftrightarrow c^l_D = p^l_{\max} = \frac{\gamma\alpha}{\gamma + \beta N^l} + \frac{\beta N^l}{\gamma + \beta N^l}\bar{p}^l. \tag{21}$$

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

The first case, which we call selection IX, results if exporting is relatively cheaper than technology adoption. The marginal exporter uses the traditional technology and has production costs that are equal to

$$\pi_X^l(c_X^l) = 0 \Leftrightarrow c_X^l = \frac{c_D^h}{\tau}. \tag{22}$$

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, $\pi_{TA}^l(c_i) \geq \pi_T^l(c_i)$. In the country with a developed credit market, country L, all high-technology firms pay only the fixed cost of purchasing/renting the advanced technology f. The resulting technology adoption cutoff, c_A^L, is given by

$$\pi_{TA,V}^L\left(c_A^L\right) - f = \pi_T^L\left(c_A^L\right) \Leftrightarrow c_A^L = \frac{1}{1+\tau}\left(c_D^L + c_D^H + t - \frac{2\gamma}{Lt}f\right). \tag{23}$$

From (20) follows that $c_{UC}^H < c_A^L$: all unconstrained firms in country H adopt the advanced technology. Hence, the marginal technology adopter is a constrained firm that has to pay for obtaining outside finance. Its production cost are equal to $c_{A,C}^H$, where

$$\pi_{TA,V}^H\left(c_{A,C}^H\right) - f - f_{ext}\left(c_{A,C}^H\right) = \pi_T^H\left(c_{A,C}^H\right) \Leftrightarrow c_{A,C}^H = \frac{1}{1+\tau}\left(c_D^L + c_D^H + t - \frac{2}{1+\mu}\frac{2\gamma}{Lt}f\right). \tag{24}$$

Comparing (23) and (24) reveals that the technology adoption cutoff is lower in country H. Firms with production cost $c_{UC}^H < c_i \leq c_{A,C}^H$ have higher total costs of technology adoption bust still adopt the advanced technology. Less productive firms with $c_i \in [c_{A,C}^H, c_A^L)$ would upgrade their production equipment in a perfect capital market but are prevented from doing so by the costs of raising outside finance. These are the "missing high-technology firms".

If technology adoption is relatively cheaper than exporting, the marginal technology adopter is a purely domestic firm, that is all exporters use the advanced technology (Selection XI)[6]. The technology adoption cutoff in country L is analogous to (11) but it is higher in country

[6] 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 $(c_D^l + t - \frac{c_D^h}{\tau})\frac{Lt}{2\gamma} < f^l < \left(c_D^l + c_D^h + t\right)\frac{Lt}{2\gamma}$.

H due to credit market frictions

$$\pi^L_{DA,V}\left(c^L_A\right) - f = \pi^L_D\left(c^L_A\right) \Leftrightarrow c^L_A = c^L_D + \frac{t}{2} - \frac{2\gamma}{Lt}f$$
$$\pi^H_{DA,V}\left(c^H_A\right) - f - f_{ext}\left(c^H_A\right) = \pi^H_D\left(c^L_A\right) \Leftrightarrow c^H_A = c^H_D + \frac{t}{2} - \frac{2}{1+\mu}\frac{2\gamma}{Lt}f.$$

The marginal exporter just breaks even on the foreign market:

$$\pi^l_{XA}(c^l_X) = 0 \Leftrightarrow c^l_X = \frac{c^h_D + t}{\tau},$$

where c^l_X is the export cost cutoff in country l. Firms with marginal costs of production below c^l_X also serve the foreign market.
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 sales. 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 $c^l_A < c^l_X < c^l_D$. 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

$$\frac{(c^L_D)^{k+2} + \tau^{-k}(c^H_D)^{k+2}}{k+2} + t(1+\tau)(c^L_A)^{k+1} - \frac{f_E 2\gamma c^k_M(k+1)}{L} \quad (27.a)$$
$$\frac{(c^H_D)^{k+2} + \tau^{-k}(c^L_D)^{k+2}}{k+2} + t(1+\tau)\left[(1+\mu)(c^H_{A,C})^{k+1} - \mu(c^H_{UC})^{k+1}\right] - \frac{f_E 2\gamma c^k_M(k+1)}{L}. \quad (27.b)$$

where c^L_A, $c^H_{A,C}$, and c^H_{UC} are given by (23), (24) and (20). In the following, we call country L low-cost country and country H high-cost country.
(27.a) and (27.b) are a system of two equations with two unknowns (c^L_D and c^H_D). Due to the nonlinearity of the equations, c^L_D and c^H_D cannot explicitly be solved for. It is however possible to represent the two equations in the (c^L_D, c^H_D) space (Fig. 2). The equilibrium entry cutoffs are given by the intersection of the two curves representing the free entry conditions. A denotes the symmetric equilibrium ($\mu = 1$ and thus $TC^H = TC^L = f$) and B

