Catching Up: The Impact of Financial Development on Technology Adoption and Participation in International Trade

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Katrin Peters

Referentin:	Prof. Dr. Monika Schnitzer
Korreferentin:	Prof. Kalina Manova, PhD
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To my family.

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Introduction

Income and productivity differences between countries are surprisingly persistent over time, given the increased integration of countries in the past three decades (e.g. Easterly and Levine, 2002; Milanovic, 2009). Among others, two channels through which countries can foster economic development have been emphasized in both the academic and public debate: innovation and participation in international trade.

For developing countries, the most important part of the innovation process is technology adoption, that is, the investment in new, more advanced technologies. The adoption of new technologies allows firms to introduce new goods and to produce more efficiently. Participation in international trade is considered to contribute to economic growth in three ways. First, lower trade barriers allow the import of foreign inputs and capital goods that are cheaper or of better quality than domestic ones. Second, a reduction in trade barriers increases the market size for exporters and therewith fosters investment in advanced technologies. Third, import competition of foreign firms forces less productive firms out of the market and leads to a more efficient allocation of resources across firms.

However, potential technology adopters, exporters and importers must be able to take advantage of these growth opportunities. Financial frictions often present an obstacle to a firm's investment (e.g. Beck, Demirgüç-Kunt, Laeven, and Levine, 2008). Investment in new technologies and international trading activities are associated with sunk costs that have to be paid *ex-ante*. If firms lack the necessary funds, the investment does not take place and growth opportunities go unused. Well functioning financial markets and institutions alleviate financial constraints and allow profitable investment opportunities to be taken. In the words of the economic historian Rondo Cameron, "[m]etaphorically, finance is the lubricant of the process of economic growth" (Cameron, 1967, p. 2).

The positive relationship between financial development and, respectively, technology adoption, international trade and economic growth is well established at the aggregate level (for an overview over the theoretical literature see Beck, 2011, for empirical evidence see e.g. Levine, Loayza, and Beck, 2000; Beck, Levine, and Loayza, 2000; Ang, 2011; Manova, 2011). Recently, researchers have started to use micro-level data to analyze these relationships at the firm level (e.g. Demirgüç-Kunt, Love, and Maksimovic, 2006; Gorodnichenko and Schnitzer, 2012). This is important in order to disentangle the microeconomic channels through which financial development affects economic growth. Furthermore, financial development has a different effect on different groups of firms. Financial constraints are a greater obstacle to the operations of smaller firms and this effect is larger in financially less developed countries (Beck, Demirgüç-Kunt, and Maksimovic, 2005; Beck, Demirgüç-Kunt, Laeven, and Levine, 2008). Accordingly, financial development might benefit smaller firms more than larger firms. Informed policy design must thus rely on firm level evidence.

This dissertation analyzes, both theoretically and empirically, how financial constraints affect technology adoption, participation in international trade and the catch-up process between countries. The first chapter explores credit constraints as one channel through which trade liberalization impedes convergence between two countries at different levels of financial market development. The second chapter studies the effect of financial market development on the probability that a firm invests in technology adoption. The impact of credit constraints on the export and import decision of firms is analyzed in the third chapter.

Trade liberalization is one of the most common policy reforms recommended to developing countries in order to enhance convergence towards the more developed countries. Recent evidence, however, suggests that despite opening up a country to trade, the productivity and income gap between developed and developing economies often does not close. A leading example is the North American Free Trade Agreement (NAFTA) between the USA, Canada and Mexico. In the years following NAFTA, income and productivity disparities between Mexico and the USA did not diminish (Lederman, Maloney, and Serven, 2005).

The first chapter examines credit constraints as one channel held responsible for hampering convergence.[1] We develop a heterogeneous firm model of international trade with variable mark-ups where firms decide whether or not to invest in a more efficient production technology. A fraction of the investment cost has to be financed externally. We consider a two-country setting where the two countries potentially differ with respect to financial market development. In a less developed financial market, the costs of obtaining external finance are higher and fewer firms invest in the more efficient technology. We use this model to study the effect of a reduction in trade barriers on technology adoption, average productivity and welfare.

In doing so, we are the first to analyze theoretically how credit constraints change the impact of trade liberalization on convergence between countries. We find that the fraction of firms investing in the more efficient technology increases in both countries after trade liberalization. Together with a reallocation of output towards the more productive firms, this increases average productivity and welfare in both, the less and the more developed country. The productivity and welfare gap between the two countries, however, increases after trade liberalization. The reason is that firms in the country with lower financial market development cannot take advantage of the export market due to credit constraints but face import competition. This result matches empirical evidence from NAFTA and has important policy implications that have been taken up in the design of The Central American Free Trade Agreement (CAFTA): a reduction of trade barriers without improving access to external finance, in particular for smaller firms, fails to promote economic convergence (Jaramillo and Lederman, 2006).

[1]This chapter is based on the article “Trade Liberalization and Credit Constraints: Why Opening Up May Fail to Promote Convergence”, which is joint work with Monika Schnitzer from the Ludwig-Maximilians-Universität München.

For developing countries, the adoption of new, more advanced technologies is the most important part of the innovation process (Hall, 2006). However, financial constraints present a major obstacle to technology adoption in these countries.

The second chapter analyzes first, whether financial development increases firm level investment in new technologies and second, which firm's investment is most affected by financial development. To guide the empirical analysis, we extend the model developed in Chapter 1 to multiple sectors. Furthermore, and consistent with the empirical evidence outlined above, the costs of obtaining external finance are larger for smaller firms. We test the predictions from the model using data from the World Bank Enterprise Surveys, that is, firm level surveys conducted in a large number of developing countries around the globe. An advantage of the Enterprise Surveys is that they collect direct measures of access to finance and of technology use. We consider two types of new technologies: investment in less costly and in very costly new technologies. For identification, we use a difference-in-difference approach in the spirit of Rajan and Zingales (1998) that allows controlling for unobserved country and industry characteristics.

We find first, that financial market development increases access to external finance. Second, we show that financial market development increases the probability that a firm invests in new technologies. In the case of less costly new technologies, financial development benefits in particular smaller firms. For costly new technologies, the effect works through larger firms that have an incentive but not the necessary means to invest in costly technologies at lower levels of financial market development.

While the positive relationship between financial development and technology adoption is well documented at the aggregate level (e.g. Aghion, Howitt, and Mayer-Foulkes, 2005), our study is the first to provide firm level evidence of the detrimental impact of financial constraints on technology adoption. This is interesting for two reasons. First, our results confirm that credit constraints are a micro-level channel through which a lack of financial development can hamper economic growth. Second, we show that the effect of financial development on technology adoption differs across the firm size distribution. This is important when designing well-targeted policies.

In the context of international trade, financial development acts as a source of comparative advantage. Financially developed countries export larger volumes, especially in industries with high demand for external finance. Since participation in international trade increases productivity, it is crucial to understand to what extent financial constraints affect entry into importing and exporting.

In the third chapter, we study the impact of credit constraints on the probability of importing and exporting using firm level surveys conducted in Eastern European and former CIS countries.[2] The data used allow the direct identification of credit constrained firms. In contrast to previous studies that take account only of rejected credit applications, we identify all firms with a demand for but no access to credit. We show that in doing so, we avoid a potential endogeneity bias. We jointly estimate the importer (exporter) and the credit constraints equation in a bivariate probit setting, as this allows us to ignore the potential endogeneity of credit constraints in the importer (exporter) equation. The cross-country nature of the data make it possible to use country- and sector-varying instruments in order to identify the effect of credit constraints on a firm's decision to import and export.

We find that credit constraints lower the probability that a firm imports and exports by 33 per cent and 17 per cent, respectively. Our study is the first to provide a comprehensive analysis of the impact of credit constraints on Eastern European firms' participation in international trade. This is of particular interest as credit constraints are still a major problem in a large number of Eastern European countries (Brown, Ongena, Popov, and Yesin, 2011). While a large body of literature has looked at the export decision, few studies have analyzed the import decision. Furthermore, we are the first to show that the negative impact of credit constraints documented for manufacturing firms is also present among service firms. This is

[2] This chapter is based on the article "Credit Constraints and The Margins of International Trade: Evidence from Eastern European Firms", which is joint work with Fergal McCann from the Central Bank of Ireland.

important for policy design. Policies aimed at improving firms' access to external finance should also be targeted to service firms that account for an increasing part of economic activity.

The three chapters taken together provide new insights into the role of finance as a "lubricant of the process of economic growth" (Cameron, 1967, p. 2). Without sufficient access to finance, firms that have an incentive to invest in, respectively, new technologies, export and import activities are prevented from doing so. The *missing technology adoption* and the *missing international trade* represent two channels through which countries in a globalized world are prevented from catching up. Financial market reforms, especially targeting small firms, contribute to countries exploiting their potential instead of missing growth opportunities.

Chapter 1

Trade Liberalization and Credit Constraints: Why Opening Up May Fail to Promote Convergence*

1.1 Introduction

Trade liberalization is one of the most common policy reforms recommended to emerging countries in order to enhance economic development and close the productivity gap towards more developed countries (Rodrik, 2006). Opening up to trade increases the market size for exporters and stimulates investment in advanced technologies. Furthermore, incoming foreign firms foster competition and contribute to a more efficient allocation of resources across firms. However, trade liberalization alone is not enough to ensure economic convergence. A leading example is the North American Free Trade Agreement (NAFTA) between developed countries, the USA and Canada, and a developing country, Mexico, in 1994. In the decade following NAFTA, GDP, exports, and investment in Mexico increased but productivity dis-

*This chapter is based on joint work with Monika Schnitzer.

parities with respect to Canada and the USA did not diminish. One key constraint to achieving convergence have been deficiencies in local credit markets. While large firms have access to foreign financing, inadequate access to domestic credit prevents the vast majority of firms, especially smaller and newer ones, from taking full advantage of the opportunities offered by NAFTA (Lederman, Maloney, and Serven, 2005).

This paper explores credit constraints as one channel through which trade liberalization might impede convergence between countries. We develop a heterogeneous firm model of international trade where firms decide whether or not to invest in a more efficient production technology. More specifically, 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. In particular, weak protection of creditor rights increases the risk premium creditors require in order to break even in expected terms. We then analyze the effects of trade liberalization on technology adoption, average productivity and welfare in a two-country setting where the two countries potentially differ with respect to credit market development.

We find that the fraction of firms adopting the advanced technology increases with trade liberalization in both countries. In addition to the reallocation of output towards more productive firms (selection effect of trade), there is thus a second source of productivity gains. Technology upgrading and the reallocation of resources lead to higher average productivity and welfare, as in Bustos (2011). However, if firms in one country face credit constraints, the difference between the two countries with respect to the fraction of firms adopting the advanced technology increases. Hence, productivity gains both through firm selection and through technology adoption are lower. As a result, the increase in average productivity in the country with a less developed credit market is lower: the productivity gap widens. Simulations show that the welfare gap between the two countries widens too.

This result has important policy implications. Unconditional trade liberalization that reduces trade barriers without improving access to domestic credit fails to promote economic convergence. First, credit constraints lead to a lower selection effect. Second, and more importantly, credit constraints impact negatively on firms' productivity gains from trade liberalization. These firm level productivity gains capture dynamic gains from trade and are considered more important for long-term growth and convergence than the static gains from resource reallocation (Lederman, Maloney, and Serven, 2005; Jaramillo and Lederman, 2006).

Our paper contributes to the literature by being, as far as we know, the first to analyze in a theoretical model how credit constraints change the effects of opening up to trade on technology upgrading, average productivity and welfare. Our model with credit constraints draws a nuanced picture of the impact of trade liberalization on economic performance and convergence. Studying trade liberalization between two countries that differ in their credit market development, we show that the financially less developed country gains through the reallocation of output towards more productive firms and a higher fraction of firms using the advanced technology. The resulting increase in average productivity, together with an increase in imported products, leads to more product variety and lower prices. However, inadequate access to credit prevents firms from taking full advantage of the larger export market while facing severe import competition, in contrast to firms in the country with a more developed credit market. Thus, while the economy as a whole becomes more affluent, the competitiveness of the corporate sector relative to the more developed country declines. These findings match empirical evidence from NAFTA: after the free trade agreement, Mexico increased its GDP and its exports. However, due to institutional gaps, in particular credit market development, the productivity gap with respect to the USA and Canada did not close.

One advantage of our framework is that it captures both features of trade liberalization, more export opportunities and increased import competition, in a direct way, by using a heterogeneous firm framework with endogenous mark-ups, without reducing tractability compared to the standard constant mark-up setup à la

Melitz (2003). Consistent with empirical evidence (e.g. Tybout, 2003; Feenstra and Weinstein, 2010; Impullitti and Licandro, 2011), endogenous mark-ups enable us to model the selection effect of trade liberalization through increased import competition. This allows us to capture in a very intuitive way the notion that credit constraints create asymmetries in the way firms benefit from improved export opportunities, are hit by increased import competition, and may thus be more or less inclined to invest in new technologies.

Our analysis builds on and contributes to two strands of literature. First, it is related to previous research that examines the impact of trade liberalization on firm productivity. Bernard, Redding, and Schott (2007) show that in the presence of heterogeneous firms, trade liberalization induces larger productivity gains in comparative advantage industries. In our model, reallocation forces are also larger in countries that have a comparative advantange in the financially dependent sector. In addition, a reduction in trade barriers entails a second, empirically important, asymmetry: the difference in the fraction of advanced technology users increases as well. Bustos (2011) and Navas-Ruiz and Sala (2007) introduce an endogenous technology adoption decision into a Melitz (2003) framework with symmetric countries.[3] 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. In contrast to these papers, we explicitly consider the financing of technology adoption and allow for firms to be financially constrained. We show that this has important implications for economic convergence. While technology adoption still increases in both countries after trade liberalization, credit constraints prevent the financially less developed country from speeding up convergence.[4]

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

[3] Unel (2011) extends the Bustos framework to allow for asymmetric countries, with ambiguous results.

[4] Another strand of literature analyzes the dynamic interaction between exporting and innovation activities (e.g. Constantini and Melitz, 2008; Atkeson and Burstein, 2010).

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 the 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 transparency 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, 2011). Alleviating financing constraints of innovators therefore significantly boosts investment in more advanced technologies (for a theoretical model see e.g. Keuschnigg and Ribi, 2010, for empirical evidence see e.g. Hajivassiliou and Savignac, 2007). Finally, our paper is related to Gorodnichenko and Schnitzer (2012) who analyze the effect of financial constraints on the relationship between exporting and innovation using BEEPS data. They argue that exporting and technology adoption are natural complements but 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.

The paper is organized as follows: Section 1.2 presents the model setup. The equilibrium is described in Section 1.3. Section 1.4 analyzes the impact of trade liberalization and implications for welfare are discussed in Section 1.5. Section 1.6 concludes.

1.2 The Model

In this section, we develop a model of the decision to export and to adopt an advanced technology in the presence of credit constraints. In the model, firms are heterogeneous as in Melitz and Ottaviano (2008), and have the option to decrease their production cost by investing in technology adoption, as in Bustos (2011). The costs of technology adoption depend on credit market frictions. We consider two countries that potentially differ with respect to credit market development. Variables of the foreign country, if different from the variables of the home country, are denoted by an asterisk.

1.2.1 Setup of the Model

Preferences. Each country consists of S consumers who have identical preferences over a continuum of varieties indexed by $i \in \Omega$ and a homogeneous good chosen as numéraire and indexed by 0 ($p_0 = 1$). Preferences are described by the quasi-linear quadratic utility function developed by Ottaviano, Tabuchi, and Thisse (2002):

$$U = q_0^c + \alpha \int_{i \in \Omega} q_i^c di - \frac{1}{2}\gamma \int_{i \in \Omega} (q_i^c)^2 \, di - \frac{1}{2}\beta \left(\int_{i \in \Omega} q_i^c di \right)^2, \tag{1.1}$$

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. The 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 ($q_0^c > 0$), the demand for variety i is given by

$$q_i \equiv S q_i^c = \frac{\alpha S}{\gamma + \beta N} - \frac{S}{\gamma} p_i + \frac{\beta N}{\gamma + \beta N} \frac{S}{\gamma} \bar{p}. \tag{1.2}$$

$\bar{p} = (1/N) \int_{i\in\Omega'} p_i di$ is the average price and N is the number of consumed varieties. Variety i is consumed whenever the price p_i is non-prohibitive:

$$p_i \leq p_{\max} \equiv \frac{\gamma\alpha}{\gamma + \beta N} + \frac{\beta N}{\gamma + \beta N}\bar{p}, \tag{1.3}$$

where $p_{\max}$ is the prohibitive price above which demand q_i is equal to zero. Equations (1.2) and (1.3) then imply a price elasticity of demand equal to

$$\epsilon_i = \left(\frac{p_{\max}}{p_i} - 1\right)^{-1}. \tag{1.4}$$

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, $\mu_i = \epsilon_i/(\epsilon_i - 1)$. The mechanism behind this result is the following: an additional variety reduces overall per-variety consumption and leads to a lower prohibitive price. The price elasticity increases and mark-ups decrease. Likewise, a lower price index $\bar{p}$, implying a higher relative price $p_i/\bar{p}$, reduces demand for variety i and thereby the mark-up μ_i.

Hence, in contrast to the case of a CES demand function, higher product market competition leads to lower mark-ups when using the linear demand system specified in (1.2).

Supply. The only factor of production, labor, is inelastically supplied in a competitive market. The market for the homogeneous good is perfectly competitive. Firms produce at constant returns to scale and require one unit of labor to produce one unit of output. Assuming a positive demand for the numéraire, the quasi-linear utility in (1.1) ensures labor market equilibrium. Moreover, the nominal wage in each economy is then equal to unity.[5]

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. The param-

[5] $q_0^c > 0$ is satisfied if β is large enough. We make this assumption in the following.

eter c_i thus reflects cost differences between firms. In order to satisfy demand q_i, firms need to hire $l_i = c_i q_i$ units of labor. In the following, we omit the subscript i for readability.

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 production cost from a common distribution $G(c)$. When learning the cost of production, firms decide (i) whether to exit the industry or to stay and produce and if they produce (ii) whether to export and whether to invest in technology adoption.

Technology adoption. In our extension of the Melitz and Ottaviano (2008) framework, firms have the option of upgrading their technology by spending f units of labor. The 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 or the periodized purchasing cost. One way to think about technology upgrading is that it reduces production cost by a fixed amount t: firms adopt a process innovation that reduces labor input requirement to $l = (c - t)q$.[6] We call t the "technological leap." The advanced technology thus comes at a higher fixed cost but increases productivity.[7]

Credit constraints. The fixed cost of adopting the more advanced technology is paid upfront and cannot be covered by future revenues. Internal funds are not sufficient to cover the investment and firms need to raise external finance for a fraction $d, d \in (0, 1)$ of the fixed cost f. In an imperfect credit market, this need for credit

[6]Note that for cost draws $c \in [0, t)$, this specification implies negative labor input. This can be ruled out by restricting cost draws to $c \geq t$. An alternative, but formally equivalent, interpretation of t is an increase in the price margin through product innovation or the adoption of an advanced technology that increases quality at unchanged cost. This interpretation does not require a restriction of cost draws and hence will be alluded to in order to avoid limiting the cost distribution.

[7]Modelling a continuous investment decision, e.g. max $\pi = t^{\phi}(p - c)q - t$, 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.

implies additional costs of external finance. We follow Rajan and Zingales (1998) in that the need for external finance arises from technological reasons and is thus the same for all firms in the differentiated good industry. Following Manova (2011), we assume imperfect contract enforcement. Creditors are repaid with probability $\lambda, \lambda \in (0,1)$. Hence, with probability $(1-\lambda)$ a firm defaults. Creditors thus require a collateral that they can seize in case of default. We assume that a fraction $\delta, \delta \in (0,1)$, of the capital and equipment required to start production (as captured by the market entry costs f_E) serves as collateral. Creditors recover only a fraction $\theta, \theta \in (0,1)$, of the collateral as they incur liquidation costs (e.g. Buch, Kesternich, Lipponer, and Schnitzer, 2009), e.g. because the collateral good cannot be sold at the original price. Another reason might be that creditors might need to invest time and effort in order to sell the collateral good because they do not have sufficient knowledge of the industry. Creditors make firms a take it or leave it offer specifying the required amount of repayment R. The credit market is perfectly competitive, that is, creditors break even in expected terms. The zero profit condition for creditors for a credit of size df is given by

$$\lambda R + (1-\lambda)\theta\delta f_E \geq df \tag{1.5}$$

implying a repayment of

$$R = \frac{d}{\lambda} f - \frac{(1-\lambda)\theta}{\lambda}\delta f_E.^{8} \tag{1.6}$$

Without advanced technology adoption, the total cost of production is given by

$$TC\,(c) = cq(c). \tag{1.7}$$

The total cost function of firms using the advanced technology, TC_A, depends on the level of credit market frictions:

$$TC_A\,(c) = (c-t)q_A(c) + (1-d)f + \lambda R + (1-\lambda)\delta f_E = (c-t)q_A(c) + f + f_{\text{ext}}, \tag{1.8}$$

[8] We assume that $f \geq (1-\lambda)\theta\delta f_E/d$ such that $R \geq 0$.

where $f_{\text{ext}} = (1-\lambda)(1-\theta)\delta f_E$. Lower contract enforcement and higher liquidation costs increase the costs of external finance and thereby the total costs of technology adoption.

Exporting. Trade between countries involves trade costs that consist of a fixed (market entry costs) and a variable component (transport costs, tariffs). Following Ottaviano, Taglioni, and Di Mauro (2009), we collapse all trade costs into a single indicator. The traditional formulation of iceberg transport costs implies that more productive firms (those with lower cost draws) have access to a transport technology of lower cost. As a consequence, reallocation forces are distorted (Schroeder and Sorensen, 2011; Irarrazabal, Moxnes, and Opromolla, 2011). Therefore, we assume per-unit trade costs, $\tau > 0$.

1.2.2 Firm Behavior

Prices and profits. Let p_D, p_X, p_{DA}, p_{XA} denote the price in the domestic and in the export market of firms using the baseline technology and of firms using the advanced technology, respectively. Profit maximization implies:

$$\begin{aligned} p_D &= \frac{1}{2}\left(p_{\max} + c\right), \quad p_X = \frac{1}{2}\left(p^*_{\max} + c + \tau\right) \\ p_{DA} &= \frac{1}{2}\left(p_{\max} + c - t\right), \quad p_{XA} = \frac{1}{2}\left(p^*_{\max} + c + \tau - t\right). \end{aligned}$$

Prices charged by firms using the advanced technology are lower, $p_{DA} = p_D - t/2$ and $p_{XA} = p_X - t/2$. Accordingly, quantities sold are higher. Technology adoption increases variable profits but involves fixed cost. The profits of firms serving only the domestic market using the baseline and the advanced technology are given by:

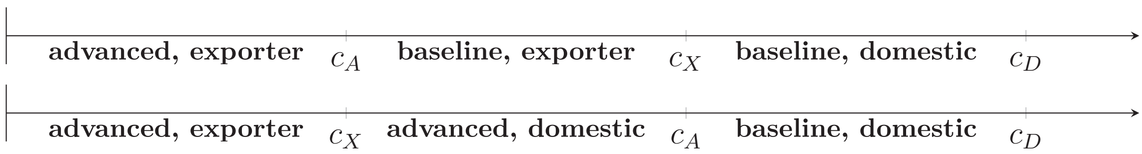
$$\pi_D = \frac{S}{4\gamma}\left(p_{\max} - c\right)^2, \quad \pi_{DA} = \frac{S}{4\gamma}\left(p_{\max} - c + t\right)^2 - f - f_{\text{ext}}. \tag{1.9}$$

Profits of firms serving also the foreign market are respectively

$$\begin{aligned} \pi &= \pi_D + \pi_X = \frac{S}{4\gamma}\left[(p^{\max} - c)^2 + (p^*_{\max} - c - \tau)^2\right] \\ \pi_A &= \pi_{DA} + \pi_{XA} = \frac{S}{4\gamma}\left[(p^{\max} - c + t)^2 + (p^*_{\max} - c - \tau + t)^2\right] - f - f^{\text{ext}}. \end{aligned} \quad (1.10)$$

Firms' sorting pattern. Denote with c_D, c_X, and c_A the cost cutoffs below which firms stay in the market and produce, serve the foreign market, and invest in technology adoption. A number of empirical studies show that only a subset of domestic producers serves the foreign market and/or uses an advanced production technology, that is, $c_X < c_D$ and $c_A < c_D$ (e.g. Bernard and Jensen, 1999). Furthermore, there are two possible sorting patterns (Figure 1.1). In the first case ($c_A < c_X$), serving

Figure 1.1: Plausible sorting patterns



only the domestic market and using an advanced technology is always dominated by some other choice. This case obtains if the fixed cost of technology adoption f is high. In the opposite case ($c_X < c_A$), the marginal technology adopter is a purely domestic firm, that is, all exporters use the advanced technology (low f). The technology adoption decision is then only indirectly affected by trade liberalization whereas in the first case, opening up to trade affects this decision directly. Given the aim of the paper, we therefore focus on the first case and assume that $c_A < c_X < c_D$. The necessary parameter restrictions are provided below.[9] Thus, there are four types of firms. Firms with a cost draw above c_D immediately exit the market. Firms with marginal cost between c_D and c_X are purely domestic producers and those with costs between c_X and c_A also serve the foreign market. The most productive firms with production cost below c_A adopt the advanced technology and

[9] Bustos (2011) and Lederman, Maloney, and Serven (2005) provide empirical support for this assumption on firms' sorting pattern.

serve the foreign market.

Firm decisions. The least productive firms serve only the domestic market and use the baseline technology. They decide to stay in the market and produce if their profits π_D are non-negative:

$$\pi_D(c_D) = 0 \;\Leftrightarrow\; c_D = p_{\max}. \tag{1.11}$$

A lower entry cutoff c_D reflects tougher selection and a more competitive market. Using (1.11), profits described in (1.9) and (1.10) can be rewritten as

$$\begin{aligned}
\pi_D &= \frac{S}{4\gamma}\left(c_D - c\right)^2 \\
\pi &= \pi_D + \pi_X = \frac{S}{4\gamma}\left[\left(c_D - c\right)^2 + \left(c_D^* - c - \tau\right)^2\right] \\
\pi_A &= \pi_{DA} + \pi_{XA} = \frac{S}{4\gamma}\left[\left(c_D - c + t\right)^2 + \left(c_D^* - c - \tau + t\right)^2\right] - f - f_{\text{ext}}.
\end{aligned} \tag{1.12}$$

Firms export if they can profitably serve the foreign market. This is the case if their production cost is below the export cutoff c_X where

$$\pi_X(c_X) = 0 \Leftrightarrow c_X = c_D^* - \tau. \tag{1.13}$$

Exporters invest in technology adoption if their total profits are higher when using the advanced technology, that is, if $\pi_A(c) \geq \pi(c)$. Technology adoption increases variable profits but involves fixed costs. This trade-off is depicted in Figure 1.2. Firms with cost draws below the technology adoption cutoff c_A invest in technology adoption. We call these firms *high-technology firms*. Their scale of production is very large so that it pays for them to bear the investment cost $f + f_{\text{ext}}$:

$$\pi_A(c_A) = \pi(c_A) \Leftrightarrow c_A = \frac{1}{2}\left(c_D + c_D^* + t - \tau - \frac{2\gamma}{St}\psi f\right), \tag{1.14}$$

where $\psi = 1 + \frac{(1-\lambda)(1-\theta)\delta f_E}{f}$. ψ is thus an indicator of credit market frictions, with higher values indicating a lower level of credit market development. Using (1.11),

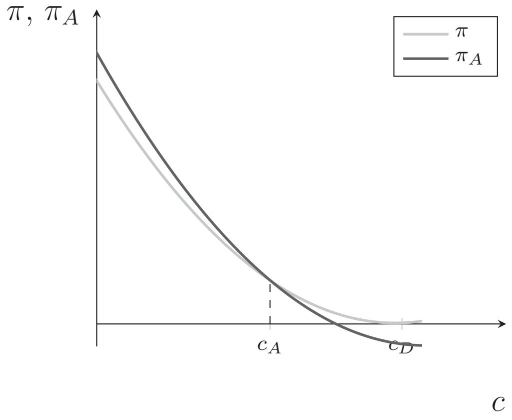


Figure 1.2: Technology adoption trade-off

(1.13), and (1.14), we can now state a condition for our assumption on firms' sorting pattern:

$$f_{\min} \equiv (c_D - c_X + t)\,\frac{St}{2\gamma\psi} < f < (c_D + c_X + t)\,\frac{St}{2\gamma\psi} \equiv f_{\max}, \tag{1.15}$$

where $f_{\min}$ and $f_{\max}$ describe the range of f as a function of ψ for which $0 < c_A < c_X < c_D$.[10]

Credit market frictions — imperfect contract enforcement and liquidation costs — decrease access to external finance and thereby increase the total costs of technology adoption. Hence, firms in a less developed credit market need to be more productive in order to have an incentive to invest in technology adoption. This is reflected by a lower technology adoption cutoff: $dc_A/d\psi < 0$. It follows that firms with cost draws $c \in [(\, c_A, c_A\,(\psi = 1)\,)$ would invest in technology adoption in a perfect credit market but are prevented from doing so by $f_{\text{ext}} > 0$. These are the missing high-technology firms.

1.2.3 Pareto Distributed Production Cost

We assume that productivity (as implied by the cost draw) $1/c$ is Pareto distributed with lower bound $1/c_M$ and shape parameter $k \geq 1$. It follows that the marginal

[10]Note that both c_D and c_D^* depend on $\tau, k, t, f, \gamma, \psi, S, f_E, c_M$.

cost c is also Pareto distributed with shape parameter $k \geq 1$ and support $[0, c_M]$:

$$G(c) = \left(\frac{c}{c_M}\right)^k, \quad c \in [0, c_M]. \tag{1.16}$$

The Pareto distribution has been intensively used in the recent literature as several studies have suggested that it matches the firm size distribution (e.g. Axtell, 2001; Helpman, Melitz, and Yeaple, 2004; Del Gatto, Ottaviano, and Mion, 2006). 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 $k = 1$, $G(c)$ 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. The ex-ante distribution of successful entrants is the Pareto distribution in (1.16) truncated at the entry cutoff c_D

$$G_{c_D}(c) \left(\frac{c}{c_D}\right)^k, \quad c \in [0, c_D]. \tag{1.17}$$

From the law of large numbers (LLN), this is also the ex-post distribution of domestic producers. The ex-ante probability of using the baseline and the advanced technology, conditional on being a producer, is given by $\left[G(c_D) - G(c_A)\right] / G(c_D)$ and $G(c_A)/G(c_D)$, respectively. By the LLN, these expressions also represent the fraction of low-technology and high-technology firms among domestic producers, N_{DL}/N_D and N_{DA}/N_D, where N_D, N_{DL} and N_{DA} denote the absolute number of domestic producers and of domestic low-technology and high-technology firms.

The average cost of production ($\overline{CoP}$) of domestic firms is then

$$\begin{aligned} \overline{CoP} =& \frac{N_{DA}}{N_D} \int_0^{c_A} (c - t) \frac{g(c)}{G(c_A)} dc + \frac{N_{DL}}{N_D} \int_{c_A}^{c_D} c \frac{g(c)}{G(c_D) - G(c_A)} dc \\ =& \frac{k}{k+1} c_D - t \left(\frac{c_A}{c_D}\right)^k. \end{aligned} \tag{1.18}$$

In the following, we focus on the average cost of production as our (inverse) measure of average productivity. As an alternative measure, we also consider aggregate cost where c is weighted either by demand $q(c)$ or by revenues $r(c)$ as (inverse) measure of aggregate productivity (see Appendix A.2 for analytical expressions of aggregate cost).