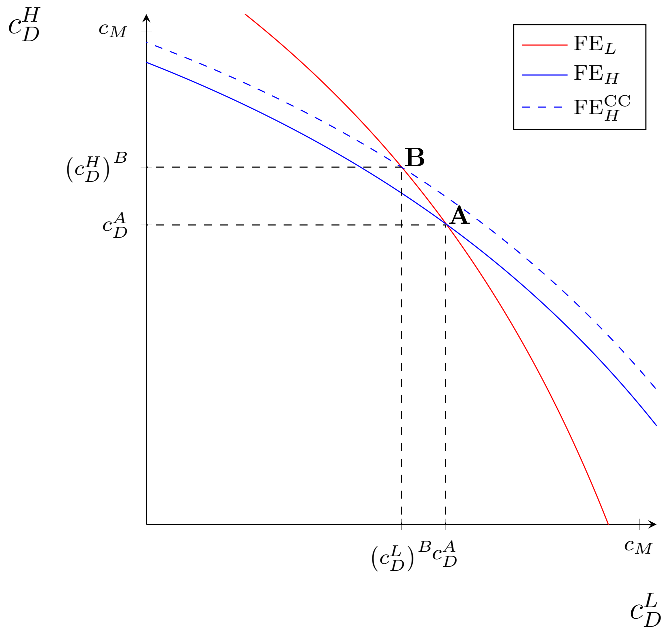

Figure 2: Open economy equilibrium

the asymmetric equilibrium ($\mu < 1$ and thus $TC^H > TC^L = f$).
In the symmetric case, countries are identical. The free entry condition of country H is symmetric to (27.a),

$$\frac{(c_D^H)^{k+2} + \tau^{-k}(c_D^L)^{k+2}}{k+2} + t(1+\tau)(c_A^H)^{k+1} - \frac{f_E 2\gamma c_M^k(k+1)}{L}, \tag{25}$$

where $c_A^H = c_A^L$. Hence, the two countries 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 (lower μ), 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 $\left(c_D^L\right)^B < c_D^A < \left(c_D^H\right)^B$. Formally, this is reflected by the free entry conditions in (27.a) and (27.b). Higher total costs of technology adoption for constrained firms imply lower expected additional profits of technology upgrading in country H, $(c_{A,C}^H)^{k+1} > (1+\mu)\left[(c_{A,C}^H)^{k+1} - \mu(c_{UC}^H)^{k+1}\right]$. Therefore, ex ante expected profits are lower leading to a higher entry cutoff c_D^H.
The intuition behind this result is as follows. Additional 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.
By (22), the export cutoff, that is the fraction of exporters, is lower in country H. From (23) and (24) follows furthermore that the technology adoption cutoff and therefore the fraction of high-technology firms is higher in the low-cost country L.

Proposition 2. *Suppose that $c_A < c_X < c_D$ and $\mu < 1$. In the open economy, welfare, average productivity, the fraction of exporters 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 (lower μ).*

Consider additional costs of external finance that are the same for all firms and denote the corresponding technology cutoff with $c^H_{A,id}$. In this case, all firms in country H have identical total costs of technology adoption, $TC^H = df$, $d > 1$[7]. In our model, on the other hand, larger firms have lower costs of external finance. The largest firms pay no additional costs and realize higher profits than in the case of identical total technology adoption costs. For a given level of competition (that is c^H_D), the fraction of high-technology firms in our model is thus lower. To see this, consider a combination of market frictions μ and d for which ex-ante expected profits and therefore the entry cutoffs are identical. From the free entry conditions in (27.a) and (27.b) follows then

$$\left(c^H_{A,C}\right)^{k+1} + \mu\left[\left(c^H_{A,C}\right)^{k+1} - \left(c^H_{UC}\right)^{k+1}\right] = \left(c^H_{A,id}\right)^{k+1}.$$

Since the term in brackets on the LHS is positive, the technology adoption cutoff in the case of identical costs of external finance, $c^H_{A,id}$ must be higher than $c^H_{A,C}$. Heterogeneous additional costs of technology adoption thus imply a lower fraction of high-technology firms. However, these high-technology firms are on average more efficient.