1.3 Equilibrium Analysis

There is an unbounded mass of ex-ante identical firms who decide whether or not to enter the differentiated good industry. 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 condition is

$$f_E = \int_0^{c_A} \pi_A(c)\, dF(c) + \int_{c_A}^{c_X} \pi(c)\, dF(c) + \int_{c_X}^{c_D} \pi_D(c)\, dF(c).$$

And, solving the integral,

$$\frac{(c_D)^{k+2} + (c_D^* - \tau)^{k+2}}{k+2} + 2t\,(c_A)^{k+1} = \frac{f_E 2\gamma\,(c_M)^k\,(k+1)}{S}, \tag{1.19}$$

where c_A is given by (1.14). The free entry condition for the foreign country is analogous. Each free entry condition will hold as long as there is a positive mass of domestic entrants $N_E > 0$ ($N_E^* > 0$). Otherwise, the respective country abandons the production of the differentiated good and specializes in the numéraire.[11]

(1.19) describes a system of two equations with two unknowns (c_D and c_D^*). An equilibrium in which both countries produce the differentiated good exists if and only if the solution of (1.19), (c_D, c_D^*), takes positive and real values. Lemma 1 shows the conditions under which this is the case. c_D and c_D^* cannot explicitly be solved for because (i) they enter c_A and c_A^* additively and (ii) c_A and c_A^* enter

[11] $N_E = \left\{(c_M)^k / \left[(c_D)^k (c_D^*)^k - (c_X)^k (c_X^*)\right]\right\} \left[N\,(c_D^*)^k - N^*\,(c_X^*)^k\right] \leq 0$ implies $N_E^* = \left\{(c_M)^k / \left[(c_D)^k (c_D^*)^k - (c_X)^k (c_X^*)\right]\right\} \left[N^*\,(c_D)^k - N\,(c_X)^k\right] > 0$. Hence, at most one country specializes in the numéraire. In the following analysis, we assume that $N_E > 0$ and $N_E^* > 0$.

in a nonlinear way. However, it is possible to show that there is a unique equilibrium.

Lemma 1. Provided that ψ, for a given ψ^*, is not too large and thus the difference in credit market development between home and foreign country is not too large, there is a unique equilibrium pair of c_D and c_D^*.

Proof. See Appendix A.1.

This is illustrated in Figures 1.3 and 1.4: FE and FE* plot the free entry con-

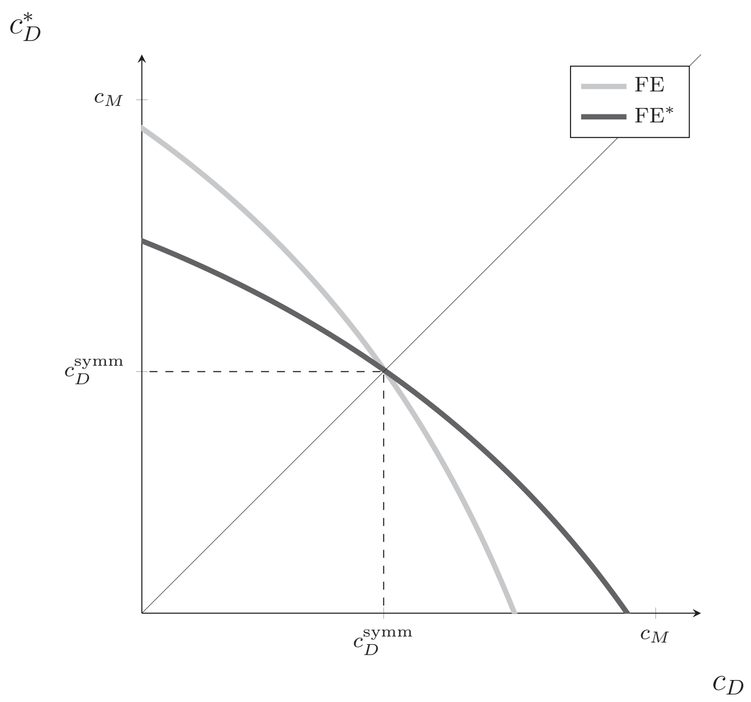


Figure 1.3: Open economy equilibrium: Symmetric countries

ditions of the home and the foreign country in the (c_D, c_D^*) space. Figure 1.3 depicts the symmetric equilibrium ($\psi = \psi^*$). In the symmetric case, the two countries share the same entry cutoff, $c_D = c_D^* = c_D^{\text{symm}}$.

In the following, we assume that the home country has a less developed credit market. Figure 1.4 shows the asymmetric equilibrium ($\psi > \psi^*$): higher costs of

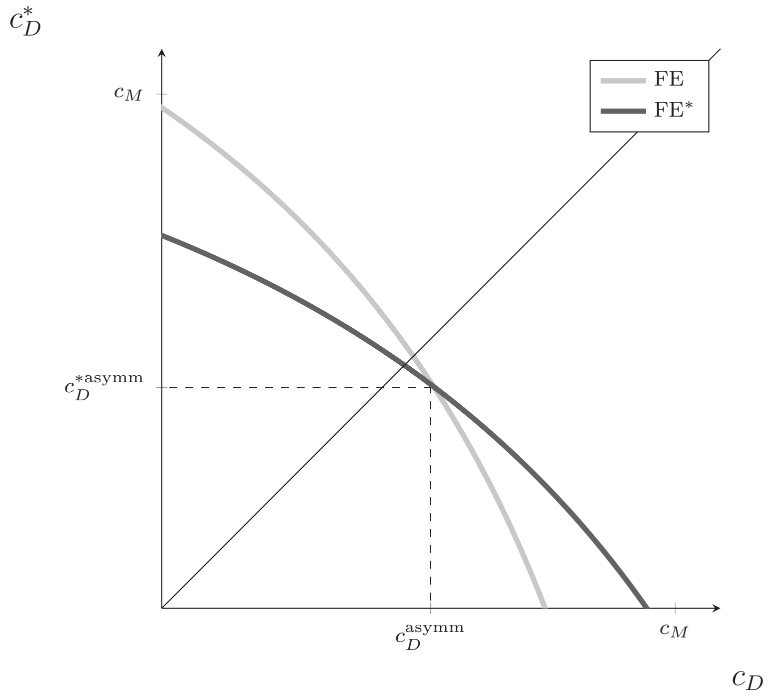


Figure 1.4: Open economy equilibrium: Asymmetric countries

external finance cause an outward shift of the home country's free entry condition curve. Compared to the symmetric case, the resulting equilibrium entry cutoff is lower in the foreign country and higher in the home country, that is, $c_D^{*\text{asymm}} < c_D^{\text{symm}} < c_D^{\text{asymm}}$. Formally, this is reflected by the free entry conditions described by (1.19). Higher costs of external finance make technology upgrading in the home country more expensive than in the foreign country. Some exporters who use the advanced technology in the symmetric case now abstain from technology upgrading. Therefore, ex-ante expected profits and firm entry are lower as reflected by a higher entry cutoff. A higher entry cutoff implies softer selection: average productivity, that is, average competitiveness, is lower. The contrary holds for the foreign country.

$c_D > c_D^*$ implies, by (1.13), that the export cutoff is lower in the home country. Furthermore, the fraction of exporters, given by $(c_X/c_D)^k$, is lower. From (1.14), it follows that the technology adoption cutoff and therefore the fraction of high-technology firms, given by $(c_A/c_D)^k$, is also lower in the home country.
The following proposition summarizes this discussion.

Proposition 1. *Suppose that $f_{min} < f < f_{max}$ such that in equilibrium the following order of cutoffs holds: $0 < c_A < c_X < c_D$. Suppose further that $\psi > \psi^*$. The fraction of exporters, the fraction of high-technology firms and the average productivity of domestic firms are higher in the foreign country. Furthermore, the larger the difference in credit market development (given ψ^*, ψ increases), the larger the absolute and relative difference between the two countries, that is:*

- $\frac{d\left[\left(\frac{c_X^*}{c_D^*}\right)^k - \left(\frac{c_X}{c_D}\right)^k\right]}{d\psi} > 0,\ \frac{d\left[\left(\frac{c_A^*}{c_D^*}\right)^k - \left(\frac{c_A}{c_D}\right)^k\right]}{d\psi} > 0,\ \frac{d\left(\overline{CoP} - \overline{CoP^*}\right)}{d\psi} > 0$
- $\frac{d\left[\left(\frac{c_X^*}{c_D^*}\right)^k / \left(\frac{c_X}{c_D}\right)^k\right]}{d\psi} > 0,\ \frac{d\left[\left(\frac{c_A^*}{c_D^*}\right)^k / \left(\frac{c_A}{c_D}\right)^k\right]}{d\psi} > 0,\ \frac{d\left(\overline{CoP} / \overline{CoP^*}\right)}{d\psi} > 0.$

Proof. See Appendix A.2.

1.4 Trade Liberalization

In the following, we study the effects of trade liberalization via a decrease in trade barriers τ.[12] As a benchmark case, we start by analyzing the symmetric case.

1.4.1 Benchmark: Symmetric Countries

The impact of trade liberalization on the symmetric equilibrium is depicted in Figure 1.5. c_D, c_D^* is the equilibrium before trade liberalization and $c_D^{'}, c_D^{*'}$ the equilibrium after trade liberalization. A reduction in trade 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. In the symmetric case, the free entry condition (1.19)

[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.

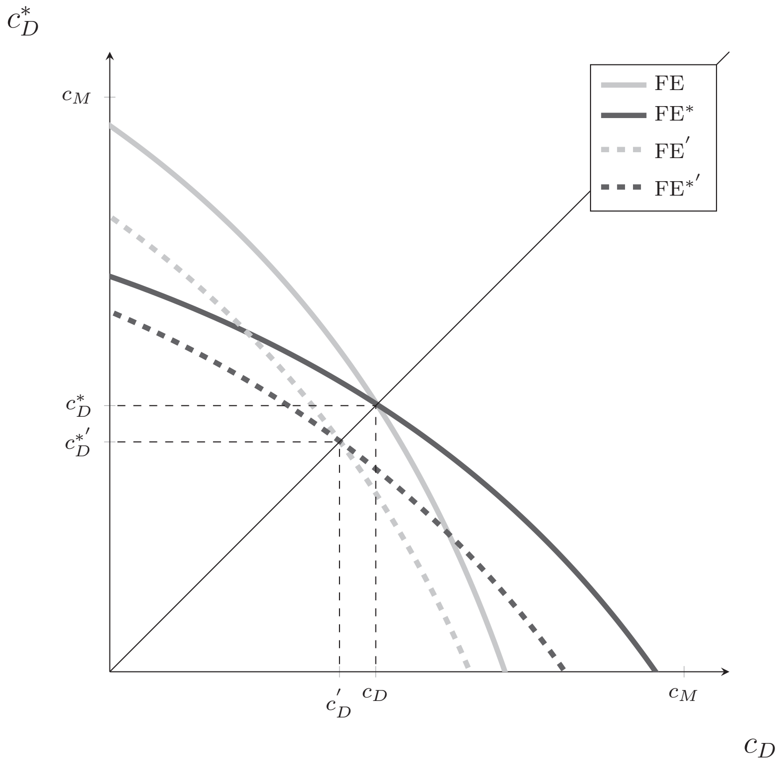


Figure 1.5: Trade liberalization: Symmetric countries

reduces to

$$\frac{(c_D)^{k+2} + (c_D - \tau)^{k+2}}{k+2} + 2t\,(c_A)^{k+1} = \frac{f_E 2\gamma c_M^k (k+1)}{S}. \tag{1.20}$$

From (1.20) we can derive that lower trade barriers τ imply higher expected profits and therefore more entries and a lower entry cutoff (see Proof of Proposition 2 in Appendix A.3):

$$\frac{dc_D}{d\tau} > 0. \tag{1.21}$$

A reduction in trade 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 also, since lower trade costs 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.

Differentiating the export cost cutoff (1.13) with respect to trade barriers τ, we obtain

$$\frac{dc_X}{d\tau} = \frac{dc_D}{d\tau} - 1 < 0. \tag{1.22}$$

Trade liberalization has two opposing effects on the export cost cutoff given by the first and second term in (1.22). Lower trade barriers allow the most productive domestic firms to start exporting (second term). On the other hand, trade liberalization increases competition abroad and makes it more difficult to profitably export (first term). It can be shown that the first effect dominates (see Proof of Proposition 2 in Appendix A.3). Hence, as in standard heterogeneous firm trade models, the export cutoff and the fraction of exporters, $(c_X/c_D)^k$, increase after trade liberalization.

The novelty here is that we can also analyze the effect on the incentive to upgrade technology. From the expression for the technology adoption cutoff (1.14), the impact of trade liberalization on technology upgrading is given by

$$\frac{dc_A}{d\tau} = \frac{1}{2}\left(2\frac{dc_D}{d\tau} - 1\right) < 0. \tag{1.23}$$

A reduction in trade barriers increases the market abroad and induces the most productive low-technology firms to upgrade their technology. This larger market or pro technology-adoption effect is reflected by the second term in the brackets. 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 on the technology adoption cutoff is pro technology-adoption: total output of the most productive low-technology firms increases. Therefore, these firms have a higher return to technology upgrading. Hence, they now invest in the advanced technology. This is expressed by an increase in the technology adoption cutoff c_A after trade liberalization. The fraction of high-technology firms, $(c_A/c_D)^k$, increases as well.

Proposition 2. *Suppose that* $f_{min} < f < f_{max}$ *such that in equilibrium the* *following order of cutoffs holds:* $0 < c_A < c_X < c_D$. *Suppose further that countries are identical. A reduction in trade costs* τ *increases the fraction of exporters, the fraction of high-technology firms, and average productivity.*[13]

Proof. See Appendix A.3.

1.4.2 Asymmetric Countries

How do the results above change if the home country has a less developed credit market and therefore higher costs of external finance? The intuition is best explained graphically (see Proof of Proposition 3 in Appendix A.4 for analytical derivations). Figure 1.6 depicts the new equilibrium.

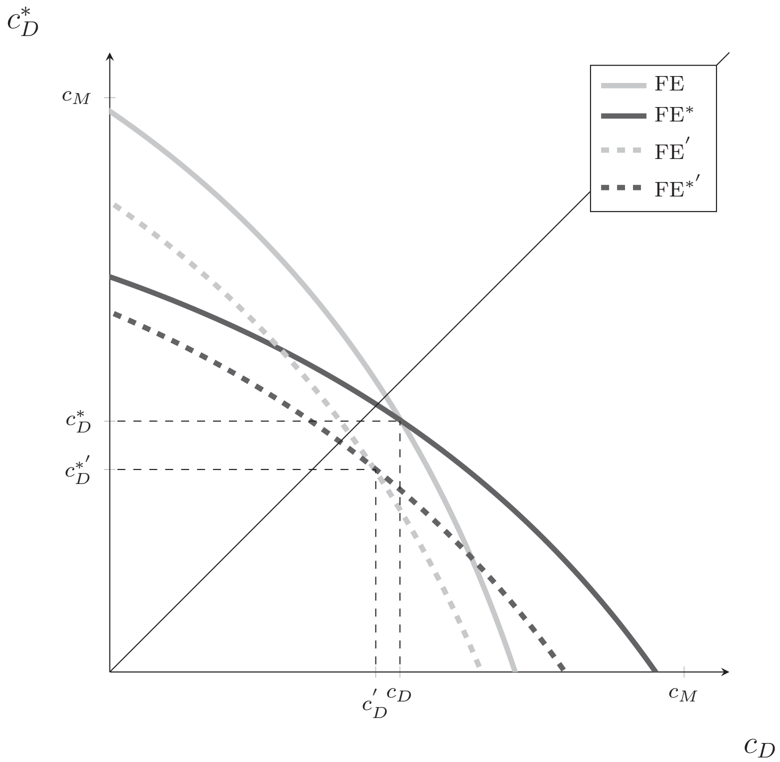


Figure 1.6: Trade liberalization: Asymmetric countries

[13]If $0 < c_X < c_A < c_D$, 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 technology adoption cutoff unambiguously decreases.

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 home country decreases less. The decrease in the entry cutoff in the foreign country, on the other hand, is stronger and the more so the more severe the credit constraints in the home country are. Hence, $dc_D/d\tau < dc_D^*/d\tau$. The reason for this is, as will be shown in the following, that the (initial) export and technology adoption cutoff are higher in the foreign country. Put differently, the (initial) fraction of exporters and high-technology firms is higher and more firms can take advantage of the larger export market after trade liberalization. Therefore, ex-ante expected profits and entry increase more in the foreign country implying a stronger selection effect.

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

$$\frac{dc_X}{d\tau} = \frac{dc_D^*}{d\tau} - 1 < 0, \frac{dc_X^*}{d\tau} = \frac{dc_D}{d\tau} - 1 < 0.$$

Hence, the export cutoff and the fraction of exporters increase in both countries if τ decreases. Moreover, it can be shown that the difference between the two countries with respect to the fraction of exporters increases as τ decreases:

$$\frac{d\left[\left(\frac{c_X^*}{c_D^*}\right)^k - \left(\frac{c_X}{c_D}\right)^k\right]}{d\tau} < 0. \tag{1.24}$$

A reduction in trade barriers increases the technology adoption cutoff (and hence, the fraction of high-technology firms):

$$\frac{dc_A}{d\tau} = \frac{dc_A^*}{d\tau} = \frac{1}{2}\left(\frac{dc_D}{d\tau} + \frac{dc_D^*}{d\tau} - 1\right) < 0. \tag{1.25}$$

The first two terms in the brackets describe again the import competition or anti technology-adoption effect and the third term the larger market or pro technology-adoption effect. The anti technology-adoption effect reflects the increase in competition in the home and in the foreign market after trade liberalization. Since high-technology firms belonging to either country are active in both markets, it is the same for both countries. It decreases in the entry cutoffs c_D and c_D^*, that is, the strength of this effect depends on the initial (before trade liberalization) level of these cutoffs: for a given increase in ex-post expected profits, the entry cutoff c_D has to decrease the more, the lower it was initially, in order to satisfy the free entry condition. The pro technology-adoption effect is also the same for both countries.[14] Hence, the marginal increase in the technology adoption cutoff after trade liberalization is identical across countries and the difference in the technology adoption cutoffs c_A and c_A^* is unchanged, $d\left(c_A^* - c_A\right)/d\tau = 0$. This implies that the percentage increase, $(dc_A/d\tau)/c_A$, is higher in the home country.

We are interested in particular in the impact on the fraction of high-technology firms, $\left(c_A/c_D\right)^k$ and $\left(c_A^*/c_D^*\right)^k$, as an indicator of the average technology level of the home and the foreign country. The increase in the technology adoption cutoff is the same in both countries. The selection effect, however, is larger in the foreign country, that is, c_D^* decreases more than c_D. Therefore, the difference in the fraction of firms that use the advanced technology increases as τ decreases:

$$\frac{d\left[\left(\frac{c_A^*}{c_D^*}\right)^k - \left(\frac{c_A}{c_D}\right)^k\right]}{d\tau} < 0. \tag{1.26}$$

From (1.18), the average cost of production (our main (inverse) measure of average productivity) in home and foreign country is given by

$$\frac{k}{k+1}c_D - t\left(\frac{c_A}{c_D}\right)^k, \frac{k}{k+1}c_D^* - t\left(\frac{c_A^*}{c_D^*}\right)^k.$$

A stronger selection effect in the foreign country implies a larger decrease in the average cost draw, that is, in the average production cost of low-technology firms (first term). Moreover, from (1.26), the difference between the two countries in terms of the fraction of high-technology firms is even larger after trade liberalization (second term). Hence, average productivity increases more in the foreign country: trade liberalization widens the average productivity gap. This is summarized in the

[14]This is due to the per-unit specification of trade costs (τ enters c_A additively).

following proposition:

Proposition 3. *Suppose that $f_{min} < f < f_{max}$ such that in equilibrium the following order of cutoffs holds: $0 < c_A < c_X < c_D$. Suppose further that $\psi > \psi^*$. A reduction in trade costs τ increases the fraction of exporters, the fraction of high-technology firms, and average productivity in both countries. However, the absolute difference between the two countries with respect to the fraction of exporters, the fraction of high-technology firms, and average productivity increases as well. Furthermore, the relative average productivity increases:*

- $\frac{d\left[\left(\frac{c_X^*}{c_D^*}\right)^k - \left(\frac{c_X}{c_D}\right)^k\right]}{d\tau} < 0$, $\frac{d\left[\left(\frac{c_A^*}{c_D^*}\right)^k - \left(\frac{c_A}{c_D}\right)^k\right]}{d\tau} < 0$, $\frac{d\left(\overline{CoP} - \overline{CoP^*}\right)}{d\tau} < 0$
- $\frac{d\left(\overline{CoP}/\overline{CoP^*}\right)}{d\tau} < 0.$

Proof. See Appendix A.4.

The impact of a reduction in τ on the relative difference between the two countries with respect to the fraction of exporters and the fraction of high-technology firms cannot be determined analytically. For our parametrization introduced in Section 1.5, we can show that the relative difference increases after trade liberalization (see Appendix A.5). In addition, we consider a measure of aggregate productivity which corresponds to the cost of production weighted either by demand $q(c)$ or by revenues $r(c)$. The impact of trade liberalization on the aggregate productivity gap can be analyzed only numerically. We do this in Section 1.5.

Thus, trade liberalization increases average productivity and the adoption of advanced technologies in both countries. However, a reduction in trade costs — without improved access to credit — is not enough to ensure convergence between the home and the foreign country. Credit market deficiencies prevent the home country from taking full advantage of the opportunities offered by trade liberalization. First, as fewer firms can take advantage of the larger export market, the selection effect is less severe. Hence, efficiency gains through resource allocation from less to more productive firms are lower. Second, while a reduction in trade costs increases the adoption of advanced technologies, the gap with respect to the fraction of high-technology firms, does not close. For both reasons, the relative average productivity of the country with a developed credit market increases.

1.5 Welfare Analysis

In the following, we parametrize the model to conduct a welfare analysis.

1.5.1 Parametrization

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 $\tau \in [0.7, 1]$ as this reduction of 30% corresponds to the typical reduction in trade costs in the industries most affected by trade liberalization (Constantini and Melitz, 2008). Del Gatto, Ottaviano, and Mion (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 $k = 3.6$. We set $k = 2.5$. The technological leap t is set to 0.5 which corresponds to 10% of the average cost of production in our basic specification below. This is in line with Constantini and Melitz (2008), who calibrate a model of trade liberalization and technology adoption. Finally, Ottaviano, Taglioni, and Di Mauro (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 cost (c_M), and market size (S), are scale parameters that are chosen to be in line with our assumption on the cutoff ranking, namely

$$0 < c_A < c_X < c_D < c_M. \tag{1.27}$$

The range of parameter values to measure credit market development (ψ, ψ^*) is selected to satisfy (1.27), $q_0^c > 0$, $N_E > 0$ and $N_E^* > 0$ and to allow for a large enough difference in the total technology adoption costs between the two countries. In particular, $S = 1$, $f_E = 10 = c_M$, $\psi, \psi^* \in [1, 1.25]$. Furthermore, the fixed cost of technology adoption is set to $f = 10$.

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

- $\tau = 0.8$
- $k = 2.5$
- $t = 0.5$
- $\gamma = 0.2$.

1.5.2 Welfare Analysis

We use the indirect utility function associated with (1.1) to analyze the implications for social welfare (see Melitz and Ottaviano (2008), p. 298):

$$W = I^c + \frac{N}{\gamma}\frac{\sigma_p^2}{2} + \frac{1}{2}\left(\frac{\gamma}{N} + \beta\right)^{-1}(\alpha - \bar{p})^2. \tag{1.28}$$

Welfare increases with an increase in the number of varieties sold in the market (N) and in the price variance (σ_p^2), and decreases with an increase in the average price $(\bar{p})$.

The average price in the open economy is

$$\bar{p} = \frac{2k+1}{2(k+1)}c_D - (p - p_A)\frac{N_A}{N} + \frac{(p_X - p)}{k+1}\frac{N_X^*}{N}, \tag{1.29}$$

where the first term gives the average price of low-technology firms and the second term the price difference between low- and high-technology firms weighted by the share of high-technology sellers in the economy. The share of high-technology sellers is the sum of the share of domestic N_{DA}/N and of foreign high-technology firms N_{XA}^*/N. The third term corresponds to difference between export and domestic prices weighted with the share of foreign firms in the economy. Because of tougher selection (lower c_D), the average price of low-technology firms is lower in the foreign country (first term). The fraction of high-technology sellers and the fraction of foreign firms might be higher in either country. Hence, it is a priori unclear if the average price is higher in the home country or in the foreign country.

The number of firms in each country is given by:

$$N = \frac{\frac{\gamma}{\beta}\frac{(\alpha - c_D)c_D^*}{2(k+1)} + \frac{t}{2}\frac{1}{D}\left[(c_D)^k (c_A^*)^k - (c_X^*)^k (c_A)^k\right]\frac{\gamma}{\beta}(c_D^* - c_D)}{\frac{c_D c_D^*}{4(k+1)^2} + \frac{t}{4(k+1)D}\Delta + \frac{t\tau}{4D(k+1)}\Theta} + \frac{\frac{\gamma}{\beta}\frac{\tau(c_X*)^k}{2D(k+1)}\left[(\alpha - c_D)(c_X)^k + (\alpha - c_D^*)(c_D)^k\right]}{\frac{c_D c_D^*}{4(k+1)^2} + \frac{t}{4(k+1)D}\Delta + \frac{t\tau}{4D(k+1)}\Theta}, \tag{1.30}$$

where

$$\begin{aligned} D &= (c_D)^k (c_D^*)^k - (c_D - \tau)^k (c_D^* - \tau)^k \\ \Delta &= c_D\left\{(c_D)^k (c_A^*)^k - (c_X^*)^k\left[(c_A)^k - \frac{\tau(c_X)^k}{t(k+1)}\right]\right\} \\ &\quad + c_D^*\left\{(c_D^*)^k (c_A)^k - (c_X)^k\left[(c_A^*)^k - \frac{\tau(c_X^*)^k}{t(k+1)}\right]\right\} \\ \Theta &= \left[(c_X)^k (c_A^*)^k + (c_X^*)^k (c_A)^k - \frac{\tau (c_X)^k (c_X^*)^k}{t(k+1)}\right]. \end{aligned}$$

The price variance σ_p^2 is the sum of the price variances of domestic and foreign sellers weighted with their shares in the total population of sellers:

$$\sigma_p^2 = \frac{N_D}{N}\sigma_{p,dom}^2 + \frac{N_X^*}{N}\sigma_{p,exp}^2. \tag{1.31}$$

We use the basic specification above to assess the overall impact of credit constraints on average price, number of sellers, price variance, and welfare. Table 1.1 shows that the fraction of high-technology sellers N_A/N is higher in the home country. This is due to the large fraction of high-technology firms that export from the foreign to the home country. However, a higher average price of low-technology firms leads to

	Home	Foreign
N_A/N	0.1822	0.1608
N_X^*/N	0.8086	0.1231
$\bar{p}$	7.0329	6.81622
N	1.7286	1.9592
σ_p^2	0.7661	0.8330
W	1.1882	1.2203

Table 1.1: Parametrization: Equilibrium outcomes
($t = 0.5$, $k = 2.5$, $\gamma = 0.2$, $S = 1$,$f = f_E = c_M = 10$, $\psi = 1.25$)

τ	$\bar{p}$	$\bar{p}^*$	N	N^*	σ_p^2	$\left(\sigma_p^2\right)^*$	W	W^*
1.0000	7.0922	6.9202	1.7094	1.8904	0.7692	0.8270	1.1825	1.2075
0.9500	7.0771	6.8956	1.7150	1.9065	0.7683	0.8280	1.1840	1.2105
0.9025	7.0629	6.8715	1.7199	1.9224	0.7675	0.8292	1.1854	1.2134
0.8574	7.0495	6.8477	1.7241	1.9382	0.7668	0.8307	1.1867	1.2164
0.8145	7.0371	6.8243	1.7276	1.9538	0.7663	0.8324	1.1878	1.2193
0.7738	7.0255	6.8013	1.7302	1.9693	0.7659	0.8343	1.1889	1.2222
0.7351	7.0147	6.7786	1.7321	1.9846	0.7656	0.8364	1.1899	1.2252

τ	$\bar{p}/\bar{p}^*$	N/N^*	$\sigma_p^2/\left(\sigma_p^2\right)^*$	W/W^*
1.0000	1.0249	0.9043	0.9301	0.9793
0.9500	1.0263	0.8996	0.9279	0.9781
0.9025	1.0279	0.8947	0.9256	0.9769
0.8574	1.0295	0.8895	0.9231	0.9756
0.8145	1.0312	0.8842	0.9206	0.9742
0.7738	1.0330	0.8786	0.9181	0.9728
0.7351	1.0349	0.8727	0.9154	0.9712

Table 1.2: Impact of a 5%-decrease in trade costs on welfare
($t = 0.5$, $k = 2.5$, $\gamma = 0.2$, $S = 1$,$f = f_E = c_M = 10$, $\psi = 1.25$)

a higher average price and, together with a lower number of sellers, to lower welfare in the home country.

We next use the basic specification to study the effect of a 5%-decrease in trade costs τ on welfare in the two countries. Table 1.2 shows the simulation results for welfare and the three variables that determine welfare ($\bar{p}$, N, σ_p^2).

A reduction in trade costs τ increases the number of varieties in both countries. However, N increases less than N^*. The average price decreases in both markets but it decreases more in the foreign country. The price variance that positively affects welfare increases more in the foreign country. Hence, welfare increases in

τ	Average productivity $\overline{CoP}$	$\overline{CoP^*}$	Aggregate productivity $\overline{CoP_q}$	$\overline{CoP_q^*}$	$\overline{CoP_r}$	$\overline{CoP_r^*}$
1.0000	5.8301	5.6914	26.3507	25.3051	177.0300	165.1811
0.9500	5.8183	5.6737	26.244	25.1547	175.9566	163.6664
0.9025	5.8071	5.6565	26.1434	25.0084	174.9478	162.1963
0.8574	5.7966	5.6398	26.0491	24.8658	174.0027	160.7685
0.8145	5.7867	5.6233	25.9609	24.7267	173.1202	159.3807
0.7738	5.7775	5.6073	25.8786	24.5911	172.2992	158.0304
0.7351	5.7690	5.5915	25.8023	24.4585	171.5386	156.7151

τ	$\overline{CoP}/\overline{CoP^*}$	$\overline{CoP_q}/\overline{CoP_q^*}$	$\overline{CoP_r}/\overline{CoP_r^*}$
1.0000	1.0244	1.0413	1.0717
0.9500	1.0255	1.0433	1.0751
0.9025	1.0266	1.0454	1.0786
0.8574	1.0278	1.0476	1.0823
0.8145	1.0291	1.0499	1.0862
0.7738	1.0304	1.0524	1.0903
0.7351	1.0317	1.0549	1.0946

Table 1.3: Impact of a 5%-decrease in trade costs on productivity ($t = 0.5$, $k = 2.5$, $\gamma = 0.2$, $S = 1$,$f = f_E = c_M = 10$, $\psi = 1.25$)

both countries but the welfare increase is larger in the foreign country. The welfare gap between the two countries thus widens.

From Section 1.4.2, we know that the average productivity gap increases too. Table 1.3 shows the simulation results for aggregate production cost, our (inverse) measures of aggregate productivity, where $\overline{CoP_q}$, $\overline{CoP_q^*}$ denotes weighting with demand $q(c)$ and $\overline{CoP_r}$, $\overline{CoP_r^*}$ describes weighting by revenues $r(c)$. Both measures of aggregate production cost decrease after trade liberalization and more so in the foreign country, that is, the relative aggregate costs increase. We interpret this result as an increase in the aggregate productivity gap.

1.6 Conclusion

Even though recommended to many developing countries, only if certain conditions are met does opening up to trade enhance economic convergence. This paper examines the role of credit market imperfections as a reason for a potentially detrimental effect of trade liberalization on convergence. In particular, we introduce the possibility of investing in a more efficient technology into a two-country heterogeneous firm model with variable mark-ups. The two countries may differ with respect to credit market development: in the less developed country, firms face more severe credit constraints and therefore higher costs of technology upgrading. As a consequence, credit constrained firms cannot take advantage of the larger market to the same extent but face fiercer import competition. Therefore, the difference between the two countries with respect to the fraction of domestic firms that invest in the advanced technology increases. Hence, the productivity gap between the two countries widens. Moreover, our simulations show that the welfare gap also increases after trade liberalization.

Our focus is on the interplay of trade liberalization and credit market frictions because credit market deficiencies are a major obstacle to achieving convergence. However, our model could naturally be extended to the analysis of other market imperfections.

Our results have important policy implications. Trade liberalization fosters convergence if and only if firms in emerging countries have equal access to external finance. In order to reduce the productivity gap, a reduction in trade barriers must thus be accompanied by credit market development. In our model, small and medium-sized firms might have an incentive to invest in technology adoption but are prevented from doing so by high costs of external finance. Policies aimed at increasing the access of smaller firms to external finance are therefore expected to have a strong effect.

Our model has abstracted from several important considerations. First, we assume a quasi-linear utility function that allows normalizing the wage to unity. In doing so, we ignore the effect that trade liberalization might have on (relative) wages (e.g. Bustos, 2011). Second, we abstract from the possibility that firms serve the foreign market through foreign direct investment. An interesting extension would thus be to include knowledge spillovers from foreign to domestic producers. Third, we focus on technology adoption and do not consider product innovation. However, following Atkeson and Burstein (2010), we can interpret entry into the differentiated good industry as product innovation. Our model then shows that trade liberalization increases the divergence between developed and less developed country in product innovation activity.

Chapter 2

Financial Constraints and the Missing Technology Adoption

2.1 Introduction

Despite numerous reform agendas, cross-country differences in per capita income are surprisingly persistent over time. One major consensus that has emerged from the discussion on why some countries grow and others don't is that innovation is a major determinant of economic growth. For developing countries, the adoption of new technologies is the most important part of the innovation process (Hall, 2006). Weak financial market development in these countries, however, is a major obstacle to technology adoption. Aghion, Howitt, and Mayer-Foulkes (2005), for example, show that financial constraints prevent less developed countries from adopting new technologies, and lead to persistent income differences between countries. While their study is at the country level, it is necessary to go to the firm level and examine how financial market development shapes firms' growth-related investments in order to provide meaningful policy implications.

This paper is an attempt to do so by providing new firm level evidence of the impact of cross-country differences in financial market development on investments in export activities and, most importantly, in new, more advanced technologies. The underlying thought experiment is as follows. Consider the probability that a firm active in a country with a developed financial market invests in the adoption of an advanced production technology. Then, compare this probability to the likelihood that the very same firm adopts an advanced technology in a less developed financial market. The difference in probabilities is what we call the *missing technology adoption*.

To guide our empirical analysis, we extend the heterogeneous firm model developed in Peters and Schnitzer (2012) to multiple industries and to allow for heterogeneous costs of external finance. In the model, firms have the option to invest in a more expensive but more efficient production technology, as in Bustos (2011). Consistent with the data used in the empirical analysis, external finance is assumed to be more costly for smaller firms. The impact of financial market development thus differs across the firm size distribution. The largest firms have sufficient access to external finance, but the very small firms, which are financially constrained, have no incentive to pay the cost of such investment. Firms in the middle of the size distribution, however, would invest in a developed financial market but are prevented from doing so in a less developed financial market. Those firms thus account for the missing technology adoption and are the most affected by financial development.

We test the predictions of the model using data from the World Bank Enterprise Surveys. These are firm level surveys conducted by the World Bank in a large number of countries. The Enterprise Surveys are ideal for the purpose of our study for two reasons. First, almost all countries which have been surveyed are developing and emerging economies. These countries are very likely to exhibit missing technology adoption and the cross-country variation is large enough to allow for robust results. Second, the survey questionnaire includes detailed questions about export behavior, investment in new technologies, and access to external finance. Hence, we are able to construct direct measures of technology use and access to finance. The use of direct measures reduces measurement error and is a major advantage over other studies that have relied on indirect proxies, for example TFP estimations and balance sheet data.

For empirical identification, we exploit the variation in financial dependence across industries, in addition to the variation in financial development across countries. In particular, the main explanatory variable is an interaction between countries' financial development and the sectoral dependence on external finance. This amounts to a comparison of industries with different external financing needs across countries at different levels of financial development: firms active in industries with high external financing needs have a relatively higher probability of exporting and of investing in new technologies in financially developed countries.[15]

This identification strategy has several advantages. Using an interaction between a country (financial development) and an industry characteristic (external financial dependence) to study the impact of financial market development on firm level investments allows the inclusion of country and industry dummies. Hence, we control for country and industry characteristics that might be correlated with both financial market development and investments, and thus avoid an important source of omitted variable bias. A further advantage is that both the variation at the country and at the industry level are exogenous to the firm. This is important because the main difficulty in most firm level studies on financial constraints is to avoid the endogeneity bias due to reverse causality.

First, we show that financial market development increases the access to external finance, especially in industries which require a lot of external funding. Second, we find that the probability that a firm exports increases with an increase in financial market development (and disproportionately so in financially dependent industries). Our results thus confirm the existence of financial constraints in international trade found in the existing literature. The positive effect of financial market development is driven by firms in the lower quartiles of the firm size distribution. Hence, financial constraints primarily prevent the smaller firms from serving foreign markets. Third, and most importantly, we provide evidence for the missing technology adoption. Given country and industry characteristics, a lower level of financial market development decreases the probability of using new technologies. This result is strongest

[15] This approach was proposed by Rajan and Zingales (1998).

in industries with high external financing needs. We consider two types of investments in new technologies: investment in less costly and investment in very costly new technologies. In the case of less costly investments, financial development has the largest effect on firms in the lower size quartiles. For very costly investments, the effect is largest for firms in the fourth size quartile.

Our paper contributes to two strands of literature. First, it is related to previous research on the determinants of economic growth and convergence. These studies document the positive effect of financial market development on technological progess and economic growth at the country level (e.g. Beck, Levine, and Loayza, 2000; Levine, Loayza, and Beck, 2000). Aghion, Howitt, and Mayer-Foulkes (2005), for example, show, both theoretically and empirically, that financial constraints prevent less developed countries from taking advantage of international technology transfers. In a similar vein, a body of work has argued that in the presence of financial constraints, financially developed countries have a comparative advantage in more financially dependent industries (e.g. Beck, 2002; Buera, Kaboski, and Shin, 2009; Manova, 2011). The present paper brings the analysis to the firm level and provides micro-level evidence of the detrimental impact of financial constraints on technology adoption. Furthermore, it shows that the impact of financial development differs across the firm size distribution. It is thus important to take into account firm heterogeneity when designing policies destined to improve sectoral competitiveness.

The second strand of literature examines empirically the effect of financial constraints on firm behavior. Beck, Demirgüç-Kunt, and Maksimovic (2005) and Beck, Demirgüç-Kunt, Laeven, and Levine (2008) use data from the World Bank Enterprise Surveys to study the effect of legal and financial constraints on firm growth. In line with our results, they show that smaller firms are those most affected by financial constraints which are the most important obstacle to firm growth. A number of empirical studies provide evidence for the detrimental effect of financial constraints on export behavior: Greenaway, Guariglia, and Kneller (2007) for firms in the UK, Muûls (2008) for Belgian firms, Minetti and Zhu (2011) for a sample of Italian firms, and McCann and Peters (2012) for Eastern European firms. Berman and Héricourt

(2010) study firms in nine developing countries using data from the Enterprise Surveys. A small number of papers analyze the effect of financial constraints on the innovative behavior of firms in different countries. Seker (2012) finds, in a sample of firms taken from the Enterprise Surveys, a positive correlation between access to finance and product and process innovation. Using BEEPS data (a subset of the World Bank Enterprise Surveys), Gorodnichenko and Schnitzer (2012) establish a negative causal effect of financial constraints on innovative activity. Our paper, on the other hand, examines the impact of financial constraints on technology adoption, an innovative activity that is particularly important for developing countries. Furthermore, none of these studies accounts for the heterogeneous effect of financial market development across the firm size distribution.

Finally, the paper probably most related to our study is Maskus, Neumann, and Seidel (2012). Using a similar identification strategy, the authors show that financial development increases the innovative activity disproportionately in industries with large external financing needs. The focus of their paper is, however, slightly different. While Maskus, Neumann, and Seidel (2012) study the effect on sectoral R&D intensity in OECD countries, our focus is on the missing technology adoption in developing economies. Moreover, our analysis uses firm level data and documents the importance of taking into account firm heterogeneity.

The paper is organized as follows. Section 2.2 presents the theoretical model and the resulting predictions. The data are described in Section 2.3. Section 2.4 explains the econometric approach and presents the results. Section 2.5 provides some sensitivity tests and Section 2.6 concludes.

2.2 The Model

This section develops a model of the decision to export and adopt an advanced technology in the presence of financial constraints. In the model, firms are heterogeneous, as in Melitz and Ottaviano (2008), and have the option to decrease their production cost by investing in technology adoption, as in Bustos (2011).[16] Furthermore, firms require external finance to cover the fixed investment cost. We consider two countries, home and foreign, that differ in their financial market development. The variables with an asterisk pertain to the foreign country.

2.2.1 Setup of the Model

Both countries have a population S and each inhabitant is endowed with one unit of labor. Labor is the only factor of production. There are two types of industries, an industry that produces a homogeneous good, which serves as numéraire, and $k = 1, ..., K$ differentiated goods industries.

Preferences. Preferences in the two countries are described by the quasi-linear quadratic utility function developed by Ottaviano, Tabuchi, and Thisse (2002):

$$U = q_0^c + \Pi_k \left[\alpha \int_{i\in\Omega_k} q_{ik}^c di - \frac{1}{2}\gamma \int_{i\in\Omega_k} \left(q_{ik}^c\right)^2 di - \frac{1}{2}\beta \left(\int_{i\in\Omega_k} q_{ik}^c di \right)^2 \right]^{\theta_k}, \qquad (2.1)$$

where $\alpha, \beta, \gamma > 0$. q_0^c and q_{ik}^c denote the per capita consumption of the homogeneous good and of each variety i of the differentiated good k. α, β characterize the substitutability of the homogeneous good for the differentiated good k. γ represents the degree of product differentiation with $\gamma = 0$ indicating perfect substitutability. The θ_k indicate the shares of the differentiated goods industries in the total expenditure on differentiated goods, and we have $\sum_k \theta_k = 1$ and $0 < \theta_k < 1$.
These preferences generate the linear demand system

$$q_{ik} = Sq_{ik}^c = \frac{\alpha S}{\gamma + \beta N_k} - \frac{S}{\gamma} p_{ik} + \frac{\beta N_k}{\gamma + \beta N_k} \frac{S}{\gamma} \overline{p_k}. \qquad (2.2)$$

$\overline{p_k} = 1/N \int_{i\in\Omega_k'} p_{ik} di$ is the average price and N_k the number of consumed varieties in industry k.

[16]The Melitz and Ottaviano framework is as tractable as the Melitz framework and models the competition effect of international linkages — which is an important determinant of the incentive to invest in exporting and technology adoption — as we observe it in the real world via the product market.

Variety ik is consumed whenever $p_{ik} \leq p_k^{\max}$ where $p_k^{\max}$ is the prohibitive price above which demand q_{ik} is equal to zero.

Supply. The homogeneous good is produced under perfect competition and at unit labor requirement. If a positive demand for the homogeneous good is assumed, the wage in both countries equals unity.

The differentiated goods industries are characterized by monopolistic competition and free entry. Production is at constant returns to scale with firm-specific labor requirement c_{ik}. c_{ik} reflects the cost differences between firms. A firm which produces at a lower cost has a larger demand, and therefore a higher output. Entry requires a fixed investment f_{Ek}. This investment is thereafter sunk: it captures start-up costs, such as setting up a facility and buying equipment. Upon entry, firms draw their production cost from a common Pareto distribution with lower bound $1/c_M$ and shape parameter $k \geq 1$, $G(c) = (c/c_M)^k$. When learning the cost of production, firms decide (i) whether to exit the industry or to stay and produce, and if they produce, then (ii) whether to export and whether to invest in technology adoption.

Technology adoption. Technology is assumed to be industry specific. Firms have the option of upgrading their technology by paying f_k units of labor. The fixed technology adoption cost f_k can be thought of as a per period fixed cost that comes with acquiring a more advanced technology, as for example the rent or the licensing fee for new machinery, or its periodized purchasing cost. One way to think about technology upgrading is that it reduces production cost by a fixed amount t_k: firms adopt a process innovation that reduces the labor input requirement. An alternative interpretation of t_k is as an increase in the price margin through the adoption of an advanced technology that increases quality at unchanged cost. t_k is called the "technological leap". Advanced technology thus comes at a higher fixed cost but increases productivity.

Financial constraints. The fixed cost of technology adoption f_k is paid upfront. Internal funds are not sufficient to cover the investment, that is, firms need to raise external finance for a fraction of the fixed technology adoption cost. For simplicity, we normalize the fraction financed externally to one. However, the results are unchanged if an industry specific fraction d_k is assumed instead.

The credit market is imperfect. In particular, we assume weak creditor protection. Creditors are repaid with probability λ, $\lambda \in (0,1)$, and with probability $1-\lambda$, firms default. Therefore, creditors require a collateral $C_{ik} > 0$ that they can seize in case the credit is not repaid. However, in case of default, they realize only a fraction θ, $\theta \in (0,1)$ of the collateral, due to liquidation costs.

The credit market is perfectly competitive. Creditors make firms a take it or leave it offer specifying the required repayment R_{ik}

$$\lambda R_{ik} + (1-\lambda)\theta C_{ik} = f_k \Leftrightarrow R_{ik} = \frac{f_k - (1-\lambda)\theta C_{ik}}{\lambda}. \tag{2.3}$$

Firms use the net revenue from technology adoption, $\pi_{ik}^{A,var}(c_{ik}) - \pi_{ik}(c_{ik})$, to repay creditors, where $\pi_{ik}^{A,var}(c_{ik})$ are the variable profits when using the advanced technology. The net revenue increases with firm size, that is, larger firms gain more from technology adoption. The idea is that this makes it easier for creditors to enforce repayment, and hence lowers the collateral requirement. Firms restrict the collateral to the minimum collateral required[17]:

$$\begin{aligned} \pi_{ik}^{A,var}(c_{ik}) - \pi_{ik}(c_{ik}) &= \frac{f_k - (1-\lambda)\theta C_{ik}}{\lambda} \\ \Leftrightarrow C_{ik} &= \max\left\{\frac{f - \lambda\left[\pi_{ik}^{A,var}(c_{ik}) - \pi_{ik}(c_{ik})\right]}{(1-\lambda)\theta}, 0\right\}. \end{aligned} \tag{2.4}$$

The total cost functions of firms using the baseline and the advanced technology, respectively, TC_{ik} and TC_{ik}^A, are

$$\begin{aligned} TC_{ik}\left(c_{ik}\right) &= c_{ik} q_{ik} \\ TC_{ik}^A\left(c_{ik}\right) &= \left(c_{ik} - t_k\right) q_{ik}^A + \lambda R_{ik} + (1-\lambda) C_{ik} = \left(c_{ik} - t_k\right) q_{ik}^A + f_k + f_{ik}^{\text{ext}}, \end{aligned} \tag{2.5}$$

[17]Hence, the collateral is endogenous, as in Buch, Kesternich, Lipponer, and Schnitzer (2009).

where $f_{ik}^{\text{ext}} = (1-\lambda)(1-\theta)C_{ik}$. Weaker creditor protection, higher liquidation costs, and a larger collateral requirement increase the cost of obtaining external finance. Very large firms have zero collateral requirement ($C_{ik} = 0$) and therefore no extra costs of obtaining external finance.

Exporting. Serving the foreign market involves per-unit trade costs, $\tau > 0$.[18]

2.2.2 Firm Behavior

Prices and profits. Let p_{ik}^{D}, p_{ik}^{X}, p_{ik}^{DA}, and p_{ik}^{XA} denote the price in the domestic and in the export market of firms using the baseline technology and of firms using the advanced technology, respectively. Profit maximization implies

$$\begin{aligned} p_{ik}^{D} &= \frac{1}{2}\left(p_k^{\max} + c_{ik}\right), \quad p_{ik}^{X} = \frac{1}{2}\left(p_{k*}^{\max} + c_{ik} + \tau\right) \\ p_{ik}^{DA} &= \frac{1}{2}\left(p_k^{\max} + c_{ik} - t_k\right), \quad p_{ik}^{XA} = \frac{1}{2}\left(p_{k*}^{\max} + c_{ik} + \tau - t_k\right). \end{aligned}$$

The prices charged by firms using the advanced technology are lower: $p_{ik}^{DA} = p_{ik}^{D} - t_k/2$ and $p_{ik}^{XA} = p_{ik}^{X} - t_k/2$. Accordingly, the quantities sold are higher. Technology adoption increases the variable profits but involves a higher fixed cost. The profits of firms serving only the domestic market using the baseline and the advanced technology are given by

$$\pi_{ik}^{D} = \frac{S}{4\gamma}\left(p_k^{\max} - c_{ik}\right)^2, \quad \pi_{ik}^{DA} = \frac{S}{4\gamma}\left(p_k^{\max} - c_{ik} + t_k\right)^2 - f_k - f_{ik}^{\text{ext}}. \tag{2.6}$$

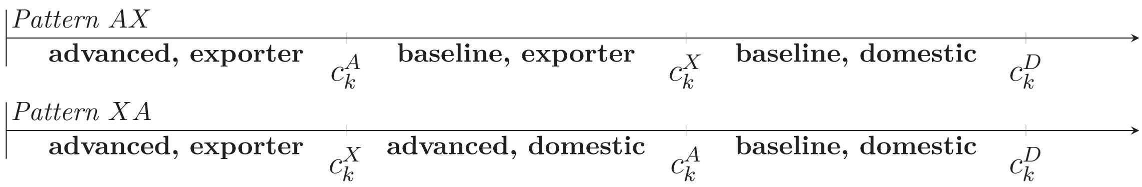
[18] The iceberg form of the trade costs implies that firms with lower production cost also have access to a transport technology of lower cost. Therefore, reallocation forces are distorted (Schroeder and Sorensen, 2011; Irarrazabal, Moxnes, and Opromolla, 2011).

The profits of firms serving also the foreign market are, respectively,

$$\begin{aligned}
\pi_{ik} &= \pi_{ik}^{D} + \pi_{ik}^{X} = \frac{S}{4\gamma}\left[(p_k^{\max} - c_{ik})^2 + (p_{k*}^{\max} - c_{ik} - \tau)^2\right] \\
\pi_{ik}^{A} &= \pi_{ik}^{DA} + \pi_{ik}^{XA} = \frac{S}{4\gamma}\left[(p_k^{\max} - c_{ik} + t_k)^2 + (p_{k*}^{\max} - c_{ik} - \tau + t_k)^2\right] - f_k - f_{ik}^{\text{ext}}.
\end{aligned} \tag{2.7}$$

Firms' sorting pattern. Denote by c_k^D, c_k^X, and c_k^A, respectively, the cost cutoffs below which firms in industry k stay in the market and produce, serve the foreign market, and invest in technology adoption. In the data used for the empirical analysis, only a subset of the domestic producers serve the foreign market and/or use an advanced production technology, that is, $c_k^X < c_k^D$ and $c_k^A < c_k^D$. Furthermore, there are two possible sorting patterns (Figure 2.1). The sorting pattern AX ($c_k^A < c_k^X$)

Figure 2.1: Sorting patterns



obtains if the fixed cost of technology adoption f_k is high. In this case, the marginal technology adopter is an exporter, that is all purely domestic firms use the baseline technology. The sorting pattern XA ($c_k^X < c_k^A$) results if f_k is low. Then, the marginal technology adopter is a purely domestic firm and all exporters use the advanced technology. In the empirical analysis, we consider two types of new technologies: one associated with low, and one associated with high cost of adoption.
In the following, the firm decisions for sorting pattern AX will be derived. The analysis for sorting pattern XA is analogous (see Appendix B.1).[19]

Firm decisions. The least productive firms serve only the domestic market and

[19] In the following, we will derive analytical expressions for the cutoffs and then provide the parameter restrictions that correpond to each sorting pattern.

use the baseline technology. They decide to stay in the market and produce if their profits π_{ik}^{D} are non-negative:

$$\pi_{ik}^{D}(c_k^D) = 0 \;\Leftrightarrow\; c_k^D = p_k^{\max}. \tag{2.8}$$

Firms export if they can profitably serve the foreign market. This is the case if their production costs are below the export cutoff c_k^X where

$$\pi_{ik}^{X}(c_k^X) = 0 \Leftrightarrow c_k^X = c_{k*}^D - \tau. \tag{2.9}$$

Exporters invest in technology adoption if their total profits are higher when using the advanced technology, that is, if $\pi_{ik}^{A}(c_{ik}) \geq \pi_{ik}(c_{ik})$. The technology adoption decision depends on the total costs of technology adoption, $f_k + f_{ik}^{\text{ext}}$. The largest firms have no extra costs of external finance, and pay only the fixed cost of technology adoption, f_k. These are the financially not constrained (NC) firms with production cost below c_{NC}, where, from (2.4),

$$c_k^{NC} = \frac{1}{2}\left(c_k^D + c_{k*}^D + t_k - \tau - \frac{1}{\lambda}\frac{2\gamma f_k}{St_k}\right). \tag{2.10}$$

Firms with production cost above c_{NC} have to pay for external finance.

The technology adoption cutoff c_k^A depends on whether the marginal technology adopter is a financially unconstrained or a financially constrained firm:

$$c_k^A = \left\{ \begin{array}{l} \frac{1}{2}\left(c_k^D + c_{k*}^D + t_k - \tau - \frac{2\gamma f_k}{St_k}\right) \text{ if } c_{ik} \leq c_k^{NC} \\ \frac{1}{2}\left[c_k^D + c_{k*}^D + t_k - \tau - \frac{1}{\theta+(1-\theta)\lambda}\frac{2\gamma f_k}{St_k}\right] \text{ if } c_{ik} > c_k^{NC} \end{array} \right\}. \tag{2.11}$$

It follows from (2.10) and (2.11) that $c_k^{NC} < c_k^A \left(c_{ik} > c_k^{NC}\right)$: all financially unconstrained firms invest in the advanced technology. The marginal technology adopter is thus a financially constrained firm and the technology adoption cutoff is

$$c_k^A = \frac{1}{2}\left[c_k^D + c_{k*}^D + t_k - \tau - \frac{1}{\theta + (1-\theta)\lambda}\frac{2\gamma f_k}{S t_k}\right].^{20} \tag{2.12}$$

Firms with cost draws $c_{ik} \in [(\, c_k^A\,(\lambda < 1)\,, c_k^A\,(\lambda = 1)\,)$ would invest in technology adoption if the financial market were perfect, but are prevented from doing so by $f_{ik}^{\text{ext}} > 0$. The probability of being in that cost interval is what we call the *missing technology adoption*.

2.2.3 Industry Equilibrium

Free entry ensures that, in each industry k, firms enter until expected profits are equal to the fixed entry cost f_{Ek}. The resulting free entry condition for industry k is

$$\begin{aligned} f_{Ek} = & \int_0^{c_k^{NC}} \left[\pi_{ik}^A\,(c_{ik}) + f_{ik}^{\text{ext}}\right] dF(c_{ik}) + \int_{c_k^{NC}}^{c_k^A} \pi_{ik}^A\,(c_{ik})\,dF(c_{ik}) \\ & + \int_{c_k^A}^{c_k^X} \pi_{ik}^X\,(c_{ik})\,dF(c_{ik}) + \int_{c_k^X}^{c_k^D} \pi_{ik}^D\,(c_{ik})\,dF(c_{ik}). \end{aligned}$$

And, solving the integral,

$$\begin{aligned} \frac{\left(c_k^D\right)^{k+2} + \left(c_{k*}^D - \tau\right)^{k+2}}{k+2} + \frac{2t_k}{\theta}\left\{[\theta + (1-\theta)\lambda]\left(c_k^A\right)^{k+1} - (1-\theta)\lambda\left(c_k^{NC}\right)^{k+1}\right\} \\ = \frac{f_{Ek} 2\gamma\,(c_M)^k\,(k+1)}{S}, \end{aligned} \tag{2.13}$$

where c_k^A and c_k^{NC} are given by (2.12) and (2.10). The free entry condition for industry k in the foreign country is analogous.

For each industry k, (2.13) is thus a system of two equations with two unknowns, c_k^D and c_{k*}^D. It can be shown that there is a unique equilibrium pair $\left(c_k^D, c_{k*}^D\right)$ provided that λ, given λ_*, is not very small (see Appendix B.2.1).

[20] For $c_k^A < c_k^X$, f_k must thus be larger than $\left(c_k^D - c_{k*}^D + t_k + \tau\right) S t_k\,[\theta + (1-\theta)\lambda]\,/2\gamma$, where both c_k^D and c_k^D depend on $\tau, k, t_k, f_k, \gamma, S, f_{Ek}, c_M$.

Assume that the creditor protection in the home country is lower than that in the foreign country, that is, $\lambda < \lambda_*$. In this case, the higher costs of external finance decrease the ex-ante probability of technology adoption in the home country. Therefore, expected profits are smaller and fewer firms pay the entry cost. In other words, competition in the home country is less intense and firms with higher costs of production are able to survive (higher entry cutoff in the home country: $c_k^D > c_{k*}^D$). As a consequence, firms from the home country are, on average, less competitive abroad than vice-versa. Hence, the ex-ante probability of exporting is lower in the home country, that is, the country with a less developed financial market. This is reflected by a lower export cutoff, $c_k^X < c_{k*}^X$. From (2.12), it follows that the technology adoption cutoff is also lower in the home country, $c_k^A < c_{k*}^A$. The missing technology adoption is thus larger. It decreases with increasing financial market development at home, for a given level of financial market development in the foreign country (see Appendix B.2.1).

2.2.4 Theoretical Predictions

Prediction 1. The probability that firm i, active in industry k, will be financially constrained is

$$\Pr\left(c_{ik} \geq c_k^{NC}\right) = \Pr\left(c_{ik} - c_k^{NC} \geq 0\right).$$

It can be shown that $dc_k^{NC}/d\lambda > 0$.

An increase in financial market development λ decreases the probability of being financially constrained.

Proof. See Appendix B.2.1.

Prediction 2. The probability that firm i, active in industry k, will export is

$$\Pr\left(c_{ik} \leq c_k^X\right) = \Pr\left(c_{k*}^D - \tau - c_{ik} \geq 0\right).$$

It can be shown that $dc^D_{k*}/d\lambda > 0$.

A higher level of financial market development λ increases the probability of exporting. From the assumption that $c^X_k \leq c^D_k$, it follows that this effect works through firms in the middle of the firm size distribution.

Proof. See Appendix B.2.1.

Prediction 3. The probability that firm i, active in industry k, will invest in new technologies is

$$\Pr\left(c_{ik} \leq c^A_k\right) = \Pr\left(c^A_k - c_{ik} \geq 0\right).$$

It can be shown that $dc^A_k/d\lambda > 0$.

A higher level of financial market development λ increases the probability of technology adoption. For advanced technologies associated with high (low) fixed costs f_k, this effect works through firms at the upper (lower) end of the firm size distribution.

Proof. See Appendix B.2.1.

We will test these predictions in the following empirical analysis.

2.3 Data

In order to test the predictions of our model, we match data from the World Bank Enterprise Surveys with country level data on financial development and industry level data on the use of external finance.

World Bank Enterprise Surveys. The Enterprise Surveys are firm level surveys conducted by the World Bank in a large number of developing and emerging countries. We focus here on the surveys conducted between 2002 and 2006, as these contain detailed information on technology use.[21] More than a third of the countries were surveyed more than once in this time period. However, as we do not know whether the same firms were surveyed more than once, and hence, whether a panel structure is available, the empirical analysis is based on the pooled data. In order to improve the representativeness, the sampling methodology used is stratified random sampling, where firms are chosen randomly within each stratum (firm size, geographical location, and sector of activity).[22] The data include firms active in manufacturing, retail and other services. However, we restrict our analysis to manufacturing firms. First, the model outlined above best applies to this sector.[23] Second, the empirical measure of the sectoral use of external finance used for identification is not available for service firms.

The Enterprise Surveys collect information on firm characteristics, such as the number of workers, their skill composition, balance sheet data, ownership, and age. From these data, we construct *Size* as the logarithm of the number of permanent workers. *Productivity* is measured as the logarithm of sales per worker.[24] Ownership information is captured by two dummy variables, *Foreign* and *State*, that take the value one if more than 10% of the firm is owned by the foreign private sector and the government/state. Finally, the skill level of the workforce is proxied by the fraction of the total workforce of the firm constituted by its non-production workers (*Skill*). Furthermore, and most important for our purposes, the Enterprise Surveys provide information on export behavior, technology use, and access to external finance.

More specifically, firms were asked *what percentage of* [their] *sales are exported directly.* We classify a firm as an exporter ($Exporter = 1$) if it exports a positive share of its sales. 33% of all firms export (standard devation: 0.47), with the minimum of

[21] As these surveys were conducted by different units within the World Bank, the different questionnaires were standardized for a joint analyis only later on. Therefore, not all questions were asked in all countries (see Table B.3). In a robustness check, we use the the BEEPS data (a subset of the WBES) based on identical questionnaires in all countries (see Table B.11).

[22] For more information, see http://www.enterprisesurveys.org/Methodology/.

[23] It seems reasonable to assume that technology adoption in the manufacturing sector is more likely to involve high acquisition costs than technology adoption in the service sector.

[24] *Productivity* is only used in robustness checks.

11% being in Uganda and the maximum of 88% being in Malaysia.[25]

We use two measures of technology adoption that are in line with the two possible sorting patterns, AX and XA.

Firms report whether they *use technology licensed from a foreign-owned company* where the license may be held by the parent company. This question measures access to foreign technology. Firms have an incentive to use foreign technology only if it increases productivity and this is especially true for the developing and emerging countries in the sample. Moreover, obtaining a license is likely to be quite costly, and thus matches firms' sorting pattern AX (high f_k). Indeed, in almost all countries, the share of firms using foreign technology is lower than the share of exporters (see Table B.4). Therefore, a firm is considered a technology adopter ($ForeignTechnology = 1$) if it reports using foreign technology. 14% of all firms that answered the question use a licensed foreign technology (standard deviation: 0.34), with the minimum of 5% being in Morocco and the maximum of 32% being in Costa Rica. One drawback of using this measure is that firms might use technology from a foreign-owned firm without a license or a formal agreement. In this case, $ForeignTechnology = 0$ while, in reality, the firm is a technology adopter. Furthermore, holding a license might be a substitute for purchasing new machinery or equipment.