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

[7] An example is Unel (2010) where all firms in the high-cost country have identical costs of technology adoption.

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). 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[8].

Proposition 3. *Suppose that $c_A < c_X < c_D$ and $\mu < 1$. In the open economy, 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[9]. 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

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

[9] 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.

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 (27.a)

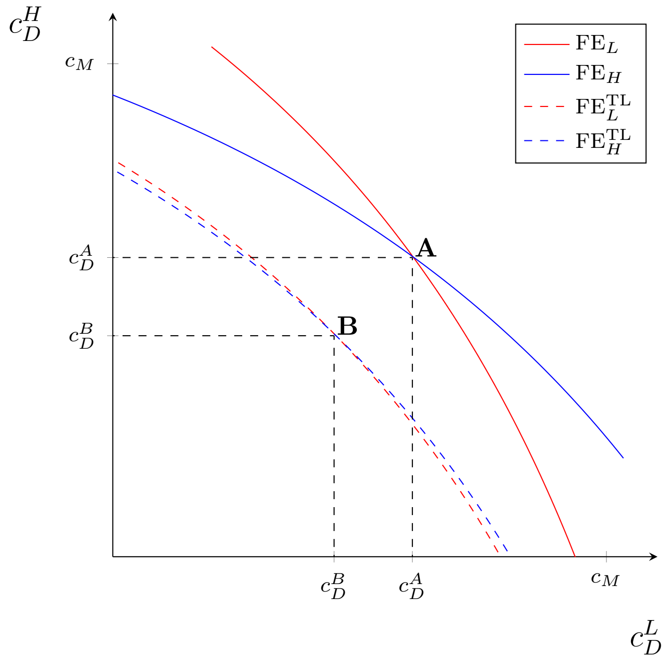

Figure 3: Trade liberalization: Symmteric countries

and (27.b), 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 (22) with respect to trade barriers τ, we obtain

$$\frac{dc_X}{d\tau} = \frac{1}{\tau}\left(\frac{dc_D}{d\tau} - \frac{c_D}{\tau}\right). \tag{26}$$

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 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 (23) and (24), the impact of trade liberalization on technology upgrading is given by

$$\frac{dc_A}{d\tau} = \frac{1}{1+\tau}\left(2\frac{dc_D}{d\tau} - c_A\right). \tag{27}$$

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 (see Appendix): total output of the most productive low-technology firms increases. Therefore, these firms have a higher return to technology upgrading and pay lower costs of external finance. Hence, they now invest in the advanced technology.

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. Furthermore, the fraction of high-technology firms increases if technology adoption is not too costly.*[10]

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. 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

[10] 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.