The second measure defines a firm as a technology adopter if it regularly uses *email [...] in its interactions with clients and suppliers* ($Email = 1$). This is in line with Hall (2006, p. 463), who takes the replacement of a wired physical connection to the internet with a wireless one as an example of "the adoption decision in a modern technological setting". In a similar vein, Comin and Mestieri (2010) use the fraction of PCs and Internet users to measure the degree of technology adoption in the respective country. The use of e-mail is associated with lower costs of technology adoption (low f_k). This measure of technology adoption is thus in line with firms' sorting pattern XA. 69% of all firms that answered the question use e-mail to interact with customers and suppliers (standard deviation: 0.46), with the minimum

[25] The results are unchanged if Malaysia, the only country with an extremely high fraction of exporters, is excluded.

of 27% being in Egypt and the maximum of 99% being in South Africa. In almost all countries, the share of firms using e-mail is higher than the fraction of exporters (see Table B.4).

The Enterprise Surveys provide two measures of financial constraints. Firms report, using a 0 ("no obstacle") to 4 ("very severe obstacle") scale, whether (i) *access to financing (e.g., collateral)* and (ii) the *cost of financing (e.g., interest rates)* are an obstacle to their operations and growth. We classify firms as being financially constrained ($ConstrAcc = 1$, $ConstrCost = 1$) if, respectively, the access to financing and the cost of financing are at least a moderate obstacle (2 on the four-point scale). 59% of the firms asked about their cost of financing report it to be at least a moderate obstacle (standard deviation: 0.5) while 37% of the firms reporting information about access to finance are considered financially constrained (standard deviation: 0.48). These self-reported and hence direct measures constitute a major advantage over the indirect proxies used in other studies (e.g., total debt/total assets or cash flow/total assets in Berman and Héricourt, 2010). However, in a cross-country study, self-reported measures might be influenced by cultural differences between countries. In order to meet this objection, we show that the percentage of firms reporting being financially constrained is negatively related to macro-level measures of financial market development (see Figures B.1 and B.2).

Financial market development. In the model, financial market development captures the overall access of firms to external finance. Our main empirical measure is the sum of private credit (provided by deposit money banks and other financial institutions) and stock market capitalization over GDP obtained from Beck, Demirgüç-Kunt, and Levine (2009). This measure has been extensively used in the literature (e.g. Rajan and Zingales, 1998; Manova, 2011). It captures the size of the financial sector and hence the actual use of external finance. This use of external finance greatly varies across countries, with the minimum of 4% being in the Kyrgyz Republic and the maximum of 326% being in Jordan.[26] In the median country,

[26]The results are unchanged if countries with very high or very low values of financial development are excluded.

Turkey, private credit amounts to 45% of GDP (see Table B.1). In the robustness checks, we consider an alternative set of measures: the rule of law, the repudiation of contracts, and the risk of expropriation from LaPorta, Lopez-de Silanes, Shleifer, and Vishny (1998).

Dependence on external finance. The definition and computation of industries' dependence on external finance follows Rajan and Zingales (1998). The need for external finance is defined as "capital expenditures minus cash flow from operations divided by capital expenditures" (Rajan and Zingales, 1998, p. 564) and is computed using Standard and Poor's Compustat North America. This database contains the financial information of all publicly listed US based firms. The idea is that the US has one of the most developed financial systems worldwide and that therefore the amount of external finance used by US firms best reflects the sectoral demand for credit. We compute for each firm the average use of external finance over the period 1996–2005 in order to smooth temporal fluctuations, and then take the median for each NAICS 3-digit industry.[27] We then calculate a weighted average to match these values to the industries in the Enterprise Surveys.[28]
We use three alternative measures of sectoral financial vulnerability, following Feenstra, Zhiyuan, and Miaojie (2011) and Askenazy, Caldera, Gaulier, and Irac (2011), in the robustness checks: tangible assets/total assets, the liquidity ratio, and trade credit accounts payable/turnover. These measures were constructed from the Amadeus database using German firms' balance sheets by Felbermayr and Yalcin (2011).

The final dataset includes over 27,500 observations. The descriptive statistics are listed in Table B.5. Financially unconstrained firms, exporters, and technology adopters operate in more developed financial markets, are larger, and more often foreign owned than financially constrained firms, non-exporters, and non-adopters.

[27] The results are equivalent to those in Chor and Manova (2012).

[28] There are only thirteen, very broadly defined, manufacturing industries. However, the surveys also provide the ISIC 3-digit industry classification of each firm's main product line. As a robustness check, we match the Compustat measure to each of those industries using the concordance table provided by the US Census Bureau. The results are similar (see Table B.12).

Moreover, technology adopters operate in industries with higher external financing needs and have a more skilled workforce than non-adopters. This descriptive evidence underlines the importance for the empirical analysis, of controlling for firm size, foreign ownership, and the skill composition of the workforce. Table B.7 gives the descriptive statistics by firm size quartile. The share of exporters increases most in the first three size quartiles, while the increase in the share of users of foreign technology is largest between the third and fourth size quartiles. This is in line with Predictions 2 and 3: financial development mostly affects the export decision (foreign technology use) of firms in the lower (the fourth) size quartile. The descriptive statistics by industry are shown in Table B.8. Substantial variation in average firm size and skill composition of the workforce across industries strengthens the assumption that technology is (at least in part) industry specific.

2.4 Empirics

This section provides an empirical test of the predictions made in Section 2.2.4. First, we will outline the econometric strategy used for identification. Then, we will study the impact of cross-country differences in financial market development on export market participation and technology adoption.

2.4.1 Econometric Specification

A difference-in-difference type approach. In order to establish causality, we exploit variation in financial market development across countries and in dependence on external finance across industries. Both sources of variation are exogenous to the firm. We thus compare firms in the same industry across countries and firms in the same country across industries. From our model, it follows that firms active in the same industry are more likely to have access to external finance (Prediction 1), export (Prediction 2), and use new, more advanced technologies (Prediction 3) if they operate in a financially more developed country. The effect of financial development is likely to be more pronounced in industries that depend more on the use of external finance (see e.g. Rajan and Zingales, 1998; Manova, 2011). Putting those two statements together, a higher level of financial market development increases the probability of having access to external finance, of exporting, and of using advanced technologies, and especially so in industries that are more dependent on external finance. This is the difference-in-difference type approach first proposed in Rajan and Zingales (1998). The argument is formalized in the following index model.

$$X_{ikmt} = \left\{ \begin{array}{lll} 1 & \text{if} & \beta_0 + \beta_1 FD_{mt} \times ExtDep_k + \beta_2 FD_{mt} \\ & & +\beta_3 Controls_{ikmt} + D_m + D_k + D_t + \epsilon_{ikmt} > 0 \\ 0 & \text{otherwise} & \end{array} \right\}. \tag{2.14}$$

Here, $X_{ikmt} = \{ConstrAcc_{ikmt}, ConstrCost_{ikmt}, Exporter_{ikmt}, Email_{ikmt}, Foreign\ Technology_{ikmt}\}$, respectively, is a dummy variable equal to one if firm i active in industry k in country m and surveyed in year t reports, respectively, being financially constrained (Prediction 1), being an exporter (Prediction 2), and using an advanced technology (Prediction 3). $Controls_{ikmt}$ is a vector of firm level controls including $Size_{ikmt}$, $Foreign_{ikmt}$, and $Skill_{ikmt}$.[29] These variables are expected to have a negative effect on the probability of being financially constrained and a positive effect on the incidence of exporting and using advanced technology.[30] The main variable of interest is the interaction between financial development and external financing needs $FD_{mt} \times ExtDep_k$, which captures the prediction about within-country differences between industries described above: financial development increases the probability of exporting and advanced technology use disproportionately in industries with a higher need for external finance. Hence, β_1 is expected to be positive in the test of Prediction 2 and 3 and negative when testing Prediction 1.

A major advantage of this difference-in-difference type approach is that it allows

[29] We exclude all state-owned firms from the sample. The results are similar if a state-ownership dummy is included.

[30] In the theoretical model, both firm size and productivity are proportional to c_{ik} and thus capture cost differences between firms. Therefore, *Productivity* is not included in the main specification. The results are unchanged if *Productivity* is included.

controlling for country and industry characteristics. This makes the analysis robust to omitted country and industry variables.[31]

In order to stress the importance of correcting for other country characteristics, we estimate (2.14) without the interaction, subsequently controlling for other country characteristics that might influence exporting and technology adoption (Table B.9). Overall, financial development reduces (increases) the probability of being financially constrained (exporting and technology adoption). However, the sign and the significance of the effect of FD_{mt} depends on whether other country characteristics are controlled for.

In addition to country and industry dummies, D_m and D_k, we include year dummies, D_t, to control for the fact that the countries were surveyed in different years.[32] Note that, in contrast to FD_{mt}, $ExtDep_k$ is time invariant and captured by the industry dummies.

Firm heterogeneity. The effect of financial market development on the decision whether to export and which technology to use is likely to differ across the firm size distribution (Prediction 2 and 3).

In order to study these heterogeneous effects, we define a set of dummies $q_{kj}, j = 1, ..., 4$ and a set of triple interactions $q_{kj} \times FD_{mt} \times ExtDep_k, j = 1, ..., 4$. q_{kj} takes the value one if the firm is in the jth quartile of the firm size distribution (in industry k). We estimate the equation

$$\begin{aligned} X_{ikmt} =& \beta_0 + \beta_1 FD_{mt} \times ExtDep_k + \sum_{j=1}^{4} \beta_1^j q_{kj} \times FD_{mt} \times ExtDep_k \\ &+ \beta_2 FD_{mt} + \beta_3 Controls_{ikmt} + D_m + D_k + D_t + \epsilon_{ikmt}, \quad \forall q_{kj} \end{aligned} \tag{2.15}$$

where $Controls_{ikmt}$ now includes the quartile dummies $q_{k1}, ..., q_{k4}$ instead of $Size_{ikmt}$.

Both (2.14) and (2.15) represent nonlinear models. Therefore, the sign of the in-

[31] In order to mitigate concerns about omitted firm level variables, we include, in addition, firm age and a dummy equal to one if the firm is part of a multinational enterprise. The results are given in Table B.10.

[32] Results are unchanged if country–time dummies are included.

teraction terms, $FD_{mt} \times ExtDep_k$ and $q_{kj} \times FD_{mt} \times ExtDep_k$, depends on the value of the covariates and does not necessarily equal the sign of the marginal effect. Although Ai, Norton, and Wang (2004), for example, explain how to compute the correct marginal effect (at least for two interacted variables), the interpretation is more straightforward when estimating a linear model. Hence, we estimate (2.14) and (2.15) using a linear probability model.[33]

2.4.2 Results

Access to external finance. Table 2.1 presents the estimation of Equations (2.14) and (2.15), where X_{ikmt} is a dummy taking the value one if the firm reports being financially constrained. This is the test of Prediction 1. In columns (1) and (2), the measurement of the financial constrainedness is based on *cost of financing*, and in columns (3) and (4) on *reduced access to financing.* Columns (1) and (3) contain the results for the baseline regression and columns (2) and (4) include the quartile interactions. The dummy for the fourth quartile (q_{k4}) and the corresponding triple interaction ($q_{k4} \times \text{FD}_{mt} \times \text{ExtDep}_k$) have been omitted and serve as a reference group.

The coefficient of the interaction term is negative and significant in the baseline regression for *cost of financing.* Financial development reduces the cost of financing and especially so in industries that depend more on the use of external finance. The coefficient of the interaction is also negative but insignificant if financial constraints are measured by reduced access to financing.

Financial market development decreases the costs of obtaining external finance, in particular for larger firms. This follows from the positive coefficient of the interactions of $\text{FD}_{mt} \times \text{ExtDep}_k$ with the dummies for the first, second, and third firm size quartile (column (2)). A possible explanation is that at lower levels of financial market development, larger firms have access to external finance: but at very high costs. Increased access to external finance through financial market development is

[33]The drawback of estimating a linear probability model is that for certain combinations of the regressors, the predicted probabilities might be larger than one or less than zero. For the results presented in the tables below, the predicted probabilities are for the most part between 0 and 1.

Dependent variable:	ConstrCost		ConstrAcc	
	(1)	(2)	(3)	(4)
FD × ExtDep	-0.004*	-0.014**	-0.002	-0.002
	(0.002)	(0.006)	(0.001)	(0.002)
q_1 × FD × ExtDep		0.017**		-0.001
		(0.006)		(0.003)
q_2 × FD × ExtDep		0.015*		0.005*
		(0.008)		(0.002)
q_3 × FD × ExtDep		0.017***		-0.000
		(0.004)		(0.003)
Foreign	-0.102***	-0.101***	-0.081***	-0.082***
	(0.012)	(0.012)	(0.010)	(0.011)
q1		0.005		0.042***
		(0.016)		(0.009)
q2		0.022		0.042***
		(0.014)		(0.008)
q3		0.015		0.038***
		(0.010)		(0.009)
Size	-0.003		-0.012***	
	(0.005)		(0.003)	
FD	-0.076	-0.081	0.093	0.088
	(0.127)	(0.126)	(0.259)	(0.259)
No. Obs.	19719	19719	26718	26718
R^2	0.159	0.160	0.308	0.309

All estimations include country, industry, and year dummies.
Standard errors clustered at the industry level in parentheses.
Significance levels: *10%,**5%, ***1%.

Table 2.1: Access to external finance

less pronounced for firms in the second (as compared to the fourth) size quartile (column (4)).

The estimated coefficients of the firm level controls show the expected signs. Larger and foreign-owned firms are less likely to be financially constrained.

Entry into export markets. The empirical test of Prediction 2 is presented in

Dependent variable:	Exporter	
	(1)	(2)
FD × ExtDep	0.015***	0.008***
	(0.002)	(0.001)
q_1 × FD × ExtDep		0.011
		(0.007)
q_2 × FD × ExtDep		0.013***
		(0.004)
q_3 × FD × ExtDep		0.008***
		(0.002)
Foreign	0.177***	0.198***
	(0.012)	(0.012)
q1		-0.492***
		(0.030)
q2		-0.402***
		(0.020)
q3		-0.229***
		(0.012)
Size	0.133***	
	(0.007)	
FD	0.161*	0.159*
	(0.075)	(0.083)
No. Obs.	26975	26975
R^2	0.308	0.295

Country, industry, and year dummies. Standard errors clustered at the industry level in parentheses. Significance levels: * 10%, ** 5%, *** 1%.

Table 2.2: Entry into export markets

Table 2.2. The coefficient of the interaction between financial development and the dependence on external finance is positive and highly significant: financial market development disproportionately increases export market participation in industries that have strong external financing needs. This effect works through firms in the

lower quartiles of the size distribution (column (2)). Financial market development thus has a larger effect on the smaller and medium-sized firms, which, at a lower level of financial market development, are less likely to serve the foreign market. The firm level determinants of export behavior show the expected sign. Larger and foreign owned firms have a higher probability of exporting. This is in line with existing studies of firms' export behavior.

Use of advanced technologies. Table 2.3 presents the empirical test of Prediction 3 for the two possible sorting patterns. In columns (1) and (2), the measure-

Dependent variable:	Email		ForeignTechnology	
	(1)	(2)	(3)	(4)
FD × ExtDep	-0.002	-0.015***	0.008***	0.014***
	(0.001)	(0.003)	(0.001)	(0.002)
q_1 × FD × ExtDep		0.032***		-0.020***
		(0.006)		(0.002)
q_2 × FD × ExtDep		0.031***		-0.006*
		(0.005)		(0.003)
q_3 × FD × ExtDep		0.012**		-0.006**
		(0.004)		(0.002)
Foreign	0.072***	0.096***	0.199***	0.213***
	(0.009)	(0.010)	(0.025)	(0.024)
Skill	0.047**	0.045**	0.028***	0.026***
	(0.020)	(0.020)	(0.008)	(0.007)
q1		-0.443***		-0.162***
		(0.026)		(0.011)
q2		-0.290***		-0.130***
		(0.024)		(0.010)
q3		-0.124***		-0.095***
		(0.015)		(0.009)
Size	0.117***		0.053***	
	(0.007)		(0.004)	
FD	-0.121	-0.176*	0.550	0.592
	(0.101)	(0.097)	(0.381)	(0.407)
No. Obs.	22782	22782	13924	13924
R^2	0.326	0.325	0.141	0.132

Country, industry, and year dummies. Standard errors clustered at the industry level in parentheses. Significance levels: *10%,**5%, ***1%.

Table 2.3: Use of advanced technologies

ment of technology adoption is based on *use of e-mail*. This measure corresponds to sorting pattern XA and captures investment in lower-cost technologies. Hence, the marginal technology adopter is a small firm and financial market development is expected to have the largest effect on firms at the lower end of the firm size distribution. In columns (3) and (4), technology adoption is measured by *foreign technology use*. This measure captures costly investments (sorting pattern AX). Therefore, financial market development should mostly affect larger firms.

The results are in line with these theoretical predictions. The overall effect of the interaction between financial development and dependence on external finance is not significant in the baseline regression for use of e-mail (column (1)). It is significantly negative when the quartile interactions are included but less so for firms in the lower quartiles of the size distribution (column (2)). Smaller firms are not able to invest if financial constraints are more severe.

The estimated coefficient of the interaction term is positive and highly significant in the regression for *foreign technology use*. Hence, financial market development increases the likelihood of using costly new technologies and especially so in more financially dependent industries. This effect works through the largest firms: this follows from the negative, and significant, coefficients of the lower quartile interactions (column (4)).

A higher level of financial development, by increasing firms' access to external finance, reduces the missing technology adoption: it allows previously constrained firms to invest in advanced technologies. Size has a positive and highly significant effect on a firm's use of advanced technology. The largest firms are indeed the most likely to invest in more efficient production technologies. Foreign-owned firms have a higher probability of advanced technology use than domestic-owned firms. This might be due to the fact that foreign firms have easier access to better technologies and to external finance. A larger fraction of non-production workers is associated with a higher probability of technology adoption.

2.5 Sensitivity Tests

2.5.1 Measurement of Financial Development and External Financial Dependence

The identification of a causal effect of the level of financial market development (in industries with high need for credit) on firms' investment hinges on the measurement of (i) the level of financial market development and (ii) the industries' need for external finance.

Alternative measures of financial market development. The main measure of financial market development, private credit plus stock market capitalization over GDP, captures the actual use of external finance in a country, an outcome that might well be influenced by institutional determinants other than the financial system. Therefore, we examine the robustness of our results to alternative measures of financial market development. In particular, we use the measures of the rule of law, the risk of expropriation, and the repudiation of contracts compiled by LaPorta, Lopez-de Silanes, Shleifer, and Vishny (1998). These measures capture the contractual environment, that is, the institutional setting that determines the enforcement of contracts: the rule of law provides an "assessment of the law and order tradition in the country;" the risk of expropriation reflects the "risk of outright confiscation or forced nationalization;" and the third measure captures the repudiation of contracts by government (LaPorta, Lopez-de Silanes, Shleifer, and Vishny, 1998, p. 1124). All three measures are based on the International Country Risk (ICR) guide and are provided on a zero to ten scale with higher scores for more of a tradition of law or for greater risks of expropriation and repudiation of contracts. The measures are time invariant and available only for a subset of the countries.[34]

[34] In LaPorta, Lopez-de Silanes, Shleifer, and Vishny (1998), higher scores imply less risk of expropriation or repudiation of contracts.

Dependent variable		Exporter			Email			ForeignTechnology	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Law × ExtDep	0.003			-0.003			0.003***		
	(0.002)			(0.002)			(0.000)		
Expr × ExtDep		-0.005**			0.000			0.003**	
		(0.002)			(0.002)			(0.001)	
Repud × ExtDep			-0.004**			0.001			0.001
			(0.001)			(0.002)			(0.001)
q_1 × Law × ExtDep	0.002***			0.006***			-0.004***		
	(0.001)			(0.001)			(0.001)		
q_2 × Law × ExtDep	0.001***			0.005***			-0.003***		
	(0.000)			(0.001)			(0.001)		
q_3 × Law × ExtDep	0.002***			0.003***			-0.001		
	(0.001)	(0.000)		(0.001)	(0.001)		(0.001)		
q_1 × Expr × ExtDep		-0.001***			-0.005***			0.003***	
		(0.000)			(0.001)			(0.001)	
q_2 × Expr × ExtDep		-0.001***			-0.004***			0.002***	
		(0.000)			(0.001)			(0.000)	
q_3 × Expr × ExtDep		-0.001***			-0.003***			0.001	
		(0.000)			(0.001)			(0.000)	
q_1 × Repud × ExtDep			-0.001***			-0.005***			0.004***
			(0.000)			(0.001)			(0.001)
q_2 × Repud × ExtDep			-0.001***			-0.005***			0.003***
			(0.000)			(0.001)			(0.001)
q_3 × Repud × ExtDep			-0.001***			-0.003***			0.001*
			(0.000)			(0.001)			(0.000)
Foreign	0.221***	0.221***	0.221***	0.086***	0.086***	0.086***	0.254***	0.254***	0.254***
	(0.017)	(0.017)	(0.016)	(0.014)	(0.014)	(0.014)	(0.029)	(0.029)	(0.029)
Skill				0.035**	0.035**	0.035**	0.020***	0.020***	0.020***
				(0.014)	(0.014)	(0.014)	(0.004)	(0.004)	(0.004)
q1	-0.494***	-0.494***	-0.494***	-0.411***	-0.412***	-0.412***	-0.159***	-0.158***	-0.158***
	(0.019)	(0.019)	(0.019)	(0.023)	(0.023)	(0.023)	(0.013)	(0.014)	(0.014)
q2	-0.405***	-0.405***	-0.405***	-0.273***	-0.274***	-0.274***	-0.129***	-0.130***	-0.129***
	(0.017)	(0.017)	(0.017)	(0.027)	(0.027)	(0.027)	(0.014)	(0.014)	(0.014)
q3	-0.238***	-0.239***	-0.239***	-0.125***	-0.125***	-0.125***	-0.091***	-0.092***	-0.091***
	(0.009)	(0.009)	(0.009)	(0.017)	(0.017)	(0.017)	(0.013)	(0.013)	(0.014)
No. Obs.	16525	16525	16525	13805	13805	13805	9429	9429	9429
R^2	0.300	0.300	0.300	0.351	0.351	0.352	0.153	0.153	0.153

All estimations include country, industry, and year dummies. Standard errors clustered at the industry level in parentheses.
Significance levels: *10%,**5%, ***1%.

Table 2.4: Alternative measures of financial market development

The results are displayed in Table 2.4. They are qualitatively similar to those using private credit as a measure of financial market development.

Alternative measures of external financial dependence. The Rajan and Zingales measure of external financial dependence quantifies sectors' needs for external finance. However, sectoral demand for credit might respond to a country's level of financial development, and is therefore potentially endogenous. Moreover, the notion of the United States having the most developed financial system worldwide might be true for the 1980s, the period considered in Rajan and Zingales (1998), but not necessarily for the years close to the millenium analyzed in this paper. Hence, the assumption that the sectoral ranking with respect to financial dependence computed from US data carries over to other countries, might be suject to doubt.
We therefore consider a number of alternative measures of sectoral financial vulnerability suggested by the recent literature. Moreover, these measures have been calculated from German balance sheet data by Felbermayr and Yalcin (2011) and thus represent an alternative to the measures based on US data. In particular, we consider the fraction of tangible assets in total assets, trade credit received, and the liquidity ratio (current liabilities over current assets). The first measure has been suggested by Feenstra, Zhiyuan, and Miaojie (2011) and quantifies the fraction of collateralizable assets. The second and third measures are taken from Askenazy, Caldera, Gaulier, and Irac (2011) and capture firms' liquidity constraints and abilities to meet their obligations. Less collateral, less trade credit received, and a higher liquidity ratio, each imply a higher degree of financial vulnerability.

Dependent variable:	Exporter			Email			ForeignTechnology		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
FD × TrCr	-0.062			0.096			0.142***		
	(0.051)			(0.073)			(0.038)		
FD × Tang		0.047			0.103			0.004	
		(0.127)			(0.085)			(0.065)	
FD × Liqu			-0.000			-0.001***			-0.004
			(0.000)			(0.000)			(0.006)
q_1 × FD × TrCr	0.094			-0.234***			-0.134***		
	(0.072)			(0.052)			(0.036)		
q_2 × FD × TrCr	0.055			-0.162**			-0.138*		
	(0.051)			(0.071)			(0.076)		
q_3 × FD × TrCr	0.134			0.037			-0.023		
	(0.085)			(0.067)			(0.156)		
q_1 × FD × Tang		-0.115**			-0.032			-0.122**	
		(0.053)			(0.049)			(0.050)	
q_2 × FD × Tang		-0.086**			-0.072			-0.146***	
		(0.032)			(0.072)			(0.044)	
q_3 × FD × Tang		-0.009			-0.016			-0.006	
		(0.050)			(0.051)			(0.075)	
q_1 × FD × Liqu			-0.000			0.001***			-0.017**
			(0.000)			(0.000)			(0.006)
q_2 × FD × Liqu			0.002***			0.001**			-0.020**
			(0.000)			(0.000)			(0.008)
q_3 × FD × Liqu			0.000			0.000*			0.004
			(0.000)			(0.000)			(0.007)
Foreign	0.185***	0.185***	0.184***	0.077***	0.077***	0.078***	0.202***	0.202***	0.203***
	(0.017)	(0.017)	(0.017)	(0.014)	(0.014)	(0.014)	(0.029)	(0.030)	(0.029)
Skill				0.035*	0.036*	0.034*	0.025***	0.027***	0.027***
				(0.019)	(0.018)	(0.018)	(0.006)	(0.006)	(0.006)
q1	-0.506***	-0.473***	-0.495***	-0.377***	-0.395***	-0.406***	-0.144***	-0.135***	-0.140***
	(0.021)	(0.029)	(0.022)	(0.037)	(0.034)	(0.037)	(0.014)	(0.017)	(0.017)
q2	-0.402***	-0.377***	-0.401***	-0.205***	-0.209***	-0.226***	-0.108***	-0.093***	-0.100***
	(0.013)	(0.015)	(0.013)	(0.028)	(0.026)	(0.029)	(0.017)	(0.018)	(0.017)
q3	-0.242***	-0.223***	-0.227***	-0.090***	-0.082***	-0.087***	-0.096***	-0.097***	-0.104***
	(0.017)	(0.025)	(0.016)	(0.015)	(0.019)	(0.015)	(0.020)	(0.020)	(0.013)
FD	-0.092	-0.084	-0.084	-0.406***	-0.433***	-0.395***	0.007	0.032	0.029**
	(0.102)	(0.090)	(0.094)	(0.078)	(0.087)	(0.072)	(0.006)	(0.029)	(0.012)
No. Obs.	16967	16967	16967	15837	15837	15837	10266	10266	10266
R^2	0.297	0.297	0.297	0.291	0.290	0.290	0.121	0.122	0.122

All estimations include country, industry, and year dummies. Standard errors clustered at the industry level in parentheses.
Significance levels: *10%,**5%, ***1%.

Table 2.5: Alternative measures of external financial dependence

The results using these measures are globally similar to those derived in Section 2.4.2 (Table 2.5). Financial market development increases the exports of smaller firms, especially in industries with low trade credit received and industries with an, on average, high liquidity ratio. A higher level of financial development increases the probability of small firms using e-mail, and this is particularly true in industries with small levels of trade credit and tangible assets, and high liquidity ratios. The probability of larger firms using foreign technologies increases especially in industries with high liquidity ratios, and (in contrast to our assumption) a higher fracton of tangible assets and trade credit received.

2.5.2 Heckscher–Ohlin Sources of Comparative Advantage

Financially developed countries have a comparative advantage in industries with a high dependence on external finance. However, the interaction between financial market development and external financial dependence might also capture traditional sources of comparative advantage. Table 2.6 therefore includes, in addition to FD $\times$ ExtDep, countries' (log) per capita endowment of human and physical capital, and natural resources interacted with industries' respective factor intensities. We construct human and physical capital endowment as outlined in Caselli (2005). The data of natural resource endowments are taken from World Bank (1997), and the sectoral factor intensities are from Braun (2003). Controlling for traditional, Heckscher–Ohlin type, sources of comparative advantage does not change the impact of financial market development on the probability of exporting and of investing in new technologies.

2.5.3 Analysis of Subsamples

The effect of financial market development might differ across types of firms. Therefore, we estimate (2.14) by firm age and ownership, and by the country's income group. Table (2.7) reports the estimated coefficient of the interaction $FD_{mt} \times ExtDep_k$.

Dependent variable:	Exporter		Email		ForeignTechnology	
	(1)	(2)	(3)	(4)	(5)	(6)
FD × ExtDep	0.013***	0.006***	-0.001	-0.015***	0.008***	0.014***
	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
q_1 × FD × ExtDep		0.010		0.033***		-0.020***
		(0.006)		(0.005)		(0.002)
q_2 × FD × ExtDep		0.013***		0.031***		-0.007**
		(0.004)		(0.005)		(0.003)
q_3 × FD × ExtDep		0.008***		0.012***		-0.006**
		(0.002)		(0.004)		(0.002)
K/L	-0.971	-0.538	-2.300***	-2.076***	1.323***	1.349***
	(0.551)	(0.599)	(0.618)	(0.564)	(0.250)	(0.250)
H/L	-0.570	-0.328				
	(0.335)	(0.400)				
N/L	1.277	-0.202	2.032	1.282	1.265***	1.292***
	(1.096)	(1.175)	(2.318)	(2.283)	(0.229)	(0.222)
K/L × K intensity	1.476**	1.471**	0.317	0.374	-0.280*	-0.355**
	(0.572)	(0.559)	(0.263)	(0.230)	(0.145)	(0.159)
H/L × H intensity	0.411***	0.408***	-0.020	-0.001	-0.140	-0.125
	(0.135)	(0.129)	(0.116)	(0.113)	(0.087)	(0.093)
N/L × N intensity	-0.010	-0.007	0.029*	0.028**	-0.004	-0.003
	(0.011)	(0.011)	(0.014)	(0.013)	(0.005)	(0.005)
Foreign	0.166***	0.189***	0.060***	0.087***	0.201***	0.216***
	(0.013)	(0.014)	(0.009)	(0.011)	(0.025)	(0.024)
Skill			0.040**	0.038**	0.027***	0.025***
			(0.016)	(0.017)	(0.007)	(0.007)
q1		-0.491***		-0.449***		-0.162***
		(0.030)		(0.023)		(0.011)
q2		-0.405***		-0.294***		-0.128***
		(0.022)		(0.023)		(0.010)
q3		-0.231***		-0.127***		-0.097***
		(0.013)		(0.016)		(0.008)
Size	0.136***		0.119***		0.054***	
	(0.008)		(0.006)		(0.004)	
FD	-1.043	0.230	-1.915	-1.328	0.993***	1.028***
	(0.933)	(1.148)	(2.060)	(2.013)	(0.279)	(0.294)
No. Obs.	22140	22140	18388	18388	13323	13323
R^2	0.314	0.301	0.340	0.339	0.145	0.136

All estimations include country, industry, and year dummies. Standard errors clustered at the industry level in parentheses. Significance levels:*10%,**5%, ***1%.

Table 2.6: Heckscher–Ohlin sources of comparative advantage

Dep. variable:		Exporter		Email		ForeignTechnology	
		Est.	Obs.	Est.	Obs.	Est.	Obs.
		(1)	(2)	(3)	(4)	(5)	(6)
Age	New	0.009***	9219	-0.004	7940	0.006***	4244
	Old	0.015***	15996	-0.001	13340	0.008***	8750
Ownership	Foreign	0.001	3194	-0.005**	2880	0.008	1647
	Domestic	0.018***	23781	0.001	19902	0.007***	12277
Inc. group	Low	-0.049	2438	-0.061*	2255	0.108***	1088
	Lower-middle	0.021***	11216	0.011***	10258	0.013***	6201
	Upper-middle	0.008**	11309	-0.006***	8328	0.006***	6586
	High	-0.020**	2012	-0.026***	1941	0.119***	49

Country, industry, and year dummies. Standard errors clustered at the industry level in parentheses. Significance levels: *10%,**5%, ***1%.

Table 2.7: Sample split with respect to firm age, ownership, and income group

First, we estimate (2.14) separately for firms which are younger (“new”) and for firms which are older than ten years (“old”). There is no significantly different effect of financial market development on the export and technology adoption probability of new and old firms. The results are similar if (2.14) is estimated for firms which are younger and older than five years. This is in line with the results in Table B.10. *age* does not enter significantly.

Second, we look at domestic versus foreign owned firms. We find that domestic firms respond to financial market development with a higher probability of exporting and investing in foreign technologies whereas financial development does not seem to affect foreign owned firms. This finding is consistent with the idea that foreign owned firms might tap internal sources and are not as financially constrained as domestic firms, whose only source of external finance is the local financial market.

The World Bank classifies countries according to their GNI per capita. Countries belong either to the low, lower-middle, upper-middle, or high income group.[35] The strength of the response to financial development varies across income groups. The effect on the use of e-mail is largest in lower-middle income countries, and the effect on the export probability works through firms in middle-income countries. These results are in line with the assumption that the use of email is less costly than exporting.

[35] See http://data.worldbank.org/about/country-classifications for more information.

2.6 Conclusion

This paper presents a model of financially constrained firms to derive predictions on the effect of cross-country differences in financial development on technology adoption. Using data from the World Bank Enterprise Surveys, we provide new firm level evidence on the impact of financial market development on the decision to invest in more advanced technologies. In particular, we show that barriers to external financing, which follow from a lack of financial development, explain cross-country differences in the use of advanced technologies. Financial market development thus reduces the missing technology adoption. This has important policy implications, as the adoption of more efficient technologies is considered to be an engine of economic growth. Moreover, we show that the effect of financial market development differs across the firm size distribution: for new technologies associated with low investment costs, the effect is largest on small firms. For high-cost investments, on the other hand, financial market development mostly affects very large firms. This is important for policy design. Depending on which technology is to be diffused, policy makers need to target primarily smaller or larger firms. If the government wanted to promote the use of e-mail, smaller firms need to be targeted. In the case of a government-led expansion of machinery industries, technology adoption in large firms has to be fostered.

Chapter 3

Credit Constraints and the Margins of International Trade: Evidence from Eastern European Firms*

3.1 Introduction

It is well established that financial market development matters for economic growth. Rajan and Zingales (1998) for example show in their seminal contribution that industries with high demand for external finance grow faster in financially developed countries. In the context of international trade, financial development has been shown to act as a source of comparative advantage. Financially advanced countries export larger volumes, a wider range of products, and to a larger number of markets. These effects are magnified in industries with high demand for external finance (see Beck, 2002, 2003; Svaleryd and Vlachos, 2005; Berthou, 2010; Manova, 2011). Recent theoretical research has attempted to explain these patterns at the firm level: there are entry costs to exporting which must be paid *ex-ante*. If access to credit

*This chapter is based on joint work with Fergal McCann.

is constrained, a range of potential exporters are not able to trade internationally. Understanding to what extent credit constraints affect participation in international trade is crucial to policy makers given that entry into international markets has been shown to increase productivity, both on the export (De Loecker, 2007) and on the import side (Kasahara and Rodrigue, 2008; McCann, 2011).

This paper provides an empirical test of the hypothesis that credit constraints affect firms' participation in international trade. We examine the impact of credit constraints on the import and export decision of firms, using data from the Business Environment and Enterprise Performance Surveys (BEEPS). BEEPS are firm level surveys conducted by the European Bank for Reconstruction and Development and the World Bank in a large number of Eastern European and former CIS countries. These countries are not among the most financially advanced worldwide and, at the same time, very heterogeneous in their level of economic and financial market development and therefore ideal for our purpose.

Moreover, surveyed firms are asked about their export and import behavior, and their financial situation. The latter information allows us to directly identify credit constrained firms. Previous studies have often relied on outcome variables from firms' balance sheets, such as leverage and liquidity, to proxy for credit constraints. There are a number of studies that use survey data to construct direct measures of credit constraints. However, these studies mostly classify firms as credit constrained if the firm's credit application was rejected (see e.g. Cole, 1998; Cole, Goldberg, and White, 2004). Our measure considers not only firms with unsuccessful credit applications as credit constrained but also captures firms which are discouraged from applying for credit for reasons such as high interest rates, corruption or collateral requirements. Hence, we identify all firms with a *demand* for but no access to credit. Thereby, we avoid an important source of bias, as recent research outside the field of international trade indicates that not accounting for credit demand impedes the correct identification of financially constrained firms (Hainz and Nabokin, 2012). We show that taking into account credit demand leads in some instances to a doubling of the estimated effect of credit constraints on the probability to export.

Credit constraints are potentially endogenous to the firm's export and import decision. Unobserved factors might affect both the level of credit constraints and the firm's trade status. Moreover, firms might be more or less credit constrained due to their desire to trade internationally. Controlling for these sources of endogeneity represents a major challenge when studying the impact of credit constraints. We show that jointly estimating the import (export) and credit constraints equation in a bivariate probit setting allows to ignore the potential endogeneity bias. Furthermore, the cross-country nature of the data allows country- and sector-varying instruments to be used to identify the effect of credit constraints on a firm's import and export decision. We are thus able to provide robust evidence on the impact of credit constraints on the international trading behavior of firms in Eastern Europe.

We find that credit constraints reduce the export probability of both manufacturing and service firms. Credit constraints also have a negative impact on a firm's decision to import material inputs and supplies. Estimated average treatment effects suggest that the existence of credit constraints lowers the probability that a firm will export and import by 17 and 33 per cent, respectively.

Our paper is among the first to study the impact of credit constraints on the export probability of firms in the BEEPS countries (see also Bernard, Stabilito, and Donghoon Yoo, 2010), and, as far as we know, the first one to study the impact on the import probability.

It contributes to three strands of literature. First, it is related to theoretical work on the relationship between financing constraints and the export and import behavior of firms (e.g. Chaney, 2005; Manova, 2011). The empirical results presented in this paper are in line with this micro-level channel between financial development and international trade.

Second, our work contributes to the growing body of empirical studies on the effect of financial constraints on exporting (Greenaway, Guariglia, and Kneller, 2007; Muûls, 2008; Forlani, 2010; Berman and Héricourt, 2010; Bellone, Musso, Nesta, and Schiavo, 2010; Minetti and Zhu, 2011) and importing (Bas and Berthou, 2012;

Eck, Engemann, and Schnitzer, 2012). These studies find that the effect of credit constraints is more pronounced on the extensive than on the intensive margin of international trade. In line with our results, they generally report a significant negative effect of credit constraints on firms' export participation. In studying the effect of credit constraints on both the exporting and importing behavior of firms, this paper's scope is wider than previous research, which has focused uniquely on one side of the firm's international trade operations.[36] Apart from Bas and Berthou (2012) and Eck, Engemann, and Schnitzer (2012), the effect of credit constraints on importing has received surprisingly little attention in the literature thus far, given that previous theoretical (Ethier, 1982; Kasahara and Lapham, 2008) and empirical (McCann, 2011; Kasahara and Rodrigue, 2008) literature suggests that the importing of intermediate inputs can lead to productivity gains.

In considering firms in the service sector separately from manufacturing firms, our paper also contributes to the growing literature on the characteristics of firms engaging in cross-border trade in services (Breinlich and Criscuolo, 2011; McCann and Toubal, 2012). Breinlich and Criscuolo (2011) report that only the more productive service firms participate in international trade. To our knowledge, we are the first to study the impact of credit constraints on the export behavior of service firms. We show that the negative impact of credit constraints documented for manufacturing firms persists when considering service firms.

Third, our work also contributes to a larger literature on the effect of credit market imperfections on the economic peformance of firms, stretching back to Fazzari, Hubbard, and Petersen (1988). Recent research has shown that credit constraints can have highly deleterious effects on a range of firm attributes such as employment, marketing expenditure, and technology investment (Campello, Graham, and Harvey, 2010; Peters, 2012).

The paper proceeds as follows. Section 3.2 provides the theoretical background to our empirical analysis. Section 3.3 describes the data used and Section 3.4 outlines

[36] A notable exception is Eck, Engemann, and Schnitzer (2012).

the empirical methodology applied. Results and robustness checks are reported in Section 3.5 and 3.6. Section 3.7 concludes.

3.2 Theoretical Background

Our empirical analysis is inspired by the theoretical literature on the relationship between financial market development and the export and import behavior of firms. In particular, we take to the data the predictions of theoretical work on the effect of credit constraints on a firm's decision to trade internationally. This strand of literature is to a large extent based on the work of Melitz (2003) and Melitz and Ottaviano (2008). The idea here is that starting to export is costly and that these costs have to be paid ex-ante. Only the more productive firms are able to overcome these costs and *self select* into exporting.

Melitz (2003) and Melitz and Ottaviano (2008) assume a perfect financial market. Hence, firms do not face financing constraints when it comes to paying the upfront costs of exporting. Recently, a growing number of studies introduce financing constraints into theoretical models of firms' international trading behavior. Chaney (2005) assumes that firms cannot borrow externally. There are two sources of internal funds: domestic profits and a random domestic liquidity shock. Potential exporters are then able to export only if they are very productive and generate high domestic profits or dispose of a large amount of exogenous liquidity. Chaney (2005) shows that there is a non-empty set of firms which are prevented from exporting by liquidity constraints.

In Manova (2011), firms need external finance for a fixed fraction of the upfront costs of exporting. There is imperfect enforcement of credit contracts: creditors are not repaid with positive probability and therefore require a higher repayment in order to break even. Only the more productive firms offer creditors high enough revenues from exporting to cover the repayment and get credit. Other studies have emphasized additional reasons for credit constraints, as for example moral hazard issues (Zia, 2008 based on Holmstrom and Tirole, 1997) and foreign market risk

(Eck, Engemann, and Schnitzer, 2012). In the presence of credit constraints, there is thus a range of firms that could profitably export (import) but are either denied a loan or discouraged from accepting (or even applying for) a loan by high interest rates or collateral requirements.

The literature thus predicts that, given other firm characteristics, credit constrained firms are less likely to export (import). In the following section, we describe the data used to test this prediction.

3.3 Data

The firm level data used come from the *Business Environment and Enterprise Performance Survey* (BEEPS), which is collected by The European Bank for Reconstruction and Development (EBRD) and the World Bank. This database collects information on, *inter alia*, a firm's sales, exports, imports, outsourcing, employment, wages, ownership, investment, and opinions on corruption and institutional quality. Data are collected for 28 countries in Eastern Europe and Central Asia for 2002, 2005, 2007, 2008 and 2009.[37] The EBRD states that "the survey universe was defined as commercial, service or industrial business establishments with at least five full-time employees". The statistical sampling technique used is stratified random sampling. The three levels of stratification used were industry, establishment size and region. Due to limited availability of data on credit constraints, regression analysis focuses on the years 2005, 2008 and 2009. The sample size by country and year that can be used in regressions is given in Table C.1. The data used will be a pooled cross section of firms across these three years.

[37] Albania, Armenia, Azerbaijan, Belarus, Bosnia, Bulgaria, Croatia, Czech Republic, Estonia, FYROM, Georgia, Hungary, Kazakhstan, Kyrgyz Republic, Latvia, Lithuania, Moldova, Montenegro, Poland, Romania, Russia, Serbia, Slovak Republic, Slovenia, Tajikistan, Turkey, Ukraine, Uzbekistan. Due to the non-availability of country level variables, observations for Azerbaijan, Belarus, Bosnia, Montenegro, Romania, Serbia, Tajikistan, Ukraine, and Uzbekistan are dropped.

3.3.1 Explanatory Variables

We define two dummy variables, *Importer* and *Exporter*, that take the value one if the firm reports to import any of its material inputs directly and export any of its output directly. Foreign ownership is captured by a dummy variable that is equal to one if more than 0 per cent of the *[...] firm is owned by private foreign individuals, companies or organizations.*[38] Employment, that is, the logarithm of the number of permanent workers (*Size*), is also used as a control variable, as is labor productivity (*Productivity*), calculated as the difference between the logarithm of of sales and the logarithm of the number of workers.

Figures for nominal monetary variables are given in local currency units. We normalize these variables by converting them to US dollar figures using the mean yearly exchange rate from the IMF International Financial Statistics database.

3.3.2 Credit Constraints

Previous research has used an array of methods to proxy for credit constraints. The much-debated method of Fazzari, Hubbard, and Petersen (1988) identifies credit constraints based on the sensitivity of investments to internal cash resources. This approach has been applied by Forlani (2010). Another strand of literature has used balance sheet data such as leverage and liquidity as proxies for financial constraints (see, for example, Greenaway, Guariglia, and Kneller, 2007; Berman and Héricourt, 2010; Bas and Berthou, 2012). Muûls (2008) takes the novel approach of using a private credit analysis firm's bankrupcy risk score to proxy credit constraints. Bellone, Musso, Nesta, and Schiavo (2010) also fall into this category, creating a composite index from seven indicators of financial health and leverage. A third strand of the literature focuses on survey-based measures of credit constraints, combined with controls at the country, sector or regional level which mitigate the cross-sectional, non-panel structure of such surveys. Such a measure is used by Minetti and Zhu

[38] 0.5 per cent of the foreign firms in our sample are between 1 and 10 per cent foreign-owned. Results are identical if the foreign ownership dummy is based on 10 per cent foreign ownership.

(2011) who identify credit rationed firms by combining two survey responses: (i) "In 2000, would the firm have liked to obtain more credit at the market interest rate?" and (ii) "In 2000, did the firm demand more credit than it actually obtained?". Firms responding positively to both questions are considered "strongly rationed" while those responding affirmatively to only (i) are considered "weakly rationed". Outside the international trade literature, such survey based measures of credit constraints have been used by Brown, Ongena, Popov, and Yesin (2011), Ferrando and Griesshaber (2011), Hainz and Nabokin (2012) and Holton, Lawless, and McCann (2012).

Among papers in the international trade literature, our method matches most closely the survey-based instrument approach of Minetti and Zhu (2011). We provide an alternative survey-based definition of credit constraints which captures a wider range of constrained firms. In particular, we capture also discouraged firms, that is, firms with a demand for credit who may not have applied to the lending institution for a loan.[39] Firms are asked two questions[40]:

1. Did this establishment apply for any new loans or new lines of credit that were rejected in [the] last fiscal year?

2. What was the main reason why this establishment did not apply for any line of credit or loan in [the] last fiscal year?

Question (1) can be answered by either "yes" or "no". We code firms responding "yes" to (1) as credit constrained. Question (2) has a range of responses:

1. No need for a loan - establishment has sufficient capital.

2. Application procedures for loans or lines of credit are complicated.

3. Interest rates are not favorable.

4. Collateral requirements are too high.

[39] The survey does not ask firms explicitly whether they were offered a credit facility and then refused it due to the terms and conditions attached. It is possible that such firms respond as "rejected" or as "discouraged" due to interest rates, however we cannot verify this in the data.

[40] See http://www.ebrd.com/downloads/research/economics/beeps_02_05_09_notes_labels.pdf.

5. Size of loan or maturity are insufficient.

6. It is necessary to make informal payments to get bank loans.

7. Did not think it would be approved.

The first column of Table 3.1 lists the relative importance of the different reasons for non-application of all firms answering Question (2). We code all firms that respond Question (2) with 1. as unconstrained firms. All firms who responded with 2. to 7. are coded as constrained. This represents a wider range of firms captured as credit constrained than in previous research. Not only do we capture firms that did not get credit upon applying, we also capture firms that opt out of the credit market due to conditions associated with credit applications such as complicated procedures, interest rates, collateral requirements, insufficient quantities, corruption or a belief that rejection was likely.

Of the 9417 firms in our regression sample, 3219 report to have applied for a new credit.

477 firms (5 per cent of the firms in our regression sample) did not receive credit upon applying (answer “yes” to Question (1)). These firms are coded as credit constrained.

6236 firms (66 per cent) report not to have been rejected for a credit (answer “no” to Question (1)). Out of these firms (that also answered Question (2)), 57 per cent did not apply for a credit because they have no credit demand while 43 per cent were discouraged from applying by the conditions associated with credit applications (see second column of Table 3.1). Classifying only firms which report a rejected credit application as credit constrained (see e.g. Cole, 1998; Cole, Goldberg, and White, 2004) implies that the latter firms are classified as not credit constrained. We argue that these firms have demand for credit but are discouraged by unfavorable conditions associated with credit applications and are thus credit constrained.

2704 firms (29 per cent) of the firms in our regression sample do not report an answer to Question (1). These firms are treated as missing observations when classifying only firms which report a rejected credit application as credit constrained. Out of these firms, 26 per cent were discouraged from applying for a credit (answer 2. to 7. to Question (2), see third column of Table 3.1). They are thus on average more credit constrained than the firms in our regression sample (26 per cent instead of 16 per cent in the regression sample).

Both, omitting these firms and misclassification of discouraged firms as not credit constrained are likely to lead to a downward bias in the estimated impact of credit constraints on importing and exporting.

	Q. (2)	"no" to Q. (1)	No answer to Q.(1)
No need for a loan	66.34	56.62	74.19
Complicated application procedures	4.45	3.77	4.96
High interest rates	10.63	6.71	13.79
High collateral requirements	3.31	3.31	4.14
Insufficient size or maturity	0.68	0.00	1.22
Informal payment necessary	0.25	0.09	0.37
Did not think it would be approved	1.52	1.75	1.33
Other	0.78	1.75	0.00
Multiple answers	11.57	26.07	0.00
Total	100	100	100

Share of firms stating respective main reason(s) for non-application among all firms: answering Question (2); answering Question (1) with "no"; not answering Question (1).

Table 3.1: Main reason(s) not to apply for a new loan

Table 3.2 reports the share of credit constrained firms by country in our regression sample. The first three columns display the share of constrained firms according to the measure of credit constraints based on rejected credit applications. The share of constrained firms according to our measure are reported in the last three columns. Taking into account credit demand increases the share of credit constrained firms in every country except Turkey. Moreover, we see that credit constraints vary widely across countries, from a low of 6.7 per cent of firms in Slovenia to a high of 27.7 per cent in Kyrgyzstan. A cusory glance at the data suggests that wealthier countries to the geographic west of our sample tend towards lower incidence of credit constrained firms. Figure C.1 confirms a negative relationship between the logarithm of GDP per capita and credit constraints.

Country	Rejected application			With credit demand		
	Unconstr. %	Constr. %	Obs. No.	Unconstr. %	Constr. %	Obs. No.
Albania	94.8	5.2	134	90.8	9.2	152
Armenia	96.0	4.0	379	82.6	17.4	524
Bulgaria	94.1	5.9	269	80.2	19.8	410
Croatia	94.9	5.1	196	90.5	9.5	241
Czech Republic	93.8	6.2	339	84.4	15.6	423
Estonia	93.6	6.4	281	91.5	8.5	390
FYROM	89.9	10.1	199	75.7	24.3	366
Georgia	91.7	8.3	242	82.2	17.8	365
Hungary	98.1	1.9	530	91.8	8.2	692
Kazakhstan	92.4	7.6	543	79.5	20.5	776
Kyrgyz Rep.	90.4	9.6	197	72.3	27.7	310
Latvia	89.3	10.7	233	81.4	18.6	344
Lithuania	94.6	5.4	258	86.8	13.2	357
Moldova	91.5	8.5	376	80.7	19.3	538
Poland	95.6	4.4	825	85.3	14.7	981
Russia	89.6	10.4	683	79.0	21.0	981
Slovakia	96.6	3.4	206	88.9	11.1	315
Slovenia	95.2	4.8	336	93.3	6.7	434
Turkey	83.8	16.2	487	85.1	14.9	818
Total	92.9	7.1	6713	83.9	16.1	9417

Table 3.2: Share of credit constrained and unconstrained firms by country

One might expect that financial development leads to improvements in credit access for firms. The relationship between financial development, as measured by the ratio of bank credit to GDP (Beck, Demirgüç-Kunt, and Levine, 2009), is shown to be very mildly positively correlated with credit constraints for our sample countries (Figure C.2). This suggests caution should be used in making inferences from such measures alone, which proxy financial development using a *stock* variable which captures the built-up output of years of behavior on the part of financial institutions. A country may have gone through a boom in credit provision, and subsequently entered a period of recession, making access to finance extremely difficult for firms, despite a higher outstanding stock of credit in the economy.

Table 3.3 shows the cross-sector variation in credit constraints. There is less variation across sectors than across countries, with the share of constrained firms ranging from 9.6 per cent in basic metals to 21.2 in the garments sector. In addition to manufacturing firms, our sample includes firms in the wholesale, retail, other services, hotels and restaurants, transport, and IT services sectors. This allows us to contribute to the growing literature on international trade in services (Breinlich and Criscuolo, 2011; McCann and Toubal, 2012).

Table 3.4 shows that the share of constrained firms increased from 2005 to 2008 to 2009, as one would expect given the proliferation of the global financial crisis from 2008 onwards. When credit constraints are measured based on rejected applications, the share of constrained firms decreases slightly between 2008 and 2009. This might be due to the fact that the number of credit applications — that is, the demand for credit — decreased.

	Rejected application			With credit demand		
Sector	Unconstr. %	Constr. %	Obs. No.	Unconst. %	Constr. %	Obs. No.
Food	93.1	6.9	824	86.0	14.0	1083
Textiles	89.8	10.2	167	85.3	14.7	258
Garments	91.7	8.3	432	78.9	21.1	592
Chemicals	85.9	14.1	149	83.7	16.3	233
Plastics & rubber	88.7	11.3	97	81.6	18.4	141
Non metallic mineral prod.	88.3	11.7	137	85.4	14.6	240
Basic metals	96.0	4.0	50	90.4	9.6	73
Fabricate metal products	94.8	5.2	460	83.8	16.2	594
Machinery and equipment	92.3	7.7	336	82.7	17.3	421
Electronics	87.5	12.5	32	87.0	13.0	69
Construction	92.0	8.0	722	83.8	16.2	995
Other services	96.6	3.4	804	87.5	12.5	889
Wholesale	93.3	6.7	568	86.9	13.1	794
Retail	91.6	8.4	1150	79.8	20.2	1926
Hotel and restaurants	96.7	3.3	270	87.4	12.6	413
Transport	93.4	6.6	452	85.5	14.5	592
IT	93.7	6.3	63	88.5	11.5	104
Total	92.9	7.1	6713	83.9	16.1	9417

Table 3.3: Share of credit constrained and unconstrained firms by sector

	Rejected application			With credit demand		
Year	Unconstr.	Constr.	Obs.	Unconstr.	Constr.	Obs.
	%	%	No.	%	%	No.
2005	97.2	2.8	4346	89.4	10.6	4346
2008	84.0	16.0	593	83.5	16.5	1047
2009	85.3	14.7	1774	78.1	21.9	4024
Total	92.9	7.1	6713	83.9	16.1	9417

Table 3.4: Share of credit constrained and unconstrained firms by year

3.3.3 Instruments

A simple regression that attempts to determine the impact of credit constraints on the likelihood of exporting or importing may be biased both because of omitted variables and reverse causality. A firm that is credit constrained due to the lender screening it on the basis of poor credit quality may be unable to participate in international trade for precisely the same reason. While we control for factors such as firm size, ownership, and productivity to attempt to alleviate such a concern, the possibility that unobserved factors, such as managerial quality or agency problems among firms' stakeholders, drive both credit constraints and trade cannot be ruled out. Furthermore, entering into export or import markets may improve a firm's financial health which then makes it a more attractive proposition for lenders, thus easing credit constraints. Alternatively, a firm might find it more difficult to obtain external finance as lenders perceive international activities as riskier than domestic ones. In these cases, firms are more or less credit constrained just because they want to trade internationally. For these reasons, care must be taken in inferring causal effects from credit constraints to international trade status. The cross-country nature of the firm level data used in this paper facilitates the search for variables that affect credit constraints while plausibly having no effect on the international trade status of a firm. We utilize three such variables, which vary at the firm level, country-sector level and country level, respectively.

At the firm level, we use the response to the question whether the firm has *payments overdue by more than 90 days* (*Overdue*). This variable has previously been used in a similar way as a proxy for liquidity constraints by Gorodnichenko and

Schnitzer (2012). A firm that is liquidity constrained is also likely to suffer from credit constraints as a result.

At the sector-country level, we create an interaction variable between a country's level of investor protection and a sector's dependence on external finance (*Disclosure*× *ExtDep*). The value of this interaction variable is larger for firms in sectors that are more dependent on external finance, in countries where transparency in investor protection is higher. The external financial dependence measure is calculated as in Rajan and Zingales (1998). The need for external finance is defined as "capital expenditures minus cash flow from operations divided by capital expenditures" (Rajan and Zingales, 1998, p. 564) and is computed using Standard and Poor's Compustat North America database. This database contains financial information of all publicly listed US based firms. The idea is that the US has one of the most developed financial systems worldwide and that therefore, the amount of external finance used by US firms best reflects sectoral demand for credit. We compute for each firm the average use of external finance over the period 1996–2005 in order to smooth temporal fluctuations and then take the median for each industry.

The measure of investor protection used comes from the World Bank *Doing Business* data base. The *Extent of Disclosure Index* measures the requirements on approval and disclosure of related-party transactions. The measure is constructed on the basis of interviews with national corporate and securities lawyers relating to a hypothetical transaction between related parties in which damages are caused to the buyer. The *Extent of Disclosure Index* combines information on the requirements around the corporate body that can provide legally sufficient approval for the transaction; whether immediate disclosure of the transaction to the public, the regulator, and the shareholders is required; whether disclosure of the transaction is required in the company's annual report; whether disclosure is required to the board of directors; whether an external body such as an auditor is required to review the transaction before it takes place. The index from 0 to 10 is calculated as the sum of the scores for these five categories, with higher scores indicating a higher extent of disclosure. It could be argued that the *Extent of Disclosure Index* itself causes lower credit constraints, as moral hazard and adverse selection problems are alleviated by such transparency-inducing protections. Introducing this measure alone into a regression could however be subject to omitted variable bias.[41] The advantage of interacting the *Extent of Disclosure Index* with a measure of the external financial dependence of a sector is that it allows a differential effect within countries to be identified, whereby firms active in more financially dependent industries benefit even more from such protections, suggesting a causal effect of disclosure requirements in alleviating credit constraints.

Our final instrument is an interaction variable at the country level. We follow previous literature in using the financial development of a country as a predictive variable for the firm's likelihood of being credit constrained. We take as a proxy for financial development the ratio of total bank and non-bank credit to GDP from Beck, Demirgüç-Kunt, and Levine (2009). However, as shown in Figure C.2, this variable alone may not have the necessary predictive power: a country might simply have a high ratio of credit to GDP because of poor regulation. With this in mind, we use as our predictive variable the interaction of private credit to GDP with the *World Governance Indicators* measure of regulatory quality (Kaufmann, Kraay, and Mastruzzi, 2009), $RegQu \times FinDev$. With this variable we hope to proxy the extent to which the country is governed by a strong, market-friendly institutional structure.

> Regulatory Quality captures "perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development" (Kaufmann, Kraay, and Mastruzzi, 2010, p. 4).

Figure C.3 shows that countries that are managed more efficiently, by this measure, are those in which less credit constrained firms are observed. By interacting regulatory quality with financial development, we aim at capturing those countries that have both liberalized financial systems combined with an effective structure for ensuring a well-run financial system.

[41] Moreover, the *Extent of Disclosure Index* varies little over time so that its effect is likely to be captured by the country dummies, if introduced alone.

3.3.4 Summary Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Credit Constrained	9417	0.161	0.367	0	1
Exporter	9408	0.245	0.430	0	1
Importer	5542	0.352	0.478	0	1
Size	9417	3.279	1.591	0	9.810
Productivity	9417	10.147	2.063	1.204	19.543
Foreign	9417	0.105	0.307	0	1
Overdue	9417	0.040	0.196	0	1
Disclosure × ExtDep	9417	5.580	6.774	0	66.092
RegQu × FinDev	9417	103.624	77.019	7.418	379.076

Table 3.5: Summary statistics for variables included in the regression sample

Summary statistics for the main variables used in the regression analysis are given in Table 3.5. In the empirical analysis, we provide sample splits for manufacturing and service firms. In the Appendix, Tables C.2 and C.3 give the same statistics for the manufacturing and services sample, respectively. We see that the fraction of exporters and the fraction of importers is higher in manufacturing than in services (39 versus 17 per cent, 42 percent versus 27 per cent), while the share of credit constrained firms is similar across the two sectors (16 per cent).

Table 3.6 reports "trade status premia", given as the coefficient of dummies for importer-only, exporter-only, and two-way trader status relative to a dummy for purely domestic firms. The dependent variables of interest are the logarithm of sales, employment and productivity, and dummies for credit constraints, foreign technology licensing, and research and development activity. We find a general hierarchy of performance: importers-only are larger (in terms of employment and sales), less credit constrained and more innovative than purely domestic firms, exporters-only outperform importers-only, and two-way traders rank highest in each case. One exception is productivity. Importers-only, exporters-only, and two-way traders are all more productive than purely domestic firms but do not appear significantly different from each other.

In the Appendix, Tables C.4 and C.5 separately replicate Table 3.6 for the manufacturing and the services sample, respectively. In each subsample, two-way traders

Table 3.6: Difference between two-way traders, importers, exporters, and purely domestic firms

	(1) Sales	(2) Employment	(3) Productivity	(4) Credit Constr.	(5) R&D	(6) Foreign Techn.
Import Only	0.519***	0.207***	0.312***	-0.014	0.060***	0.016**
	(0.064)	(0.041)	(0.046)	(0.011)	(0.011)	(0.007)
Export Only	1.158***	0.805***	0.353***	-0.049***	0.157***	0.029**
	(0.071)	(0.053)	(0.049)	(0.013)	(0.016)	(0.014)
Two-Way Trade	1.656***	1.312***	0.345***	-0.083***	0.204***	0.081***
	(0.068)	(0.049)	(0.046)	(0.011)	(0.015)	(0.010)
Constant	15.010***	3.769***	11.241***	0.134***	0.254***	0.255***
	(0.263)	(0.161)	(0.184)	(0.042)	(0.066)	(0.065)
No. Obs.	9417	9417	9417	9417	8628	6355
R^2	0.413	0.231	0.513	0.048	0.134	0.179
F	161.207	74.313	222.875	12.800	31.318	16.268

OLS regressions. Year, country, sector dummies. Robust standard errors in parentheses. (d) for discrete change of dummy variable from 0 to 1. Significance levels: *10%,**5%, ***1%.

have a productivity advantage over exporters-only and importers-only. In terms of sales and employment, the premium of each trading category over purely domestic firms is larger in the manufacturing sample than in the total sample whereas it is smaller in the services subsample. This suggests that manufacturing firms are different from service firms, perhaps due to the potential for scale economies to be more easily exploited by the largest, most productive firms.