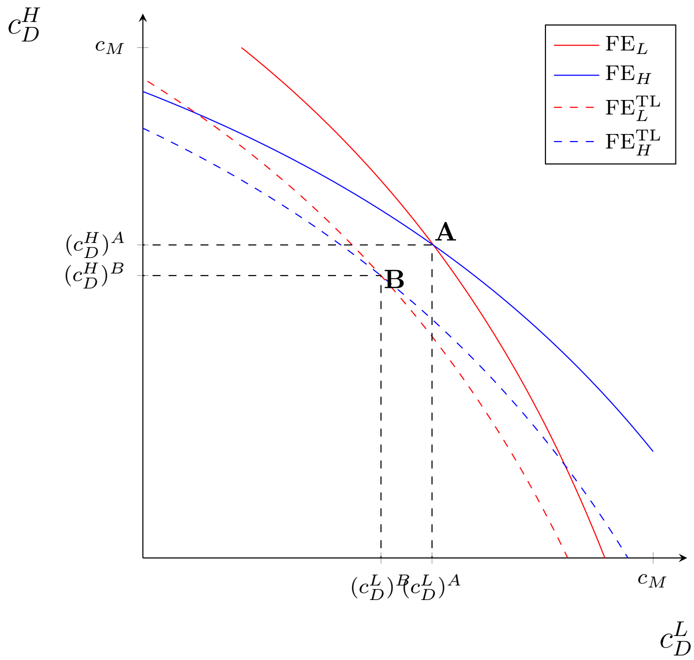

Figure 4: Trade liberalization: Asymmteric countries and weak credit constraints

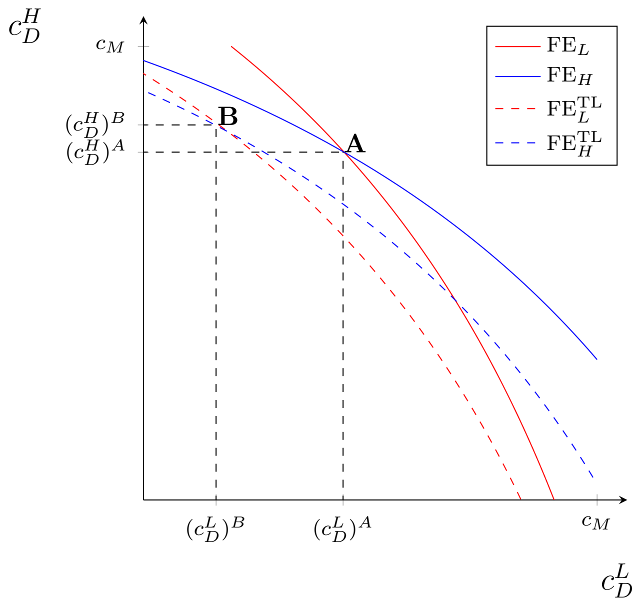

Figure 5: Trade liberalization: Asymmteric countries and severe credit constraints

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, the welfare increase is lower in the high-cost country. If credit constraints are severe, welfare might even decrease. In other words, the welfare gap between the two countries widens. This divergence is stronger 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.

The effect of trade liberalization on the export cost cutoff is positive and given by

$$\frac{dc_X^l}{d\tau} = \frac{1}{\tau}\left(\frac{dc_D^h}{d\tau} - \frac{c_D^h}{\tau}\right) < 0. \tag{28}$$

From the free entry conditions (27.a) and (27.b), 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 in country H 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 (27) the effect on the technology adoption cutoff is

$$\frac{dc_A^l}{d\tau} = \frac{1}{1+\tau}\left(\frac{dc_D^L}{d\tau} + \frac{dc_D^H}{d\tau} - c_A^l\right) \gtrless 0. \tag{29}$$

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. 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 depends 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[11]. Eq. (29) 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 $\mu < 1$. 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 (lower μ).*

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. 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), Behrens, Mion, and Ottaviano (2007) calibrate $k = 3.6$. Balistreri et al.

[11] From (20), $\frac{dc^H_{UC}}{d\tau} = \frac{1}{1+\tau}\left(\frac{dc^L_D}{d\tau} + \frac{dc^H_D}{d\tau} - c^H_{UC}\right) > \frac{dc^H_{A,C}}{d\tau}$: because of Pareto distributed production cost, the fraction of high-technology firms might increase even if the fraction of unconstrained firms decreases.

(2008), obtain $k = 4.5$ by dividing the world in 12 regions. We consider $k = \{2, 2.5, 3.6, 4.5\}$ to examine how higher average costs 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 costs. 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 $\gamma = 0.2$.

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

$$0 < c_A < c_X < c_D < c_M. \tag{30}$$

The range of parameter values to measure credit market development (μ^l, μ^h) is selected to satisfy (30) and to allow for a large enough difference in the total technology adoption costs between the two countries. In particular, $L = 1$, $f_E = 10 = c_M$, $\mu^l, \mu^h \in [0.5, 1]$. Furthermore, the purchasing/renting cost are set to 150% of the fixed market entry costs, $f = 15$.

Our preferred specification ("basic specification") is given by

- $\tau = 1.1$
- $k = 2.5$
- $t = 0.75 \equiv 10\%$ of average costs
- $\gamma = 0.2$

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 costs on technology upgrading ($\frac{dc_A}{d\tau}$) and welfare ($\frac{dc_D}{d\tau}$) for different combinations of credit market frictions (μ^l, μ^h). The TA_l-line represents combinations for which "opening up" to trade has no effect on technology upgrading in country l. Technology upgrading increases for combinations of (μ^l, μ^h) on the right-hand side and decreases for combinations on the left-hand side. Analogously, the TA_h-line represents combinations for which technology upgrading is unchanged in country h. Technology upgrading in country h increases for (μ^l, μ^h)-combinations above the hh-line and decreases for combinations below the TA_h-line. The two lines divide the (μ^l, μ^h)-space in four areas. Technology upgrading, that is the fraction of high-technology

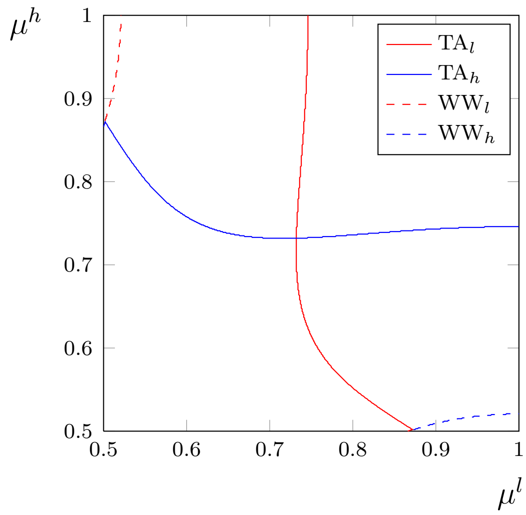

Figure 6: Illustration: Impact of trade liberalization on technology adoption and welfare

firms, increases (i) in both countries if μ^l, μ^h are both high (upper-right area), (ii) only in the low-cost country if the difference in total technology adoption costs is large (upper-left area and lower-right area) and (iii) in neither country if μ^l, μ^h are both low (lower-left area). The WW-lines represent μ^l, μ^h)-combinations for which welfare is unchanged after trade liberalization: welfare decreases in country l (country h) for combinations on the left-hand side of the WW_l-line (below the WW_h-line). Following our previous analyis, welfare decreases in the high-cost country if the difference in total 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. (B.7) shows how the impact of trade liberalization changes if countries are initially more closed. Higher (initial) trade barriers shift the TA_l-line and the TA_h-line outwards and thus increase the area of (μ^l, μ^h)-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 less integrated, welfare in the high-cost country increases also if the difference in total technology adoption costs is larger.

For $\tau \geq 1.15$, welfare increases for every level of μ^l, μ^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 the increase in sales abroad, lower import competition implies a lower decrease in domestic 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 costs of production. The effect of a higher k on the impact of trade liberalization is shown in Fig. (B.8). Higher average costs of production lead to an outward shift of the TA-lines. The WW-lines also shift outwards. Welfare and technology adoption increase now also in less developed countries with higher total 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 technology upgrading parameter t

t represents the return to technology upgrading: purchasing/renting the advanced technology decreases production cost by t. In the comparative statics exercise, we consider $t = [1, 1.125, 1.5, 1.875] \equiv [13\%, 15\%, 20\%, 25\%]$ of average costs (Fig. (B.9)). A higher return to technology adoption leads to an outward shift of the TA-lines: as the return to technology adoption becomes larger, trade liberalization increases technology adoption also in countries with less developed credit markets. However, the WW-lines shift inwards (and remain unchanged for $t = 1.875$). Welfare in the high-cost country now decreases also in countries with more developed credit markets.
A higher return to technology adoption makes technology upgrading profitable for a larger range of firms and leads to a higher initial fraction of high-technology firms. Therefore, initial aggregate productivity and competition are also higher. Because of Pareto distributed production cost, a larger initial fraction of high-technology producers implies a stronger pro-technology adoption effect. However, from above, a higher initial level of competition

implies a larger increase in import competition after trade liberalization. While the most productive low-technology firms increase output and upgrade technology, higher import competition forces a larger fraction of domestic firms to shut down. The number of firms and therewith aggregate productivity and welfare decrease.

5.3.4. Change in the product differentiation parameter γ

A lower γ implies less product differentiation. We allow for $\gamma \in [0.1, 0.225]$ in the comparative statics analysis. The effect of a decrease in product differentiation is similar to the effect of an increase in the return to technology adoption t (Fig. (B.10)). In a less differentiated industry, technology adoption increases also in less developed countries whereas welfare now decreases in more developed countries.

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 the initial fraction of high-technology firms. The resulting higher average efficiency increases initial welfare and the intensity of competition. From above follows that more intense competition increases import competition after trade liberalization and therefore reduces welfare also in countries with a more developed credit market.