3.4 Empirical Strategy

We study the impact of credit constraints on the extensive margin of trade, that is, on the probability that a firm i active in industry k in country c exports and imports, respectively. In the following, we will derive the empirical strategy for the extensive margin of exporting. The strategy for the extensive margin of importing is analogous.

The probability of being an exporter can be written as follows:

$$Exp_{ikct} = \left\{ \begin{array}{lll} 1 & \text{if} & \alpha_0 + \alpha_1 Constr_{ikct} + \boldsymbol{\alpha_2 Contr_{ikct}} \\ & & +D_k + D_c + D_t + \epsilon_{ikct} > 0 \\ 0 & \text{otherwise} & \end{array} \right\}, \quad (3.1)$$

where Exp_{ikct} is the exporter dummy. $Constr_{ikct}$ is a binary variable that takes the value one if the firm reports to be credit constrained. $\boldsymbol{Contr_{ikct}}$ is a vector of firm level controls that includes $Size_{ikct}$, $Productivity_{ikct}$ and $Foreign_{ikct}$. D_k, D_c, D_t are a set of industry, country and year dummies and ϵ_{ikct} is a normally distributed random error.

The major challenge of estimating (3.1) is that $Constr_{ikct}$ is potentially endogenous. There might be unobserved factors that determine both the export decision and the credit constraints faced by firms. Furthermore, exporter status and credit constraints might be simultaneously determined (see discussion in Section 3.3.2). Then, cov $(Constr_{ikct}, \epsilon_{ikct}) \neq 0$ and $\hat{\alpha_1}$ does not correspond to the true α_1.

The usual approach to tackle these endogeneity issues is to use non-linear instrumental variable (IV) techniques, such as IV probit. However, IV probit is only applicable if the endogenous regressor is a continuous variable. Here, the potentially endogenous regressor, $Constr_{ikct}$, is a binary variable.[42]

There exists a simple solution (Greene, 2002, p. 716). We write the probability that a firm is credit constrained as

$$Constr_{ikct} = \begin{cases} 1 \quad \text{if} & \beta_0 + \boldsymbol{\beta_1 Z_{ikct}} + \boldsymbol{\beta_2 Contr_{ikct}} \\ & +D_k + D_c + D_t + \mu_{ikct} > 0 \\ 0 \quad \text{otherwise} & \end{cases} . \tag{3.2}$$

$\boldsymbol{Z_{ikct}}$ includes $Overdue_{ikct}$, $Disclosure_{ct} \times ExtDep_k$ and $RegQu_{ct} \times FinDev_{ct}$. These variables are regarded as instruments: they affect the degree of credit constraints reported by firms but are exogenous to the export decision given the other regressors (see Section 3.3.2). μ_{ikct} is a normally distributed random error.

We assume that ϵ_{ickt} and μ_{ikct} are jointly normally distributed according to $\Phi_2(0, 0, 1, 1, \rho)$, where Φ_2 denotes the cumulative distribution function of the bivariate normal distribution. Equations (3.1) and (3.2) then represent a recursive bivariate probit model that can be consistently estimated using maximum likelihood techniques:

$$\begin{aligned} \text{pr}\left(Exp_{ikct} = 1\right) &= \Phi\left(\boldsymbol{\gamma_1 X_1} + \delta Constr_{ikct}\right) \\ \text{pr}\left(Constr_{ikct} = 1\right) &= \Phi\left(\boldsymbol{\gamma_2 X_2}\right), \\ \text{where} \qquad \boldsymbol{\gamma_1 X_1} &= \alpha_0 + \boldsymbol{\alpha_2 Contr_{ikct}} + D_k + D_c + D_t \\ \boldsymbol{\gamma_2 X_2} &= \beta_0 + \boldsymbol{\beta_1 Z_{ikct}} + \boldsymbol{\beta_2 Contr_{ikct}} + D_k + D_c + D_t. \end{aligned} \tag{3.3}$$

The recursive structure follows from the fact that only one endogenous variable, $Constr_{ikct}$, is allowed on the right-hand side of (3.3). The vector of instruments $\boldsymbol{Z_{ikct}}$ — included only in the second equation — generates variation in the treatment and allows the identification of a causal effect of credit constraints on the export probability.

In particular, the probability that a firm is credit constrained and exports is

$$\begin{aligned} \text{pr}\left(Exp_{ikct} = 1, Constr_{ikct} = 1\right) &= \text{pr}\left(Exp_{ikct} = 1 | Constr_{ikct} = 1\right) \text{pr}\left(Constr_{ikct} = 1\right) \\ &= \frac{\Phi_2\left(\boldsymbol{\gamma_1 X_1} + \delta Constr_{ikct}, \boldsymbol{\gamma_2 X_2}, \rho\right)}{\Phi\left(\boldsymbol{\gamma_2 X_2}\right)} \Phi\left(\boldsymbol{\gamma_2 X_2}\right) \\ &= \Phi_2(\boldsymbol{\gamma_1 X_1} + \delta Constr_{ikct}, \boldsymbol{\gamma_2 X_2}, \rho). \end{aligned} \tag{3.4}$$

[42] Moreover, the simultaneous likelihood estimation described in the following is considered superior to conventional two-stage IV procedures. See, for example, Marra and Radice (2011).

(3.4) is just the unconditional bivariate probability of exporting and being credit constrained, that is, the probability one obtains when estimating (3.3) without paying attention to the endogeneity issue. The probabilities of the other cells

- $\text{pr}\left(Exp_{ikct} = 1, Constr_{ikct} = 0\right)$,
- $\text{pr}\left(Exp_{ikct} = 0, Constr_{ikct} = 1\right)$,
- $\text{pr}\left(Exp_{ikct} = 0, Constr_{ikct} = 0\right)$

are computed analogously to (3.4). Standard bivariate probit software then maximizes the log-likelihood

$$L = \sum_{i=0}^{1} \sum_{j=0}^{1} \text{pr}\left(Exp_{ikct} = i, Constr_{ikct} = j\right). \tag{3.5}$$

3.5 Empirical Results

3.5.1 Main Results

The results are reported in Table 3.7. In each specification, sector, year and country dummies are included.

First, we estimate Equation (3.1) using probit, that is, we treat credit constraints as exogenous. Marginal effects at the mean are displayed in column (1). Credit constraints have a statistically significant negative effect on the export probability: at the mean, credit constraints reduce the export probability by 3.2 per cent. Larger, more productive and foreign owned firms have a higher probability of exporting.

Column (2) reports the results for the bivariate probit estimation of Equation (3.3). The lower cell of column (2) confirms that the coefficients of the instruments have the expected sign and are all statistically significant at the one per cent level. Firms that have payments overdue by more than 90 days are found to be more likely to be credit constrained. At the country level, the interaction of regulatory quality and financial development is shown to influence credit constraints in the expected direction: for a given level of financial development, firms in countries with higher regulatory quality are less credit constrained. Similarly, firms with higher reliance on external finance in countries with more transparent

	Exporter		Importer	
	(1)	(2)	(3)	(4)
	Probit	Biv. Probit	Probit	Biv. Probit
Credit Constr. (d)	-0.032***	-0.876***	0.020	-1.270***
	(0.012)	(0.214)	(0.021)	(0.117)
Size	0.062***	0.209***	0.033***	0.034**
	(0.003)	(0.018)	(0.004)	(0.014)
Productivity	0.022***	0.075***	-0.007	-0.026*
	(0.004)	(0.015)	(0.005)	(0.013)
Foreign (d)	0.191***	0.574***	-0.005	-0.064
	(0.018)	(0.053)	(0.021)	(0.055)
		Credit Constr.		Credit Constr.
Disclosure × ExtDep		-0.022***		-0.018**
		(0.007)		(0.007)
Overdue (d)		0.266***		0.118
		(0.075)		(0.106)
RegQu × FinDev		-0.003***		-0.004***
		(0.001)		(0.002)
Size		-0.162***		-0.168***
		(0.013)		(0.018)
Productivity		-0.040***		-0.045***
		(0.011)		(0.017)
Foreign (d)		-0.145**		-0.273***
		(0.061)		(0.086)
No. Obs.	9408	9408	5542	5542
Pseudo-R^2	0.275		0.090	
ρ		0.429***		0.762***
ATE		-0.172		-0.330

Marginal effects at the mean for probit regressions. Year, country, sector dummies. Robust standard errors in parentheses. (d) for discrete change of dummy variable from 0 to 1. Significance levels: *10%,**5%, ***1%.

Table 3.7: Extensive Margin – All Firms

investor protection are less likely to be credit constrained. Furthermore, larger, more productive and foreign owned firms are less likely to be credit constrained. In the upper cell of Column (2), firm size, productivity and foreign ownership have the expected positive effect on exporter status. Credit constraints have a negative effect on the likelihood of a firm exporting. The average treatment effect (ATE) of credit constraints on exporting is given by $\Phi(\boldsymbol{\gamma_1 X_1} + \delta) - \Phi(\boldsymbol{\gamma_1 X_1})$, that is, the export probability of a credit constrained firm, conditional on the other regressors, as compared to a firm that is not credit constrained (Wooldridge, 2002, p. 477). It is equal to -0.172 and significant at the one per cent level. This implies that after controlling for the endogeneity of credit constraints as well as for firm, sector, time, and country characteristics, credit constraints lead to a 17.2 per cent reduction in the probability that a firm will export. ρ, the correlation coefficient between the residuals of the export (ϵ_{ikct}) and the credit constraints equation (u_{ikct}), is equal to 0.429 and significantly different from zero. This indicates that we can reject the hypothesis that credit constraints are exogenous. Hence, the bivariate probit specification is preferable to two individual probit regressions.

Columns (3) and (4) report the estimates from the probit and bivariate probit estimation of the extensive margin of importing. Larger firms are more likely to import material inputs. Credit constraints have no significant effect on the import probability when credit constraints are treated as exogenous (Column (3)). After controlling for the endogeneity of credit constraints in Column (4), we find that credit constraints do have a significant negative effect on the probability of importing. ρ is again significantly different from zero. The average treatment effect is equal to -0.33, indicating that credit constraints reduce the import probability by 33 per cent.

Estimating a linear probability model by Two Stage Least Squares (2SLS) instead of the bivariate probit specification in (3.3), we obtain similar results (see Table C.6). However, caution should be used when drawing conclusions from the linear probability model as the predicted probabilities might be larger than one or less than zero.

The results of Table 3.7 combine effects for firms in the manufacturing, construction, and service sectors. In the following, we study the impact of credit constraints on the export and import probability separately for manufacturing and service firms.

Table 3.8 repeats the four specifications of Table 3.7 for manufacturing firms only. Larger, more productive, and foreign owned manufacturers are less likely to be credit constrained and more likely to export. Column (1) reports that the effect of credit constraints on the export probability of manufacturers is negative but not statistically signficant if credit constraints are treated as exogenous. Column (2) then confirms that the negative effect

	Exporter		Importer	
	(1)	(2)	(3)	(4)
	Probit	Biv. Probit	Probit	Biv. Probit
Credit Constr. (d)	-0.032	-0.914***	0.058*	-1.049***
	(0.025)	(0.265)	(0.030)	(0.173)
Size	0.148***	0.344***	0.054***	0.080***
	(0.007)	(0.031)	(0.007)	(0.021)
Productivity	0.036***	0.077***	0.051***	0.099***
	(0.008)	(0.023)	(0.012)	(0.030)
Foreign (d)	0.303***	0.729***	-0.012	-0.053
	(0.033)	(0.087)	(0.031)	(0.078)
		Credit Constr.		Credit Constr.
Disclosure × ExtDep		-0.022***		-0.023***
		(0.008)		(0.008)
Overdue (d)		0.281**		0.225
		(0.117)		(0.153)
RegQu × FinDev		-0.003*		-0.005**
		(0.002)		(0.002)
Size		-0.187***		-0.182***
		(0.020)		(0.023)
Productivity		-0.071***		-0.061***
		(0.019)		(0.023)
Foreign (d)		-0.143		-0.244**
		(0.096)		(0.108)
No. Obs.	3698	3698	2864	2864
Pseudo-R^2	0.284		0.152	
ρ		0.475***		0.672***
ATE		-0.234		-0.308

Marginal effects at the mean for probit regressions. Year, country, sector dummies. Robust standard errors in parentheses. (d) for discrete change of dummy variable from 0 to 1. Significance levels: *10%,**5%, ***1%.

Table 3.8: Extensive Margin – Manufacturing Firms

of credit constraints on the export probability identified for all firms is present for manufacturing firms, if endogeneity is controlled for. The three instruments in the lower cell of Column (2) have almost identical coefficients to Table 3.7. The average treatment effect is equal to -0.234, and hence larger than that for the sample spanning all sectors.

	Exporter	
	(1)	(2)
	Probit	Biv. Probit
Credit Constr. (d)	-0.030**	-1.339***
	(0.012)	(0.359)
Size	0.025***	0.078**
	(0.003)	(0.033)
Productivity	0.021***	0.096***
	(0.004)	(0.022)
Foreign (d)	0.108***	0.383***
	(0.020)	(0.088)
		Credit Constr.
Disclosure × ExtDep		0.001
		(0.021)
Overdue (d)		0.180
		(0.117)
RegQu × FinDev		-0.003***
		(0.001)
Size		-0.139***
		(0.018)
Productivity		-0.017
		(0.016)
Foreign (d)		-0.078
		(0.082)
No. Obs.	4715	4715
Pseudo-R^2	0.202	
ρ		0.702*
ATE		-0.199

Marginal effects at the mean for probit regressions. Year, country, sector dummies. Robust standard errors in parentheses. (d) for discrete change of dummy variable from 0 to 1. Significance levels: *10%,**5%, ***1%.

Table 3.9: Extensive Margin – Service Firms

Firm size and productivity positively affect the import probability while foreign ownership has no effect on the import decision. As in the full sample, credit constraints have a positive effect on the import probability (that is here statistically significant at the 10 per cent level) when estimating the probit specification. The effect turns negative and highly significant when controlling for the endogeneity of the credit constraints variable. ρ is statistically significant at the one per cent level, underlining the importance of jointly estimating the importer and the credit constraints equation. The average treatment effect amounts to -0.308 and is thus similar to that for the full sample. The effect of credit constraints is again similar if estimating a linear probability model (see Table C.7).

Firms in the service sector are studied in Table 3.9. Results are reported for the export equation only, as the import equation does not converge without the removal of sector and country dummies.[43] Larger, more productive and foreign owned firms are more likely to export. Larger firms are, in addition, less likely to report credit constraints. Credit constraints have a negative and statistically significant effect on the export probability that persists when we control for endogeneity in the bivariate probit specification.

In all, we find that credit constraints negatively affect firms' participation in international trade. Credit constraints reduce the export probability of both manufacturing and service firms and the import probability of manufacturing firms. Moreover, we confirm that more productive, larger and foreign owned firms are more likely to trade internationally. Finally, our results stress the importance of taking into account the potential endogeneity of the credit constraints variable.

3.5.2 Comparison with Measure Based on Rejected Applications

Table 3.10 displays the results when using the measure of credit constraints that is based on rejected applications. This measure classifies only firms which report a rejected credit application as credit constrained (see Section 3.3.2).

Column (1) reports the results for the full sample. Credit constraints negatively affect the export probability. The reported statistical significance and the average treatment effect are slightly lower than those in Table 3.7, pointing to a downward bias in the estimates

[43] Table C.8 reports the results of a 2SLS estimation. However, the three instruments are not significant in the first stage regression.

when using this measure of credit constraints. The equation for the importer status does not converge without the removal of sector and country dummies.

The results for manufacturing firms are shown in Columns (3) to (6). The effect of credit constraints on the export probability is negative but not significant. Moreover, the average treatment effect (ATE) is -0.113 and thus much smaller than that in Table 3.8. This points to a downward bias when using this measure of credit constraints that does not account for the firm's credit demand. Most importantly, the correlation coefficient ρ is not significant. This indicates that the hypothesis that credit constraints are exogenous cannot be rejected. Hence, we can estimate the exporter and the credit constraints equation separately. However, the results from the probit estimation in Column (3) show no significant effect of credit constraints on the export probability.

The estimated average treatment effect of credit constraints on the import probability is similar to that reported in Table 3.7.

The same is true for the average treatment effect of credit constraints on the export probability of service firms (Column (8)). Unfortunately, the equation for the importer status does not converge.

	All Firms		Manufacturing Firms				Service Firms	
	Exporter		Exporter		Importer		Exporter	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Probit	Biv. Probit	Probit	Biv. Probit	Probit	Biv. Probit	Probit	Biv. Probit
Credit Constr. (d)	0.004	-0.775**	0.013	-0.428	0.091*	-1.228***	-0.003	-1.428***
	(0.021)	(0.357)	(0.042)	(0.480)	(0.047)	(0.218)	(0.025)	(0.227)
Size	0.067***	0.227***	0.155***	0.397***	0.034***	0.069***	0.028***	0.103***
	(0.004)	(0.016)	(0.009)	(0.026)	(0.008)	(0.020)	(0.004)	(0.019)
Productivity	0.017***	0.059***	0.021**	0.051*	0.037***	0.080**	0.023***	0.103***
	(0.005)	(0.016)	(0.010)	(0.026)	(0.014)	(0.033)	(0.005)	(0.022)
Foreign (d)	0.224***	0.649***	0.281***	0.711***	-0.059*	-0.161*	0.158***	0.540***
	(0.023)	(0.062))	(0.038)	(0.101)	(0.034)	(0.091)	(0.029)	(0.085)
		Credit Constr.		Credit Constr.		Credit Constr.		Credit Constr.
Disclosure × ExtDep		-0.019**		-0.018*		-0.022**		0.056**
		(0.009)		(0.010)		(0.010)		(0.027)
Overdue (d)		0.241**		0.493***		0.513***		-0.202
		(0.104)		(0.147)		(0.174)		(0.189)
RegQu × FinDev		-0.003**		-0.006**		-0.005*		-0.004*
		(0.001)		(0.003)		(0.003)		(0.002)
Size		-0.087***		-0.097***		-0.103***		-0.064**
		(0.019)		(0.028)		(0.033)		(0.027)
Productivity		-0.031*		-0.070**		-0.032		0.015
		(0.017)		(0.028)		(0.035)		(0.026)
Foreign (d)		-0.050		-0.076		-0.223		0.104
		(0.095)		(0.143)		(0.146)		(0.123)
No. Obs.	6705	6705	2679	2679	2295	2295	3304	3304
Pseudo-R^2	0.261		0.284		0.159		0.192	
ρ		0.421*		0.247		0.740***		0.802***
ATE		-0.156		-0.113		-0.332		-0.196

Marginal effects at the mean reported for probit regressions. Year, country, sector dummies. Robust standard errors in parentheses. Significance levels: *10%,**5%, ***1%.

Table 3.10: Measure based on rejected applications

3.6 Sensitivity Tests

3.6.1 Additional Controls: Firm Age and Transparency

We test whether the negative impact of credit constraints on the export and import probability found in the previous section is robust to the inclusion of additional firm level controls. In particular, we include firm age and an audit dummy, in addition to firm size, productivity and foreign ownership. Firm age is the difference between the year in which the survey took place and the year in which the firm began operations. Our assumption is that older firms are less likely to be credit constrained as they have longer credit records. The audit dummy takes the value one if the firm had its *annual financial statements checked and certified by an external auditor*. This variable captures how opaque the firm is to outsiders: audited firms signal transparency and good quality to potential creditors and trading partners.

The results are displayed in Table 3.11. Our previous results are unchanged: larger and foreign-owned firms are less likely to be credit constrained and more likely to export and import. Credit constraints significantly reduce the probability of both exporting and importing. The audit dummy has a negative (though not statistically significant) effect on the probability of being credit constrained and a positive effect on the export probability. Firm age does not affect the export and import probability. However, older firms are more likely to be credit constrained. This is, at first sight, surprising. A potential explanation is the following: older firms have been founded before the fall of the Iron Curtain or shortly after. Hence, they were established as state-owned firms whereas younger firms have, for the most part, been founded as private firms. They might be more competitive and therefore preferred by creditors.

3.6.2 Entry and Exit into Importing and Exporting

In the following, we use the panel structure in our data to study the effect of credit constraints on entry into and exit from exporting and importing (see Bernard, Sta-

	Exporter			Importer		
	(1)	(2)	(3)	(4)	(5)	(6)
Credit Constr. (d)	-0.878***	-0.877***	-0.879***	-1.267***	-1.276***	-1.271***
	(0.218)	(0.210)	(0.213)	(0.115)	(0.116)	(0.113)
Size	0.203***	0.196***	0.192***	0.028*	0.031**	0.026*
	(0.019)	(0.018)	(0.019)	(0.015)	(0.015)	(0.015)
Productivity	0.075***	0.072***	0.072***	-0.027**	-0.029**	-0.029**
	(0.015)	(0.015)	(0.015)	(0.013)	(0.013)	(0.013)
Foreign (d)	0.578***	0.560***	0.563***	-0.058	-0.067	-0.061
	(0.054)	(0.053)	(0.053)	(0.055)	(0.055)	(0.055)
Age	0.001		0.001	0.001		0.001
	(0.001)		(0.001)	(0.001)		(0.001)
Audit (d)		0.098**	0.097**		0.035	0.031
		(0.038)	(0.038)		(0.040)	(0.041)
	Credit Constr.			Credit Constr.		
Disclosure × ExtDep	-0.021***	-0.022***	-0.021***	-0.018**	-0.018**	-0.018**
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)
Overdue (d)	0.264***	0.277***	0.274***	0.117	0.126	0.123
	(0.075)	(0.075)	(0.075)	(0.106)	(0.105)	(0.106)
RegQu × FinDev	-0.003***	-0.003***	-0.003**	-0.004***	-0.004***	-0.004***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
Size	-0.170***	-0.157***	-0.165***	-0.184***	-0.161***	-0.178***
	(0.014)	(0.014)	(0.014)	(0.020)	(0.019)	(0.021)
Productivity	-0.040***	-0.039***	-0.039***	-0.047***	-0.045***	-0.046***
	(0.011)	(0.011)	(0.011)	(0.017)	(0.017)	(0.017)
Foreign (d)	-0.136**	-0.136**	-0.125**	-0.258***	-0.261***	-0.243***
	(0.062)	(0.062)	(0.062)	(0.086)	(0.087)	(0.087)
Age	0.003**		0.003***	0.004***		0.005***
	(0.001)		(0.001)	(0.001)		(0.001)
Audit (d)		-0.037	-0.042		-0.048	-0.054
		(0.037)	(0.037)		(0.052)	(0.052)
No. Obs.	9370	9298	9261	5527	5469	5454
ρ	0.430***	0.431***	0.432***	0.762***	0.770***	0.769***
ATE	-0.172	-0.173	-0.173	-0.329	-0.331	-0.330

Bivariate probit estimations. Year, country, sector dummies. Robust standard errors in parentheses. (d) for discrete change of dummy variable from 0 to 1. Significance levels: *10%,**5%, ***1%.

Table 3.11: Robustness Check: Firm age and audit dummy included

bilito, and Donghoon Yoo, 2010). We keep observations of firms which were surveyed both in 2005 and 2008/2009. No firm was surveyed in both 2008 and 2009. We then create two dummy variables, *entry* and *exit*. *entry* takes the value one if a firm did not export in 2005 but exported in 2008/2009 and *exit* is equal to one if a firm exported in 2005 but no longer exported in 2008/2009. We estimate the following equations using probit to examine the impact of credit constraints on entry and exit

$$\begin{aligned} Entry_{ikc} &= \alpha_0 + \alpha_1 Constr_{ikc05} + \boldsymbol{\alpha_2 Contr_{ikc05}} + D_k + D_c + \epsilon_{ikct} \\ Exit_{ikc} &= \alpha_0 + \alpha_1 Constr_{ikc08/9} + \boldsymbol{\alpha_2 Contr_{ikc08/9}} + D_k + D_c + \epsilon_{ikct}. \end{aligned} \quad (3.6)$$

Table 3.12 shows the results.

	Entry		Exit	
	Exporter	Importer	Exporter	Importer
	(1)	(2)	(3)	(4)
Credit Constr. (d)	-0.033*	0.164	-0.000	0.400**
	(0.020)	(0.167)	(0.097)	(0.169)
Size	0.021***	0.063	-0.056**	-0.129**
	(0.007)	(0.043)	(0.028)	(0.060)
Productivity	0.038**	0.150*	-0.056**	0.219*
	(0.015)	(0.087)	(0.028)	(0.124)
Foreign (d)	0.090	-0.085	-0.186**	-0.465**
	(0.066)	(0.170)	(0.078)	(0.193)
No. Obs.	518	108	229	58
Pseudo-R^2	0.264	0.285	0.256	0.272

Marginal effects at the mean. Year, country, sector dummies. Robust standard errors in parentheses. (d) for discrete change of dummy variable from 0 to 1. Significance levels: *10%,**5%, ***1%.

Table 3.12: Robustness Check: Entry and Exit

Only 531 firms in our sample have been surveyed both in 2005 and in 2008/2009. Each firm corresponds to one observation as we no longer use the pooled data. Hence, the number of observations drops dramatically. The results should therefore be interpreted with caution.

Columns (1) and (3) display the results of the entry and exit equation for exporting. Larger, more productive, and foreign owned firms are more likely to start exporting and less likely to exit the export market. The impact of credit constraints on the entry probability is negative and statistically significant while credit constraints do not seem to affect the exit probability. This result is in line with the Melitz model of selection into exporting due to fixed export costs.

The results of the entry and exit equation for importing are reported in Columns (2) and (4). More productive firms are more likely to start importing while larger and foreign-owned firms are less likely to exit the import market. Credit constraints do not affect entry into importing but foster exit.

3.7 Conclusion

The importance of financial development for economic growth in general, and international trade in particular, is well established. Recent theoretical work stresses sunk entry costs as a potential explanation for why imperfections in credit markets may impede firms' entry into export markets. We study empirically the impact of credit constraints on the export and import decision of firms in Eastern Europe. We document a negative impact of credit constraints on a firm's participation in international trade, both for manufacturers and service firms. These findings are in line with the predictions of the related theoretical literature. They have implications for policy makers aiming to promote productivity growth by widening participation in export and import markets. Policies designed to improve access to external finance must be implemented for firms in the services, as well as the manufacturing sector. Moreover, smaller firms that are discouraged by high interest rates or collateral requirements are to be encouraged to apply for a credit.

Appendix A

Appendix to Chapter 1

A.1 Proof of Lemma 1

Total differentiation of (1.19) yields the slopes of the free entry conditions of the home country and of the foreign country in the (c_D, c_D^*) space:

$$\begin{aligned} FE : \frac{dc_D^*}{dc_D} &= -\frac{(c_D)^{k+1} + t(k+1)(c_A)^k}{(c_X)^{k+1} + t(k+1)(c_A)^k} \\ FE^* : \frac{dc_D^*}{dc_D} &= -\frac{(c_X^*)^{k+1} + t(k+1)(c_A^*)^k}{(c_D^*)^{k+1} + t(k+1)(c_A^*)^k}. \end{aligned} \tag{A.1}$$

Both curves are downward sloping. From our assumption that $c_X < c_D$ follows that $(c_X)^{k+1} < (c_D)^{k+1}$. The absolute amount of the slope of FE is unambiguously larger than one and the absolute amount of the slope of FE^* is unambiguously smaller than one. Hence, there is a unique intersection if the two curves intersect.

For a given (ψ, ψ^*), let $c_D(1)$ denote the solution to home's free entry condition for $c_D^* = c_M$. Furthermore, denote with $\bar{\psi}$ the value of ψ, given ψ^*, for which $(c_D(1), c_M)$ is the solution to foreign's free entry condition. It follows that for $\psi < \bar{\psi}$ and, by symmetry, for $\psi^* < \bar{\psi}$ the two curves intersect.

A.2 Proof of Proposition 1

Entry cutoffs

The RHS of the two free entry conditions is identical. For a given entry cutoff in the other country, (i) the LHS monotonously increases in the own entry cutoff and (ii) the LHS of (1.19) is larger in the foreign country. Therefore, $c_D^* < c_D$.

Average productivity

From (1.18) the average cost of domestic firms, our (inverse) measure of average productivity, is

$$\overline{CoP} = \frac{k}{k+1} c_D - t\left(\frac{c_A}{c_D}\right)^k. \tag{A.2}$$

Since $c_D^* < c_D$ and, from (1.14), $c_A^* > c_A$, $\overline{CoP}^* < \overline{CoP}$, that is, average productivity is higher in the foreign country.

The aggregate production cost is obtained by weighting the production cost either with output $q(c)$ or with revenues $r(c)$:

$$\begin{aligned}
\overline{CoP_q} =& \frac{N_{DA}}{N_D}\int_0^{c_A}(c-t)q^A(c)\frac{g(c)}{G(c_A)}dc + \frac{N_{DL}}{N_D}\int_{c_A}^{c_D} cq(c)\frac{g(c)}{G(c_D)-G(c_A)}dc \\
=& \frac{S}{2\gamma}\left\{\frac{k(c_D)^2}{(k+1)(k+2)} - t\left(\frac{c_A}{c_D}\right)^k\left[c_D - \frac{2k}{k+1}c_A + t\right]\right\} \qquad (A.3)\\
\overline{CoP_r} =& \frac{N_{DA}}{N_D}\int_0^{c_A}(c-t)r^A(c)\frac{g(c)}{G(c_A)}dc + \frac{N_{DL}}{N_D}\int_{c_A}^{c_D} cr(c)\frac{g(c)}{G(c_D)-G(c_A)}dc \\
=& \frac{S}{4\gamma}\left\{\frac{2k(c_D)^3}{(k+1)(k+3)} - \frac{t(c_A)^k}{(c_D)^{k-2}} - \frac{t^2k(c_A)^{k+1}\left[(k+2)-(k+1)c_A\right]}{(k+1)(k+2)(c_D)^k} + t^3\right\}.
\end{aligned}$$

(A.4)

Fraction of exporters and high-technology firms

From (1.13) and (1.14), it follows directly that $\left(\frac{c_X}{c_D}\right)^k < \left(\frac{c_X^*}{c_D^*}\right)^k$ and $\left(\frac{c_A}{c_D}\right)^k < \left(\frac{c_A^*}{c_D^*}\right)^k$: the fraction of exporters and high-technology firms is larger in the foreign country.