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 and (ii) average costs in the industry are higher. Furthermore, technology adoption (welfare) increases (decreases) also in countries with a less (more) developed credit market if (iii) the return to technology adoption is higher and (iv) the industry is less differentiated.*

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, smaller 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, aggregate 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).

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Appendix A. Proofs

to be completed

Appendix B. Tables

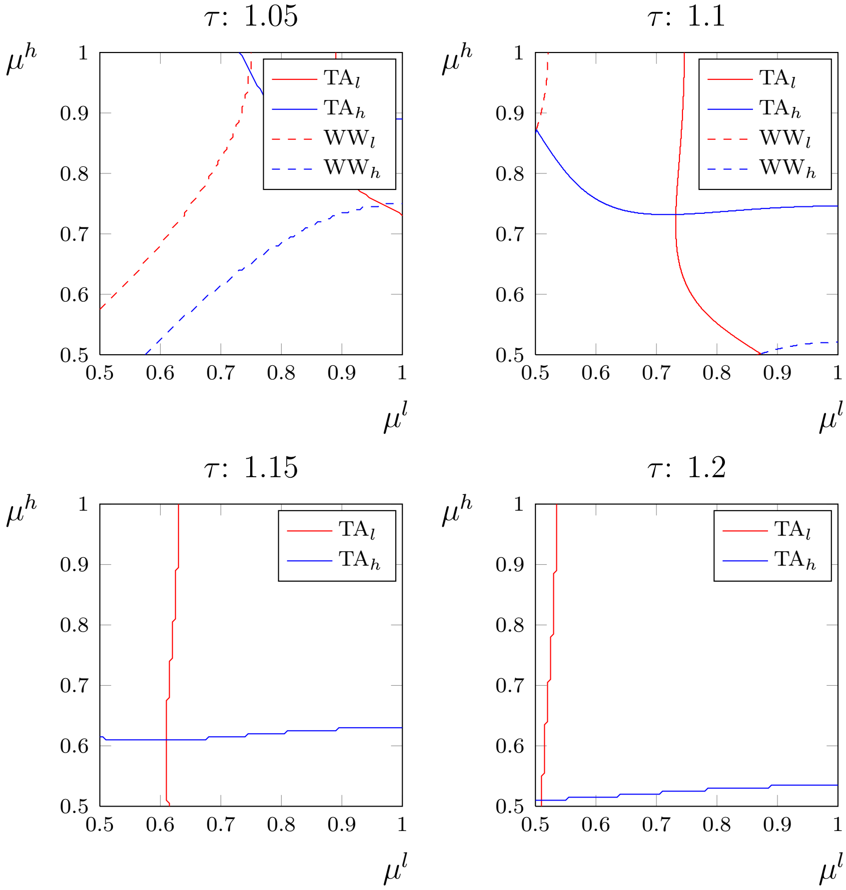