Divergence

Total differentiation of (1.19) yields $\frac{dc_D}{d\psi} > 0$ and $\frac{dc_D^*}{d\psi} < 0$. Intuitively, given ψ^*, an increase in ψ lowers (increases) ex-ante expected profits in the home (foreign) country leading to less (more) entry and hence to a higher (lower) entry cutoff. Furthermore,

$\frac{dc_X}{d\psi} = \frac{dc^*_D}{d\psi} < 0$, $\frac{dc^*_X}{d\psi} = \frac{dc_D}{d\psi} > 0$, $\frac{dc_A}{d\psi} = \frac{dc_D}{d\psi} + \frac{dc^*_D}{d\psi} - \frac{2\gamma f}{St} < 0$ and $\frac{dc^*_A}{d\psi} = \frac{dc_D}{d\psi} + \frac{dc^*_D}{d\psi} > 0$. It follows that $\overline{CoP} - \overline{CoP}^*$, $\left(\frac{c^*_X}{c^*_D}\right)^k - \left(\frac{c_X}{c_D}\right)^k$ and $\left(\frac{c^*_A}{c^*_D}\right)^k - \left(\frac{c_A}{c_D}\right)^k$ increase. Moreover:

$$\begin{aligned}
\frac{d\left[\left(\frac{c^*_X}{c^*_D}\right)^k / \left(\frac{c_X}{c_D}\right)^k\right]}{d\psi} =& k\left(\frac{c^*_X c_D}{c^*_D c_X}\right)^k \frac{\left[c_D \frac{dc^*_X}{d\psi} + c^*_X \frac{dc_D}{d\psi}\right] c^*_D c_X - \left[c_X \frac{dc^*_D}{d\psi} + c^*_D \frac{dc_X}{d\psi}\right] c_D c^*_X}{\left(c^*_D c_X\right)^2} \\
=& k\left(\frac{c^*_X c_D}{c^*_D c_X}\right)^k \frac{\left(c_D + c^*_X\right) \frac{dc_D}{d\psi} c^*_D c_X - \left(c_X + c^*_D\right) \frac{dc^*_D}{d\psi} c_D c^*_X}{\left(c^*_D c_X\right)^2} > 0 \\
\frac{d\left[\left(\frac{c^*_A}{c^*_D}\right)^k / \left(\frac{c_A}{c_D}\right)^k\right]}{d\psi} =& k\left(\frac{c^*_A c_D}{c^*_D c_A}\right)^k \frac{\left[c_D \frac{dc^*_A}{d\psi} + c^*_A \frac{dc_D}{d\psi}\right] c^*_D c_A - \left[c_A \frac{dc^*_D}{d\psi} + c^*_D \frac{dc_A}{d\psi}\right] c_D c^*_A}{\left(c^*_D c_A\right)^2} \\
=& k\left(\frac{c^*_A c_D}{c^*_D c_A}\right)^k \left\{ \frac{\left[c_D \left(\frac{dc_D}{d\psi} + \frac{dc^*_D}{d\psi}\right) + c^*_A \frac{dc_D}{d\psi}\right] c^*_D c_A}{\left(c^*_D c_A\right)^2} \right. \\
& \left. - \frac{\left[c_A \frac{dc^*_D}{d\psi} + c^*_D \left(\frac{dc_D}{d\psi} + \frac{dc^*_D}{d\psi} - \frac{2\gamma f}{St}\right)\right] c_D c^*_A}{\left(c^*_D c_A\right)^2} \right\} > 0 \\
\frac{d\left(\overline{CoP}/\overline{CoP^*}\right)}{d\psi} =& \frac{\left[\frac{k}{k+1}\frac{dc_D}{d\psi} - tk\left(\frac{c_A}{c_D}\right)^{k-1} \frac{\frac{dc_A}{d\psi} c_D - \frac{dc_D}{d\psi} c_A}{\left(c_D\right)^2}\right] \overline{CoP^*}}{\left(\overline{CoP}\right)^2} \\
& - \frac{\left[\frac{k}{k+1}\frac{dc^*_D}{d\psi} - tk\left(\frac{c^*_A}{c^*_D}\right)^{k-1} \frac{\frac{dc^*_A}{d\psi} c^*_D - \frac{dc^*_D}{d\psi} c^*_A}{\left(c^*_D\right)^2}\right] \overline{CoP}}{\left(\overline{CoP}\right)^2} > 0. \qquad \text{(A.5)}
\end{aligned}$$

A.3 Proof of Proposition 2

Fraction of exporters and high-technology firms

In the symmetric case, $\psi = \psi^*$. The free entry condition (1.19) reduces to:

$$\frac{\left(c_D\right)^{k+2} + \left(c_D - \tau\right)^{k+2}}{k+2} + 2t\left(c_A\right)^{k+1} = \frac{f_E 2\gamma c^k_M (k+1)}{S}. \qquad \text{(A.6)}$$

Total differentiation of (A.6) yields

$$\frac{dc_D}{d\tau} = \frac{\left(c_D - \tau\right)^{k+1} + t(k+1)\left(c_A\right)^k}{\left(c_D\right)^{k+1} + \left(c_D - \tau\right)^{k+1} + 2t(k+1)\left(c_A\right)^k}. \qquad \text{(A.7)}$$

c_X then decreases in τ:

$$\begin{aligned}\frac{dc_X}{d\tau} &= \frac{dc_D}{d\tau} - 1 < 0 \\ &\iff -\left(c_D\right)^{k+1} - t(k+1)\left(c_A\right)^k < 0.\end{aligned}$$

Since c_D increases in τ, the fraction of exporters, given by $\left(\frac{c_X}{c_D}\right)^k$ unambiguously decreases in τ.

c_A decreases in τ

$$\begin{aligned}\frac{dc_A}{d\tau} &= \frac{1}{2}\left(2\frac{dc_D}{d\tau} - 1\right) < 0 \\ &\iff \left(c_D - \tau\right)^{k+1} - \left(c_D\right)^{k+1} < 0.\end{aligned}$$

The fraction of high-technology firms also unambiguously decreases in τ.

A.4 Proof of Proposition 3

Entry cutoffs

Total differentiation of the free entry conditions yields the following expressions:

$$\begin{aligned}\frac{dc_D}{d\tau} &= \frac{\left[\left(c_X\right)^{k+1} + t(k+1)\left(c_A\right)^k\right]\left[\left(c_D^*\right)^{k+1} - \left(c_X^*\right)^{k+1}\right]}{\left[\left(c_D\right)^{k+1} + t(k+1)\left(c_A\right)^k\right]\left[\left(c_D^*\right)^{k+1} + t(k+1)\left(c_A^*\right)^k\right] - \left[\left(c_X\right)^{k+1} + t(k+1)\left(c_A\right)^k\right]\left[\left(c_X^*\right)^{k+1} + t(k+1)\left(c_A^*\right)^k\right]} \\ \frac{dc_D^*}{d\tau} &= \frac{\left[\left(c_X^*\right)^{k+1} + t(k+1)\left(c_A^*\right)^k\right]\left[\left(c_D\right)^{k+1} - \left(c_X\right)^{k+1}\right]}{\left[\left(c_D^*\right)^{k+1} + t(k+1)\left(c_A^*\right)^k\right]\left[\left(c_D\right)^{k+1} + t(k+1)\left(c_A\right)^k\right] - \left[\left(c_X^*\right)^{k+1} + t(k+1)\left(c_A^*\right)^k\right]\left[\left(c_X\right)^{k+1} + t(k+1)\left(c_A\right)^k\right]}.\end{aligned} \tag{A.8}$$

Hence, $\frac{dc_D}{d\tau} > 0$, $\frac{dc_D^*}{d\tau} > 0$, and $\frac{dc_D}{d\tau} < \frac{dc_D^*}{d\tau}$. Moreover, $\frac{dc_D}{d\tau} + \frac{dc_D^*}{d\tau} < 1$.

Average productivity, fraction of exporters and high-technology firms

From (A.8) follows that $\frac{dc_X}{d\tau} = \frac{dc_D^*}{d\tau} - 1 < 0$, $\frac{dc_X^*}{d\tau} = \frac{dc_D}{d\tau} - 1 < 0$. Moreover, $\frac{dc_A}{d\tau} = \frac{dc_A^*}{d\tau} = \frac{1}{2}\left(\frac{dc_D}{d\tau} + \frac{dc_D^*}{d\tau} - 1\right) < 0$.

It follows that the difference between the countries with respect to average productivity of domestic firms, the fraction of exporters and the fraction of high-technology firms decreases in τ.

Moreover:

$$\frac{d\left[\left(\frac{c_X^*}{c_D^*}\right)^k/\left(\frac{c_X}{c_D}\right)^k\right]}{d\tau} = k\left(\frac{c_X^* c_D}{c_D^* c_X}\right)^k \frac{\left[c_D \frac{dc_X^*}{d\tau} + c_X^* \frac{dc_D}{d\tau}\right] c_D^* c_X - \left[c_X \frac{dc_D^*}{d\tau} + c_D^* \frac{dc_X}{d\tau}\right] c_D c_X^*}{\left(c_D^* c_X\right)^2} >< 0$$

$$\frac{d\left[\left(\frac{c_A^*}{c_D^*}\right)^k/\left(\frac{c_A}{c_D}\right)^k\right]}{d\tau} = k\left(\frac{c_A^* c_D}{c_D^* c_A}\right)^k \frac{\left[c_D \frac{dc_A^*}{d\tau} + c_A^* \frac{dc_D}{d\tau}\right] c_D^* c_A - \left[c_A \frac{dc_D^*}{d\tau} + c_D^* \frac{dc_A}{d\tau}\right] c_D c_A^*}{\left(c_D^* c_A\right)^2} >< 0$$

$$\begin{aligned}\frac{d\left(\overline{CoP}/\overline{CoP^*}\right)}{d\tau} =& \frac{\left[\frac{k}{k+1}\frac{dc_D}{d\tau} - tk\left(\frac{c_A}{c_D}\right)^{k-1}\frac{\frac{dc_A}{d\tau}c_D - \frac{dc_D}{d\tau}c_A}{(c_D)^2}\right]\overline{CoP}^*}{\left(\overline{CoP}^*\right)^2} \\ &- \frac{\left[\frac{k}{k+1}\frac{dc_D^*}{d\tau} - tk\left(\frac{c_A^*}{c_D^*}\right)^{k-1}\frac{\frac{dc_A^*}{d\tau}c_D^* - \frac{dc_D^*}{d\tau}c_A^*}{(c_{D^*})^2}\right]\overline{CoP}}{\left(\overline{CoP}^*\right)^2} \\ =& \frac{k}{\left(\overline{CoP^*}\right)^2(k+1)}\left[\frac{dc_D}{d\tau}\overline{CoP^*} - \frac{dc_D^*}{d\tau}\overline{CoP}\right] - \frac{tk}{\left(\overline{CoP^*}\right)^2}\left\{\frac{dc_A}{d\tau}\left[\left(\frac{c_A}{c_D}\right)^{k-1}\frac{\overline{CoP}^*}{c_D}\right.\right. \\ &\left.\left. - \left(\frac{c_A^*}{c_D^*}\right)^{k-1}\frac{\overline{CoP}}{c_D^*}\right] - \left[\left(\frac{c_A}{c_D}\right)^k\frac{\overline{CoP}^*}{c_D}\frac{dc_D}{d\tau} - \left(\frac{c_A^*}{c_D^*}\right)^k\frac{\overline{CoP}}{c_D^*}\frac{dc_D^*}{d\tau}\right]\right\} < 0.\end{aligned} \tag{A.9}$$

A.5 Welfare Analysis

Average price

The average price of varieties sold in the home country is the sum of the average price of domestic and the average price of foreign sellers weighted with their share in the total population of sellers:

$$\bar{p} = \frac{N_D}{N}\bar{p}_{dom} + \frac{N_X^*}{N}\bar{p}_{exp}^*, \tag{A.10}$$

where N, N_D and N_X^* are the total number of sellers, the number of domestic sellers, and the number of foreign sellers in the home country. The average price in the foreign country is analogous.

Moreover:

(1) The number of sellers in each market is the sum of domestic and foreign sellers:

$$
\begin{aligned}
N &= G\left(c_D\right) N_E + G\left(c_X^*\right) N_E^* \\
N^* &= G\left(c_D^*\right) N_E^* + G\left(c_X\right) N_E. \qquad \text{(A.11)}
\end{aligned}
$$

(A.11) can be solved for the number of entrants N_E and N_E^*:

$$
\begin{aligned}
N_E &= \frac{\left(c_M\right)^k}{\left(c_D\right)^k \left(c_D^*\right)^k - \left(c_X^*\right)^k \left(c_X\right)^k} \left[N \left(c_D^*\right)^k - N^* \left(c_X^*\right)^k\right] \\
N_E^* &= \frac{\left(c_M\right)^k}{\left(c_D\right)^k \left(c_D^*\right)^k - \left(c_X^*\right)^k \left(c_X\right)^k} \left[N^* \left(c_D\right)^k - N \left(c_X\right)^k\right]. \qquad \text{(A.12)}
\end{aligned}
$$

Using (A.12), the fraction of domestic and foreign producers is then

$$
\begin{aligned}
\frac{N_D}{N} &= \frac{1}{\left(c_D\right)^k \left(c_D^*\right)^k - \left(c_X^*\right)^k \left(c_X\right)^k} \left[\left(c_D\right)^k \left(c_D^*\right)^k - \frac{N^*}{N} \left(c_D\right)^k \left(c_X^*\right)^k\right] \\
\frac{N_X^*}{N} &= \frac{1}{\left(c_D\right)^k \left(c_D^*\right)^k - \left(c_X^*\right)^k \left(c_X\right)^k} \left[\frac{N^*}{N} \left(c_X^*\right)^k \left(c_D\right)^k - \left(c_X\right)^k \left(c_X^*\right)^k\right]. \qquad \text{(A.13)}
\end{aligned}
$$

(2) The average price of domestic sellers is the sum of the average price of domestic low- and high-technology firms weighted with their share in the total population of domestic sellers, $\frac{N_{DL}}{N_D} = \frac{G(c_D)-G(c_A)}{G(c_D)}$ and $\frac{N_{DA}}{N_D} = \frac{G(c_A)}{G(c_D)}$:

$$
\begin{aligned}
\bar{p}_{dom} &= \frac{N_{DA}}{N_D} \int_0^{c_A} p_{DA} \frac{g(c)}{G\left(c_A\right)} dc + \frac{N_{DL}}{N_D} \int_{c_A}^{c_D} p_D \frac{g(c)}{G\left(c_D\right) - G\left(c_A\right)} dc \\
&= \frac{2k+1}{2(k+1)} c_D - \frac{t}{2} \left(\frac{c_A}{c_D}\right)^k. \qquad \text{(A.14)}
\end{aligned}
$$

Analogously, the average price of foreign sellers is the sum of the average price of foreign low- and high-technology firms weighted with their share in the total population of foreign sellers, $\frac{N_{XL}^*}{N_X^*} = \frac{G\left(c_X^*\right)-G\left(c_A^*\right)}{G\left(c_X^*\right)}$ and $\frac{N_{XA}^*}{N_X^*} = \frac{G\left(c_A^*\right)}{G\left(c_X^*\right)}$;:

$$
\begin{aligned}
\bar{p}_{exp}^* &= \frac{N_{XA}^*}{N_X^*} \int_0^{c_A^*} p_{XA}^* \frac{g(c)}{G\left(c_A^*\right)} dc + \frac{N_{XL}^*}{N_X^*} \int_{c_A^*}^{c_X^*} p_X^* \frac{g(c)}{G\left(c_X^*\right) - G\left(c_A^*\right)} dc \\
&= \frac{2k+1}{2(k+1)} c_D - \frac{t}{2} \left(\frac{c_A^*}{c_X^*}\right)^k + \frac{\tau}{2(k+1)}. \qquad \text{(A.15)}
\end{aligned}
$$

Substituting (A.13), (A.14) and (A.15) into (A.10) gives

$$\begin{aligned}\bar{p} &= \frac{2k+1}{2(k+1)}c_D - \frac{t}{2}\left\{\frac{N_D}{N}\left(\frac{c_A}{c_D}\right)^k + \frac{N_X^*}{N}\left[\left(\frac{c_A^*}{c_X^*}\right)^k - \frac{\tau}{t(k+1)}\right]\right\} \\ &= \frac{2k+1}{2(k+1)}c_D - (p - p_A)\frac{N_A}{N} + \frac{(p_X - p)}{k+1}\frac{N_X^*}{N}. \end{aligned} \tag{A.16}$$

Number of firms in the market

From (2.8) follows that

$$\bar{p} = c_D - \frac{\gamma(\alpha - c_D)}{\beta N}. \tag{A.17}$$

Equating (A.17) with (A.16) yields the following expression for N:

$$N = \frac{\frac{\gamma}{\beta}(\alpha - c_D) - \frac{t}{2}\frac{1}{(c_D)^k\left(c_D^*\right)^k - (c_D-\tau)^k\left(c_D^*-\tau\right)^k}N^*\left\{(c_D)^k\left[\left(c_A^*\right)^k - \frac{\tau(c_D-\tau)^k}{t(k+1)}\right] - (c_D-\tau)^k(c_A)^k\right\}}{\frac{c_D}{2(k+1)} + \frac{t}{2}\frac{1}{(c_D)^k\left(c_D^*\right)^k - (c_D-\tau)^k\left(c_D^*-\tau\right)^k}\left\{\left(c_D^*\right)^k(c_A)^k - \left(c_D^*-\tau\right)^k\left[\left(c_A^*\right)^k - \frac{\tau(c_D-\tau)^k}{t(k+1)}\right]\right\}}. \tag{A.18}$$

The expression for N^* is symmetric:

$$N^* = \frac{\frac{\gamma}{\beta}(\alpha - c_D^*) - \frac{t}{2}\frac{1}{(c_D)^k\left(c_D^*\right)^k - (c_D-\tau)^k\left(c_D^*-\tau\right)^k}N\left\{\left(c_D^*\right)^k\left[(c_A)^k - \frac{\tau(c_D^*-\tau)^k}{t(k+1)}\right] - \left(c_D^*-\tau\right)^k\left(c_A^*\right)^k\right\}}{\frac{c_D^*}{2(k+1)} + \frac{t}{2}\frac{1}{(c_D)^k\left(c_D^*\right)^k - (c_D-\tau)^k\left(c_D^*-\tau\right)^k}\left\{(c_D)^k\left(c_A^*\right)^k - (c_D-\tau)^k\left[(c_A)^k - \frac{\tau\left(c_D^*-\tau\right)^k}{t(k+1)}\right]\right\}}. \tag{A.19}$$

Plugging (A.18) into (A.19) gives

$$\begin{aligned} N =& \frac{\frac{\gamma}{\beta}\frac{(\alpha-c_D)c_D^*}{2(k+1)} + \frac{t}{2}\frac{1}{D}\left[(c_D)^k\left(c_A^*\right)^k - \left(c_X^*\right)^k(c_A)^k\right]\frac{\gamma}{\beta}(c_D^* - c_D)}{\frac{c_D c_D^*}{4(k+1)^2} + \frac{t}{4(k+1)D}\Delta + \frac{t\tau}{4D(k+1)}\Theta} \\ &+ \frac{\frac{\gamma}{\beta}\frac{\tau(c_X^*)^k}{2D(k+1)}\left[(\alpha - c_D)(c_X)^k + (\alpha - c_D^*)(c_D)^k\right]}{\frac{c_D c_D^*}{4(k+1)^2} + \frac{t}{4(k+1)D}\Delta + \frac{t\tau}{4D(k+1)}\Theta} \\ N^* =& \frac{\frac{\gamma}{\beta}\frac{(\alpha-c_{D^*})c_D}{2(k+1)} + \frac{t}{2}\frac{1}{D}\left[\left(c_D^*\right)^k(c_A)^k - (c_X)^k\left(c_A^*\right)^k\right]\frac{\gamma}{\beta}(c_D - c_D^*)}{\frac{c_D c_D^*}{4(k+1)^2} + \frac{t}{4(k+1)D}\Delta + \frac{t\tau}{4D(k+1)}\Theta} \\ &+ \frac{\frac{\gamma}{\beta}\frac{\tau(c_X)^k}{2D(k+1)}\left[(\alpha - c_D^*)\left(c_X^*\right)^k + (\alpha - c_D)\left(c_D^*\right)^k\right]}{\frac{c_D c_D^*}{4(k+1)^2} + \frac{t}{4(k+1)D}\Delta + \frac{t\tau}{4D(k+1)}\Theta}, \end{aligned} \tag{A.20}$$

where

$$
\begin{aligned}
D =& (c_D)^k (c_D^*)^k - (c_D - \tau)^k (c_D^* - \tau)^k \\
\Delta =& c_D \left\{ (c_D)^k (c_A^*)^k - (c_X^*)^k \left[(c_A)^k - \frac{\tau (c_X)^k}{t(k+1)} \right] \right\} + c_D^* \left\{ (c_D^*)^k (c_A)^k - (c_X)^k \left[(c_A^*)^k - \frac{\tau (c_X^*)^k}{t(k+1)} \right] \right\} \\
\Theta =& \left[(c_X)^k (c_A^*)^k + (c_X^*)^k (c_A)^k - \frac{\tau (c_X)^k (c_X^*)^k}{t(k+1)} \right].
\end{aligned}
$$

Price variance

The price variance σ_p^2 is the sum of the price variances of domestic and foreign sellers weighted with their shares in the total population of sellers:

$$
\sigma_p^2 = \frac{N_D}{N} \sigma_{p,dom}^2 + \frac{N_X^*}{N} \sigma_{p,exp}^2, \tag{A.21}
$$

where the price variance of domestic firms is the sum of the price variances of domestic low-and high-technology firms weighted with their shares in the total population of domestic firms, $\frac{N_{DL}}{N_D} = \frac{G(c_D)-G(c_A)}{G(c_D)}$ and $\frac{N_{DA}}{N_D} = \frac{G(c_A)}{G(c_D)}$,

$$
\sigma_{p,dom}^2 = \frac{N_{DA}}{N_D} \int_0^{c_A} [p_{DA} - \bar{p}]^2 \frac{g(c)}{G(c_A)} dc + \frac{N_{DL}}{N_D} \int_{c_A}^{c_D} [p_D - \bar{p}]^2 \frac{g(c)}{G(c_D) - G(c_A)} dc. \tag{A.22}
$$

Analogously, the price variance of foreign sellers is the sum of the price variances of foreign low- and high-technology firms weighted with their shares in the total population of foreign sellers, $\frac{N_{XL}^*}{N_X^*} = \frac{G(c_X^*)-G(c_A^*)}{G(c_X^*)}$ and $\frac{N_{XA}^*}{N_X^*} = \frac{G(c_A^*)}{G(c_X^*)}$,

$$
\sigma_{p,exp}^2 = \frac{N_{XA}^*}{N_X^*} \int_0^{c_A^*} [p_{XA}^* - \bar{p}]^2 \frac{g(c)}{G(c_A^*)} dc + \frac{N_{XL}^*}{N_X^*} \int_{c_A^*}^{c_X^*} [p_X^* - \bar{p}]^2 \frac{g(c)}{G(c_X^*) - G(c_A^*)} dc. \tag{A.23}
$$

τ	$\left(\frac{c_X}{c_D}\right)^k$	$\left(\frac{c_X^*}{c_D^*}\right)^k$	$\left(\frac{c_A}{c_D}\right)^k$	$\left(\frac{c_A^*}{c_D^*}\right)^k$
1.0000	0.6900	0.7530	0.0739	0.1615
0.9500	0.6999	0.7674	0.0746	0.1633
0.9025	0.7093	0.7815	0.0753	0.1649
0.8574	0.7181	0.7953	0.0759	0.1665
0.8145	0.7263	0.8089	0.0764	0.1681
0.7738	0.7340	0.8222	0.0769	0.1696
0.7351	0.7412	0.8352	0.0774	0.1710

τ	$\left(\frac{c_X}{c_D}\right)^k / \left(\frac{c_X^*}{c_D^*}\right)^k$	$\left(\frac{c_A}{c_D}\right)^k / \left(\frac{c_A^*}{c_D^*}\right)^k$
1.0000	0.9163	0.4576
0.9500	0.9120	0.4568
0.9025	0.9076	0.4566
0.8574	0.9029	0.4559
0.8145	0.8979	0.4545
0.7738	0.8927	0.4534
0.7351	0.8875	0.4526

Table A.1: Impact of a 5%-decrease in trade costs on the fraction of exporters and high-technology firms
($t = 0.5$, $k = 2.5$, $\gamma = 0.2$, $S = 1$,$f = f_E = c_M = 10$, $\psi = 1.25$)

Appendix B

Appendix to Chapter 2

B.1 Selection XA

Exporters invest in technology adoption if their profits are higher when using the advanced technology, that is, if $\pi_{ik}^{DA}(c_{ik}) \geq \pi_{ik}^{D}(c_{ik})$. The technology adoption decision depends on the total costs of technology adoption, $f_k + f_{ik}^{\text{ext}}$. Firms with production costs below c_{NC} have no extra costs of external finance, where

$$c_k^{NC} = c_k^D + \frac{t_k}{2} - \frac{1}{\lambda}\frac{2\gamma f_k}{St_k}. \tag{B.1}$$

Firms with production costs above c_{NC} have to pay for external finance. The technology adoption cutoff c_k^A that depends on whether the marginal technology adopter is a financially unconstrained or a financially constrained firm is given by

$$c_k^A = \left\{ \begin{array}{c} c_k^D + \frac{t_k}{2} - \frac{2\gamma f_k}{St_k} \text{ if } c_{ik} \leq c_k^{NC} \\ c_k^D + \frac{t_k}{2} - \frac{1}{\theta+(1-\theta)\lambda}\frac{2\gamma f_k}{St_k} \text{ if } c_{ik} > c_k^{NC}. \end{array} \right\} \tag{B.2}$$

It follows from (B.1) and (B.2) that $c_k^{NC} < c_k^A(c_{ik} \leq c_k^{NC})$. The technology adoption cutoff is

$$c_k^A = c_k^D + \frac{t_k}{2} - \frac{1}{\theta + (1-\theta)\lambda}\frac{2\gamma f_k}{St_k}. \tag{B.3}$$

Firms export if $c_{ik} \leq c_k^X$ where

$$\pi_{ik}^{XA}(c_k^X) = 0 \Leftrightarrow c_k^X = c_{k*}^D - \tau + t_k.^{44} \tag{B.4}$$

Given (B.1), (B.3), and (B.4), the free entry condition for industry k is

$$\begin{aligned} f_{Ek} = & \int_0^{c_k^{NC}} \left[\pi_{ik}^A(c_{ik}) + f_{ik}^{\text{ext}}\right] dF(c_{ik}) + \int_{c_k^{NC}}^{c_k^X} \pi_{ik}^A(c_{ik})\, dF(c_{ik}) \\ & + \int_{c_k^X}^{c_k^A} \pi_{ik}^{DA}(c_{ik})\, dF(c_{ik}) + \int_{c_k^A}^{c_k^D} \pi_{ik}^D(c_{ik})\, dF(c_{ik}). \end{aligned}$$

And, solving the integral,

$$\begin{aligned} \frac{\left(c_k^D\right)^{k+2} + \left(c_{k*}^D - \tau + t_k\right)^{k+2}}{k+2} + \frac{t_k}{\theta}\left\{[\theta + (1-\theta)\lambda]\left(c_k^A\right)^{k+1} - (1-\theta)\lambda\left(c_k^{NC}\right)^{k+1}\right\} \\ = \frac{f_{Ek} 2\gamma\, (c_M)^k\, (k+1)}{S}, \end{aligned} \tag{B.5}$$

where c_k^A and c_k^{NC} are given by (B.3) and (B.1). The free entry condition for industry k in the foreign country is analogous.

[44] We assume that $c_k^X > c_k^{NC}$. Therefore, $(c_k^D - c_{k*}^D - t_k/2 + \tau)St_k[\theta + (1-\theta)\lambda]/2\gamma > f_k > (c_k^D - c_{k*}^D - t_k/2 + \tau)St_k\lambda/2\gamma$ for Selection XA.

B.2 Mathematical Appendix

B.2.1 Existence of a Unique Equilibrium

Total differentiation of (2.13) yields the slopes of the free entry conditions of the home country and of the foreign country in the (c_k^D, c_{k*}^D) space (Selection AX):

$$FE: \frac{dc_{k*}^D}{dc_k^D} = -\frac{\left(c_k^D\right)^{k+1} + \frac{t_k}{\theta}(k+1)\left\{[\theta+(1-\theta)\lambda]\left(c_k^A\right)^k - (1-\theta)\lambda\left(c_k^{NC}\right)^k\right\}}{\left(c_k^X\right)^{k+1} + \frac{t_k}{\theta}(k+1)\left\{[\theta+(1-\theta)\lambda]\left(c_k^A\right)^k - (1-\theta)\lambda\left(c_k^{NC}\right)^k\right\}}$$
$$FE^*: \frac{dc_{k*}^D}{dc_k^D} = -\frac{\left(c_{k*}^X\right)^{k+1} + \frac{t_k}{\theta}(k+1)\left\{[\theta+(1-\theta)\lambda_*]\left(c_{k*}^A\right)^k - (1-\theta)\lambda_*\left(c_{k*}^{NC}\right)^k\right\}}{\left(c_{k*}^D\right)^{k+1} + \frac{t_k}{\theta}(k+1)\left\{[\theta+(1-\theta)\lambda_*]\left(c_{k*}^A\right)^k - (1-\theta)\lambda_*\left(c_{k*}^{NC}\right)^k\right\}}. \tag{B.6}$$

Total differentiation of (B.5) yields the slopes of the free entry conditions of the home country and of the foreign country in the (c_k^D, c_{k*}^D) space (Selection XA):

$$FE: \frac{dc_{k*}^D}{dc_k^D} = -\frac{\left(c_k^D\right)^{k+1} + \frac{t_k}{\theta}(k+1)\left\{[\theta+(1-\theta)\lambda]\left(c_k^A\right)^k - (1-\theta)\lambda\left(c_k^{NC}\right)^k\right\}}{\left(c_k^X\right)^{k+1}}$$
$$FE^*: \frac{dc_{k*}^D}{dc_k^D} = -\frac{\left(c_{k*}^X\right)^{k+1}}{\left(c_{k*}^D\right)^{k+1} + \frac{t_k}{\theta}(k+1)\left\{[\theta+(1-\theta)\lambda_*]\left(c_{k*}^A\right)^k - (1-\theta)\lambda_*\left(c_{k*}^{NC}\right)^k\right\}}. \tag{B.7}$$

Both curves are downward sloping. From our assumption that $c_k^X < c_k^D$, it follows that $\left(c_k^X\right)^{k+1} < \left(c_k^D\right)^{k+1}$. Hence, the absolute amount of the slope of home's free entry condition is unambigously larger than one and the absolute amount of the slope of foreign's free entry condition is unambigously smaller than one. Hence, there is a unique intersection if the two curves intersect.

For a given (λ, λ_*), let $c_k^D(1)$ denote the solution to home's free entry condition for $c_{k*}^D = c_M$. Furthermore, denote by $\bar{\lambda}$ the value of λ, given λ_*, for which $\left(c_k^D(1), c_M\right)$ is the solution to foreign's free entry condition. It follows that for $\bar{\lambda} < \lambda$, and, by symmetry, for $\bar{\lambda} < \lambda_*$, the two curves intersect.

B.2.2 Proof of Theoretical Predictions 1-3 for Selection AX

Define:

$$\begin{aligned} D \equiv & \left\{ \left(c_k^D\right)^{k+1} + \frac{t_k}{\theta}(k+1) \left\{ [\theta + (1-\theta)\lambda] \left(c_k^A\right)^k - (1-\theta)\lambda \left(c_k^{NC}\right)^k \right\} \right\} \\ & \times \left\{ \left(c_{k*}^D\right)^{k+1} + \frac{t_k}{\theta} \left\{ [\theta + (1-\theta)\lambda_*] \left(c_{k*}^A\right)^k - (1-\theta)\lambda_* \left(c_{k*}^{NC}\right)^k \right\} \right\} \\ & - \left\{ \left(c_{k*}^D - \tau\right)^{k+1} + \frac{t_k}{\theta}(k+1) \left\{ [\theta + (1-\theta)\lambda] \left(c_k^A\right)^k - (1-\theta)\lambda \left(c_k^{NC}\right)^k \right\} \right\} \\ & \times \left\{ \left(c_k^D - \tau\right)^{k+1} + \frac{t_k}{\theta}(k+1) \left\{ [\theta + (1-\theta)\lambda_*] \left(c_{k*}^A\right)^k - (1-\theta)\lambda_* \left(c_{k*}^{NC}\right)^k \right\} \right\}. \end{aligned} \tag{B.8}$$

Assume that $t_k < 1$ and $(1-\theta)\gamma f_k / [\theta + (1-\theta)\lambda]^2 \, St_k > 1$.