Figure B.7: Comparative statics: Trade barriers τ

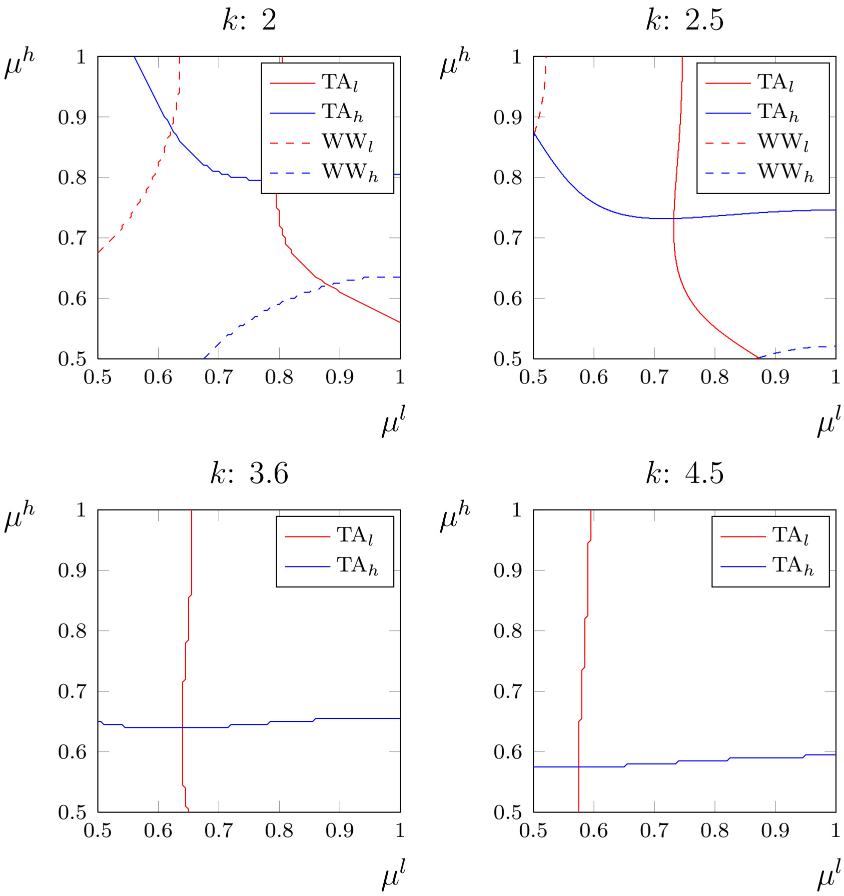

Figure B.8: Comparative statics: Cost effectiveness k

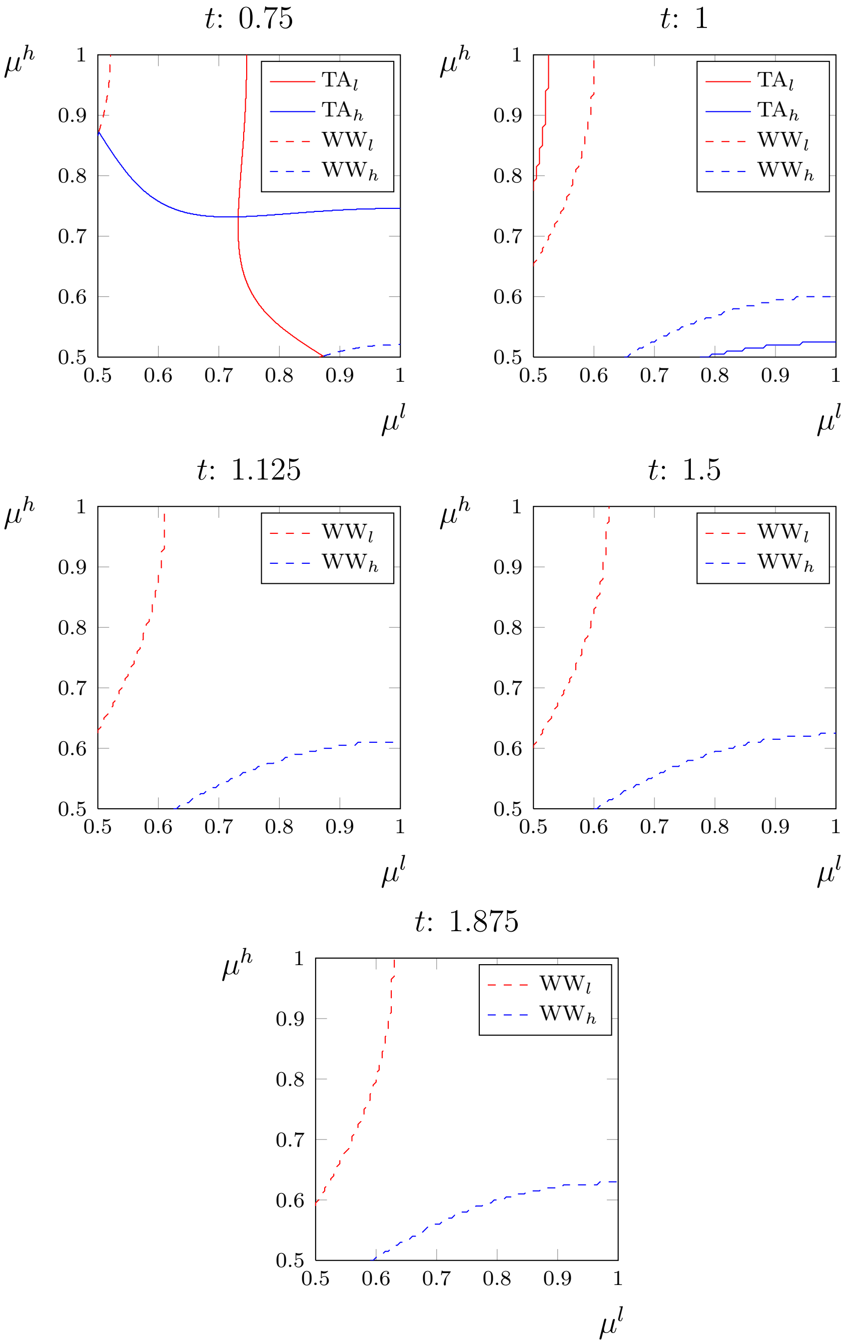

Figure B.9: Comparative statics: Technological leap t

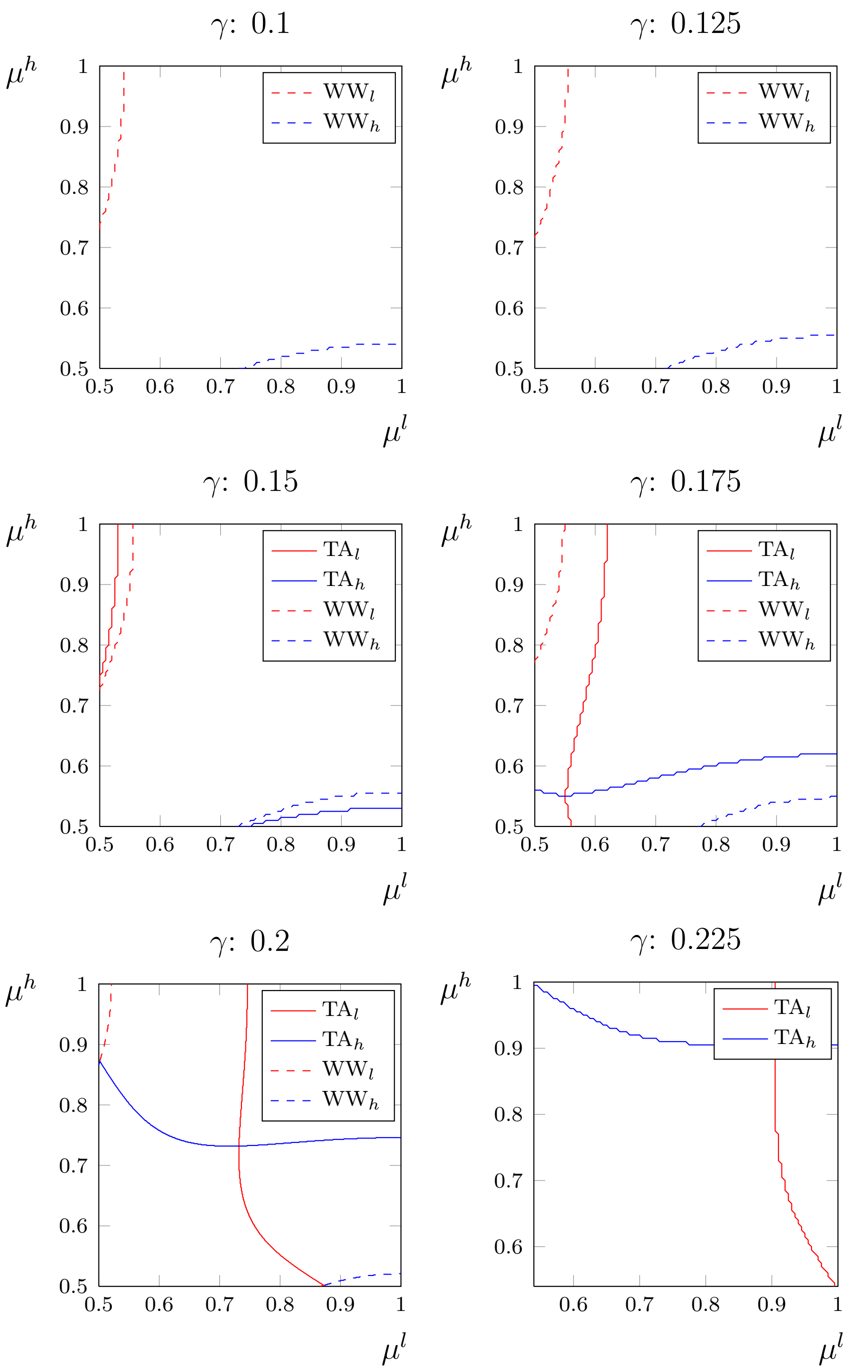

Figure B.10: Comparative statics: Product differentiation γ