Proof of Theoretical Prediction 1

From (2.10), it follows that

$$\begin{aligned} \frac{dc_k^{NC}}{d\lambda} =& \frac{1}{2} \left(\frac{dc_k^D}{d\lambda} + \frac{dc_{k*}^D}{d\lambda} + \frac{2\gamma f_k}{\lambda^2 St_k} \right) \\ =& \frac{1}{2} \left\{ -\frac{2t_k(1-\theta)}{\theta} \left\{ \left[\left(c_k^A\right)^{k+1} - \left(c_k^{NC}\right)^{k+1} \right] + \frac{2\gamma(k+1)f_k}{St_k} \left[\frac{1}{\theta + (1-\theta)\lambda} \left(c_k^A\right)^k - \frac{1}{\lambda} \left(c_k^{NC}\right)^k \right] \right\} \right. \\ & \left. \left[\left(c_{k*}^D\right)^{k+1} - \left(c_{k*}^X\right)^{k+1} \right] + \frac{2\gamma f_k}{\lambda^2 St_k} D \right\} > 0. \end{aligned} \tag{B.9}$$

where

$$\begin{aligned} \frac{dc_k^D}{d\lambda} =& -\frac{\left\{ \left(c_{k*}^D\right)^{k+1} + \frac{t_k}{\theta}(k+1) \left\{ [\theta + (1-\theta)\lambda_*] \left(c_{k*}^A\right)^k - (1-\theta)\lambda_* \left(c_{k*}^{NC}\right)^k \right\} \right\}}{D} \\ & \times \frac{\frac{2t_k(1-\theta)}{\theta} \left\{ \left[\left(c_k^A\right)^{k+1} - \left(c_k^{NC}\right)^{k+1} \right] + \frac{2\gamma(k+1)f_k}{St_k} \left[\frac{1}{\theta+(1-\theta)\lambda} \left(c_k^A\right)^k - \frac{1}{\lambda} \left(c_k^{NC}\right)^k \right] \right\}}{D} < 0 \end{aligned} \tag{B.10}$$

$$\begin{aligned} \frac{dc_{k*}^D}{d\lambda} =& \frac{\left\{ \left(c_{k*}^X\right)^{k+1} + \frac{t_k}{\theta}(k+1) \left\{ [\theta + (1-\theta)\lambda_*] \left(c_{k*}^A\right)^k - (1-\theta)\lambda_* \left(c_{k*}^{NC}\right)^k \right\} \right\}}{D} \\ & \times \frac{\frac{2t_k(1-\theta)}{\theta} \left\{ \left[\left(c_k^A\right)^{k+1} - \left(c_k^{NC}\right)^{k+1} \right] + \frac{2\gamma(k+1)f_k}{St_k} \left[\frac{1}{\theta+(1-\theta)\lambda} \left(c_k^A\right)^k - \frac{1}{\lambda} \left(c_k^{NC}\right)^k \right] \right\}}{D} > 0. \end{aligned} \tag{B.11}$$

Proof of Theoretical Prediction 2

From (2.9), it follows that

$$\frac{dc_k^X}{d\lambda} = \frac{dc_{k*}^D}{d\lambda} > 0. \tag{B.12}$$

Proof of Theoretical Prediction 3

From (2.12), it follows that

$$\begin{aligned}\frac{dc_k^A}{d\lambda} =& \frac{1}{2}\left(\frac{dc_k^D}{d\lambda} + \frac{dc_{k*}^D}{d\lambda} + \frac{2\gamma(1-\theta)f_k}{[\theta+(1-\theta)\lambda]^2\, St_k}\right)\\ =& \frac{1}{2}\left\{-\frac{2t_k(1-\theta)}{\theta}\left\{\left[\left(c_k^A\right)^{k+1} - \left(c_k^{NC}\right)^{k+1}\right] + \frac{2\gamma(k+1)f_k}{St_k}\left[\frac{1}{\theta+(1-\theta)\lambda}\left(c_k^A\right)^k - \frac{1}{\lambda}\left(c_k^{NC}\right)^k\right]\right\}\right.\\ &\left.\left[\left(c_{k*}^D\right)^{k+1} - \left(c_{k*}^X\right)^{k+1}\right] + \frac{2\gamma(1-\theta)f_k}{[\theta+(1-\theta)\lambda]^2\, St_k}D\right\} > 0. \end{aligned} \tag{B.13}$$

B.2.3 Proof of Theoretical Predictions 1-3 for Selection XA

Define:

$$\begin{aligned} D \equiv& \left\{\left(c_k^D\right)^{k+1} + \frac{t_k}{\theta}(k+1)\left\{[\theta+(1-\theta)\lambda]\left(c_k^A\right)^k - (1-\theta)\lambda\left(c_k^{NC}\right)^k\right\}\right\}\\ &\times\left\{\left(c_{k*}^D\right)^{k+1} + \frac{t_k}{\theta}(k+1)\left\{[\theta+(1-\theta)\lambda_*]\left(c_{k*}^A\right)^k - (1-\theta)\lambda_*\left(c_{k*}^{NC}\right)^k\right\}\right\}\\ &-\left(c_k^X\right)^{k+1}\left(c_{k*}^X\right)^{k+1}. \end{aligned} \tag{B.14}$$

Assume that $t_k < 1$ and $\frac{2\gamma f_k}{[\theta+(1-\theta)\lambda]^2 St_k}\left[\left(c_k^D\right)^{k+1} - \left(c_k^X\right)^{k+1}\left(c_{k*}^X\right)^{k+1}\right] \geq \frac{t_k}{\theta}\left[\left(c_k^A\right)^{k+1} - \left(c_k^{NC}\right)^{k+1}\right]$.

Proof of Theoretical Prediction 1

From (B.1), it follows that

$$\begin{aligned}\frac{dc_k^{NC}}{d\lambda} =& \frac{dc_k^D}{d\lambda} + \frac{2\gamma f_k}{\lambda^2 St_k}\\ =& -\frac{t_k(1-\theta)}{\theta}\left\{\left[\left(c_k^A\right)^{k+1} - \left(c_k^{NC}\right)^{k+1}\right] + \frac{2\gamma(k+1)f_k}{St_k}\left[\frac{1}{\theta+(1-\theta)\lambda}\left(c_k^A\right)^k - \frac{1}{\lambda}\left(c_k^{NC}\right)^k\right]\right\}\\ &\times\left\{\left(c_{k*}^D\right)^{k+1} + \frac{t_k(k+1)}{\theta}\left\{[\theta+(1-\theta)\lambda_*]\left(c_{k*}^A\right)^k - (1-\theta)\lambda_*\left(c_{k*}^{NC}\right)^k\right\}\right\} + \frac{2\gamma f_k}{\lambda^2 St_k}D > 0. \end{aligned} \tag{B.15}$$

where

$$\frac{dc_k^D}{d\lambda} = -\frac{\frac{t_k(1-\theta)}{\theta}\left\{\left[\left(c_k^A\right)^{k+1} - \left(c_k^{NC}\right)^{k+1}\right] + \frac{2\gamma(k+1)f_k}{St_k}\left[\frac{1}{\theta+(1-\theta)\lambda}\left(c_k^A\right)^k - \frac{1}{\lambda}\left(c_k^{NC}\right)^k\right]\right\}}{D}$$
$$\times \frac{\left\{\left(c_{k*}^D\right)^{k+1} + \frac{t_k(k+1)}{\theta}\left\{\left[\theta+(1-\theta)\lambda_*\right]\left(c_{k*}^A\right)^k - (1-\theta)\lambda_*\left(c_{k*}^{NC}\right)^k\right\}\right\}}{D} < 0 \tag{B.16}$$

Proof of Theoretical Prediction 2

From (B.4), it follows that

$$\frac{dc_k^X}{d\lambda} = \frac{dc_{k*}^D}{d\lambda}$$
$$= \frac{\frac{t_k(1-\theta)}{\theta}\left\{\left[\left(c_k^A\right)^{k+1} - \left(c_k^{NC}\right)^{k+1}\right] + \frac{2\gamma(k+1)f_k}{St_k}\left[\frac{1}{\theta+(1-\theta)\lambda}\left(c_k^A\right)^k - \frac{1}{\lambda}\left(c_k^{NC}\right)^k\right]\right\}\left(c_{k*}^X\right)^{k+1}}{D} > 0 \tag{B.17}$$

Proof of Theoretical Prediction 3

From (B.3), it follows that

$$\frac{dc_k^A}{d\lambda} = \frac{dc_k^D}{d\lambda} + \frac{2\gamma(1-\theta)f_k}{\left[\theta+(1-\theta)\lambda\right]^2 St_k}$$
$$= -\frac{t_k(1-\theta)}{\theta}\left\{\left[\left(c_k^A\right)^{k+1} - \left(c_k^{NC}\right)^{k+1}\right] + \frac{2\gamma(k+1)f_k}{St_k}\left[\frac{1}{\theta+(1-\theta)\lambda}\left(c_k^A\right)^k - \frac{1}{\lambda}\left(c_k^{NC}\right)^k\right]\right\}$$
$$\times \left\{\left(c_{k*}^D\right)^{k+1} + \frac{t_k(k+1)}{\theta}\left\{\left[\theta+(1-\theta)\lambda_*\right]\left(c_{k*}^A\right)^k - (1-\theta)\lambda_*\left(c_{k*}^{NC}\right)^k\right\}\right\}$$
$$+ \frac{2\gamma(1-\theta)f_k}{\left[\theta+(1-\theta)\lambda\right]^2 St_k} D > 0. \tag{B.18}$$

B.2.4 Financial Market Development and the Missing Technology Adoption

Define $c_k^{DP} = c_k^D(\lambda = 1)$ and $c_k^{AP} = c_k^A(\lambda = 1)$.

The missing technology adoption corresponds to the range of firms which would invest in technology adoption in a perfect financial market but are prevented from investing by financial constraints:

$$\Pr\left(c_k^A \le c_{ik} \le c_k^{AP}\right) = \left(\frac{c_k^{AP}}{c_M}\right)^k - \left(\frac{c_k^A}{c_M}\right)^k. \tag{B.19}$$

The effect of financial market development, that is an increase in λ, is then given by

$$\frac{d\left(\frac{c_k^{AP}-c_k^A}{c_M}\right)^k}{d\lambda} = -\frac{k}{(c_M)^k}\left(c_k^A\right)^{k-1}\frac{dc_k^A}{d_\lambda} < 0. \tag{B.20}$$

Note that c_k^{AP} is evaluated at $\lambda = 1$, the maximum value of λ. Therefore, c_k^{AP} does not change.

B.3 Figures

Figure B.1: Correlation between the cost of financing and financial development

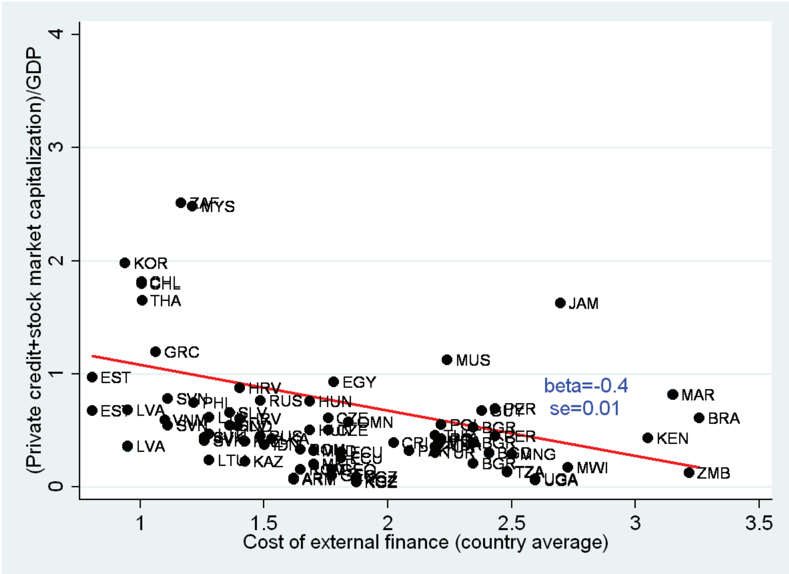
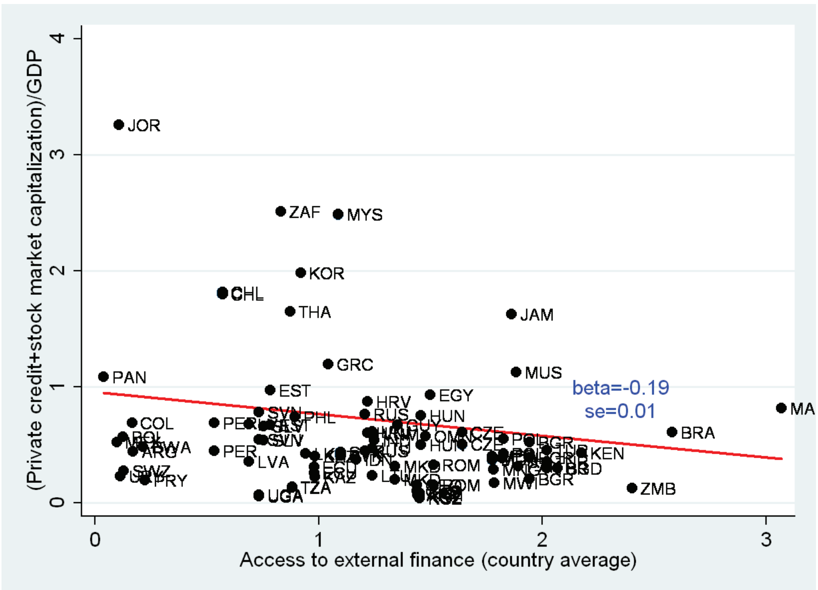


Figure B.2: Correlation between the difficulty in access to financing and financial development



B.4 Tables

Country	Year	Fin. Dev.	No. Obs.	Country	Year	Fin. Dev.	No. Obs.
Kyrgyz Republic	2002	0.04	42	Russian Federation	2002	0.45	110
Kyrgyz Republic	2003	0.05	102	Turkey	2005	0.45	1278
Uganda	2003	0.06	134	Lithuania	2004	0.47	160
Armenia	2002	0.07	53	Botswana	2006	0.49	113
Uganda	2006	0.07	306	Hungary	2002	0.50	49
Armenia	2005	0.08	217	Czech Republic	2002	0.50	63
Kyrgyz Republic	2005	0.09	53	Bulgaria	2005	0.52	53
Georgia	2002	0.10	30	Mexico	2006	0.52	1157
Zambia	2002	0.13	83	India	2002	0.54	1632
Tanzania	2003	0.13	166	El Salvador	2003	0.54	465
Tanzania	2006	0.14	267	Slovenia	2002	0.55	45
Romania	2002	0.16	70	Poland	2005	0.55	514
Georgia	2005	0.16	47	Bolivia	2006	0.57	405
Malawi	2005	0.17	153	Oman	2003	0.57	97
Paraguay	2006	0.20	432	Vietnam	2005	0.59	234
Macedonia, FYR	2002	0.20	41	Croatia	2002	0.60	29
Bulgaria	2002	0.21	44	Brazil	2003	0.61	1634
Kazakhstan	2002	0.22	41	Czech Republic	2005	0.61	78
Uruguay	2006	0.23	395	Lithuania	2005	0.62	41
Lithuania	2002	0.24	34	El Salvador	2006	0.66	467
Ecuador	2003	0.26	432	Estonia	2002	0.67	29
Swaziland	2006	0.28	70	Guyana	2004	0.67	153
Mongolia	2004	0.29	188	Latvia	2005	0.68	33
Bangladesh	2002	0.30	967	Colombia	2006	0.69	649
Turkey	2002	0.30	133	Peru	2006	0.69	361
Ecuador	2006	0.31	392	Philippines	2003	0.74	620
Macedonia, FYR	2005	0.32	55	Hungary	2005	0.75	352
Pakistan	2002	0.32	893	Russian Federation	2005	0.76	137
Romania	2005	0.33	374	Slovenia	2005	0.78	55
Turkey	2004	0.36	155	Morocco	2004	0.82	838
Latvia	2002	0.36	28	Croatia	2005	0.87	62
Moldova	2002	0.37	42	Egypt, Arab Rep.	2004	0.93	962
Indonesia	2003	0.37	680	Estonia	2005	0.97	39
Costa Rica	2005	0.39	341	Panama	2006	1.09	313
Bulgaria	2004	0.39	326	Mauritius	2005	1.12	163
Moldova	2003	0.40	103	Greece	2005	1.20	98
Kazakhstan	2005	0.40	334	Jamaica	2005	1.62	67
Slovak Republic	2005	0.41	32	Thailand	2004	1.65	1383
Poland	2002	0.41	95	Chile	2004	1.80	682
Poland	2003	0.42	105	Chile	2006	1.82	694
Sri Lanka	2004	0.43	368	Korea, Rep.	2005	1.98	215
Kenya	2003	0.43	224	Malaysia	2002	2.48	139
Slovak Republic	2002	0.44	24	South Africa	2003	2.51	573
Argentina	2006	0.45	740	Jordan	2006	3.26	350
Peru	2002	0.45	118				

Table B.1: Private credit + stock market capitalization/GDP across countries

Industry	**ExtDep**	**Liqu**	**Tang**	**TrCr**
Food	-0.535	1.554	0.302	0.241
Beverages	-0.274	1.554	0.302	0.241
Textiles	-0.123	1.268	0.128	0.081
Garments	-0.729	1.268	0.128	0.081
Leather	-1.822	0.640	0.110	0.059
Paper	-0.386	0.763	0.268	0.065
Chemicals and pharmaceutics	5.175	1.337	0.193	0.081
Non-metallic and plastic materials	-0.273	1.128	0.216	0.077
Metals and machinery	-0.480	7.378	0.192	0.102
Electronics	0.357	0.827	0.106	0.077
Other transport equipment	-0.451	1.330	0.138	0.095
Wood and furniture	-0.788	0.994	0.168	0.126
Other manufacturing	0.141	1.330	0.138	0.095

2002-2006 average for $Liqu$ and $TrCr$.

Table B.2: External financial dependence across industries

Country	Year	ConstrCost	ConstrAcc	Exporter	For.Techn.	Email
Argentina	2006		x	x	x	x
Armenia	2002,2005	x	x	x		x
Bangladesh	2002	x	x	x		x
Bolivia	2006		x	x	x	x
Botswana	2006		x	x	x	x
Brazil	2003	x	x	x	x	x
Bulgaria	2002,2004,2005	x	x	x		x
Chile	2004,2006	x,-	x	x	x	x
Colombia	2006			x	x	x
Costa Rica	2005	x	x	x	x	x
Croatia	2002,2005	x	x	x		x
Czech Republic	2002,2005	x	x	x		x
Ecuador	2003,2006	x,-	x	x	x	x
Egypt, Arab Rep.	2004	x	x	x	x	x
El Salvador	2003,2006	x,-	x	x	x	x
Estonia	2002,2005	x	x	x		x
Georgia	2002,2005	x	x	x		x
Greece	2005	x	x	x		x
Guyana	2004	x	x	x	x	x
Hungary	2002,2005	x	x	x		x
India	2002	x	x	x		x
Indonesia	2003	x	x	x	x	x
Jamaica	2005	x	x	x	x	x
Jordan	2006		x	x	x	x
Kazakhstan	2002,2005	x	x	x		x
Kenya	2003	x	x	x	x	x
Korea, Rep.	2005	x	x	x		x
Kyrgyz Republic	2002,2003,2005	x	x	x		x
Latvia	2002,2005	x	x	x		x
Lithuania	2002,2004,2005	x	x	x	-,x,-	x
Macedonia, FYR	2002,2005	x	x	x		x
Malawi	2005	x	x	x	x	x
Malaysia	2002	x	x	x		x
Mauritius	2005	x	x	x	x	x
Mexico	2006		x	x	x	x
Moldova	2002,2003	x	x	x		x
Mongolia	2004	x	x	x	x	x
Morocco	2004	x	x	x	x	x
Oman	2003	x	x	x	x	x
Pakistan	2002	x	x	x		x
Panama	2006		x	x	x	x
Paraguay	2006		x	x	x	x
Peru	2002,2006	x,-	x	x	-,x	x
Philippines	2003	x	x	x	x	x
Poland	2002,2003,2005	x	x	x		x
Romania	2002,2005	x	x	x		x
Russian Federation	2002,2005	x	x	x		x
Slovak Republic	2002,2005	x	x	x		x
Slovenia	2002,2005	x	x	x		x
South Africa	2003	x	x	x	x	x
Sri Lanka	2004	x	x	x		x
Swaziland	2006		x	x	x	x
Tanzania	2003,2006	x,-	x	x	x	x
Thailand	2004	x	x	x		x
Turkey	2002,2004,2005	x	x	x	-,-,x	x
Uganda	2003,2006	x,-	x	x	-,x	x
Uruguay	2006		x	x	x	x
Vietnam	2005	x	x	x		x
Zambia	2002	x	x	x	x	x

Table B.3: Data availability

Country	Exporter	Email	ForeignTechnology
Argentina	47.31	95.94	15.50
Armenia	26.67	52.59	
Bangladesh	38.02	70.19	
Bolivia	18.81	84.90	14.01
Botswana	18.58	57.52	19.47
Brazil	25.52	92.04	7.47
Bulgaria	39.76	78.35	
Chile	30.75	90.07	15.89
Colombia	18.51	85.67	6.65
Costa Rica	24.10	87.14	32.26
Croatia	50.57	83.52	
Czech Republic	48.20	82.98	
Ecuador	22.58	87.86	20.36
Egypt, Arab Rep.	17.56	27.37	9.87
El Salvador	34.88	68.78	15.48
Estonia	50.00	97.06	
Georgia	44.16	45.45	
Greece	41.84	61.22	
Guyana	30.26	30.92	10.42
Hungary	46.29	87.78	
India	16.57	62.00	
Indonesia	38.43	50.00	18.29
Jamaica	34.92	68.18	18.75
Jordan	49.28	64.00	21.49
Kazakhstan	14.67	50.40	
Kenya	50.78	77.58	8.38
Korea, Rep.	41.23	88.37	
Kyrgyz Republic	30.10	42.13	
Latvia	55.00	77.05	
Lithuania	45.30	68.09	20.00
Macedonia, FYR	42.71	63.54	
Malawi	22.30	67.97	15.69
Malaysia	88.35	58.70	
Mauritius	58.86	90.18	17.79
Mexico	11.68	60.33	10.14
Moldova	44.14	55.86	
Mongolia	13.98	44.00	8.51
Morocco	54.85	79.17	5.29
Oman	32.63	59.79	12.22
Pakistan	17.69	30.01	
Panama	15.71	82.75	11.34
Paraguay	17.40	78.94	11.80
Peru	31.71	78.39	10.56
Philippines	30.57	49.35	16.67
Poland	31.97	70.59	
Romania	26.53	65.77	
Russian Federation	23.97	71.66	
Slovak Republic	69.64	89.29	
Slovenia	79.00	93.00	
South Africa	57.19	98.60	22.69
Sri Lanka	46.17	71.20	
Swaziland	36.23	71.43	14.29
Tanzania	12.50	46.84	14.65
Thailand	54.20	54.09	
Turkey	53.14	77.33	16.20
Uganda	11.42	32.05	9.80
Uruguay	30.75	81.77	8.31
Vietnam	24.36	56.41	
Zambia	25.32	91.46	6.10

Table B.4: Fractions of exporters, users of e-mail and of foreign technology

	All firms	ConstrAcc			ConstrCost			Exporter		
		Constr.	Non-constr.	*t*-test	Constr.	Non-constr.	*t*-test	Exp.	Non-exp.	*t*-test
Financial development	0.72	0.62	0.78	23.48	0.62	0.84	26.09	0.83	0.67	-19.32
External fin. dependence	0.09	-0.10	0.20	14.67	-0.08	0.03	5.14	0.04	0.09	2.58
Access to finance										
Access is obstacle	0.37				0.76	0.13	-120.00	0.38	0.37	-2.94
Costs are obstacle	0.59	0.89	0.28	-110.00				0.58	0.60	3.24
Market participation										
Export partipation	0.33	0.34	0.32	-2.94	0.35	0.37	3.24			
Domestic sales (thds.)	174.53	367.57	73.98	-1.21	335.11	110.65	-1.07	429.47	80.31	0.86
Foreign sales (thds.)	230.92	299.58	196.79	-0.36	265.37	150.23	-0.51			
Total sales (thds.)	236.52	423.85	136.48	-0.95	386.35	160.37	-0.87	564.38	80.15	-1.39
Technology use										
Foreign technology	0.14	0.11	0.15	7.11	0.12	0.18	7.69	0.22	0.10	-19.37
Use of e-mail	0.69	0.68	0.70	3.49	0.69	0.64	-7.06	0.89	0.59	-59.70
Firm characteristics										
Employment	149.96	140.00	156.96	2.91	151.98	196.67	5.78	319.30	66.80	-30.54
Foreign-owned	0.12	0.08	0.14	14.69	0.09	0.16	13.51	0.24	0.06	-37.03
Share skilled workers	0.16	0.11	0.20	22.26	0.11	0.11	-0.21	0.15	0.17	2.91
Firm age	19.51	17.59	20.57	13.11	17.99	19.23	4.72	22.45	17.96	-17.55
MNE	0.09	0.08	0.11	6.68	0.08	0.10	3.72	0.17	0.04	-25.30
Observations		9941	16777		11652	8067		8795	18180	

The table reports the mean statistics and the t-test statistics for the test of mean differences.

Table B.5: Descriptive statistics (i)

	All firms	ForeignTechnology			Email		
		Yes	No	*t*-test	Yes	No	*t*-test
Financial development	0.72	0.84	0.76	-4.85	0.76	0.66	-13.16
External fin. dependence	0.09	0.53	0.10	-9.25	0.20	-0.13	-16.40
Access to finance							
Access is obstacle	0.37	0.26	0.34	7.16	0.36	0.38	3.49
Costs are obstacle	0.59	0.54	0.66	7.79	0.60	0.55	-7.06
Market participation							
Export partipation	0.33	0.51	0.28	-20.31	0.42	0.12	-60.22
Domestic sales (thds.)	174.53	1154.78	48.77	-1.04	222.95	91.72	-0.99
Foreign sales (thds.)	230.92	1225.91	36.25	-1.37	261.70	28.37	-1.73
Total sales (thds.)	236.52	1677.51	59.82	-1.19	315.04	90.15	-1.33
Technology use							
Foreign technology	0.14				0.17	0.05	-23.49
Use of e-mail	0.69	0.89	0.71	-24.92			
Firm characteristics							
Employment	149.96	339.59	106.18	-11.63	195.15	58.31	-28.89
Foreign-owned	0.12	0.31	0.08	-23.19	0.15	0.05	-28.75
Share skilled workers	0.16	0.25	0.20	-2.08	0.18	0.14	-10.73
Firm age	19.51	23.64	20.79	-6.15	20.92	16.24	-21.65
MNE	0.09	0.25	0.09	-13.19	0.12	0.03	-23.76
Observations		2242	14207		18440	8246	

The table reports the mean statistics and the t-test statistics for the test of mean differences.

Table B.6: Descriptive statistics (ii)

	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Financial development	0.61	0.69	0.76	0.84
External financial dependence	0.07	0.10	0.09	0.09
Access to finance				
Access is obstacle	0.34	0.38	0.41	0.36
Costs are obstacle	0.58	0.62	0.62	0.55
Market participation				
Export partipation	0.10	0.19	0.39	0.65
Domestic sales (thds.)	20.22	44.76	91.24	467.70
Foreign sales (thds.)	1.21	6.87	28.29	270.18
Total sales (thds.)	21.56	52.25	122.23	745.23
Technology use				
Foreign technology use	0.06	0.09	0.14	0.28
Use of e-mail	0.48	0.62	0.78	0.89
Firm characteristics				
Employment	8.06	22.29	64.43	508.34
Foreign-owned	0.04	0.06	0.13	0.26
Share skilled workers	0.18	0.18	0.15	0.14
Firm age	15.22	17.60	19.62	25.62
MNE	0.02	0.04	0.08	0.18

Mean statistics and t-test statistics for the test of mean differences reported.

Table B.7: Descriptive statistics by firm size quartile

Industry	ConstrCost		ConstrAcc		Exporter		Email		No. Obs.
	Mean	St.Dev.	Mean	St.Dev.	Mean	St.Dev.	Mean	St.Dev.	
Food	0.55	0.50	0.30	0.46	0.25	0.43	0.61	0.49	4696
Beverages	0.55	0.50	0.45	0.50	0.21	0.41	0.53	0.50	896
Textiles	0.63	0.48	0.42	0.49	0.32	0.47	0.64	0.48	3036
Garments	0.66	0.47	0.41	0.49	0.40	0.49	0.70	0.46	4681
Leather	0.72	0.45	0.66	0.47	0.39	0.49	0.66	0.47	682
Wood and furniture	0.62	0.48	0.47	0.50	0.26	0.44	0.60	0.49	1626
Paper	0.51	0.50	0.39	0.49	0.27	0.45	0.84	0.37	536
Chemicals and pharmaceutics	0.55	0.50	0.28	0.45	0.31	0.46	0.81	0.39	2630
Non-metallic and plastic materials	0.54	0.50	0.36	0.48	0.34	0.47	0.60	0.49	1699
Metals and machinery	0.59	0.49	0.44	0.50	0.38	0.49	0.76	0.43	3677
Electronics	0.54	0.50	0.37	0.48	0.38	0.49	0.72	0.45	1043
Other transport equipment	0.55	0.50	0.47	0.50	0.34	0.47	0.75	0.44	646
Other manufacturing	0.44	0.50	0.09	0.29	0.30	0.46	0.85	0.36	1672

Industry	ForeignTechnology		Employment		Foreign		Skill		No. Obs.
	Mean	St.Dev.	Mean	St.Dev.	Mean	St.Dev.	Mean	St.Dev.	
Food	0.12	0.33	170.04	661.26	0.10	0.29	0.23	0.21	4696
Beverages	0.19	0.40	123.01	311.26	0.16	0.36	0.09	0.14	896
Textiles	0.12	0.33	205.05	577.56	0.09	0.29	0.15	0.34	3036
Garments	0.10	0.30	177.74	413.16	0.10	0.30	0.14	0.63	4681
Leather	0.07	0.25	91.89	177.45	0.04	0.20	0.10	0.14	682
Wood and furniture	0.09	0.29	91.34	270.94	0.08	0.27	0.11	0.32	1626
Paper	0.16	0.37	86.51	196.40	0.14	0.35	0.10	0.13	536
Chemicals and pharmaceutics	0.20	0.40	112.79	314.14	0.16	0.36	0.28	0.23	2630
Non-metallic and plastic materials	0.12	0.32	104.95	269.18	0.15	0.36	0.13	0.14	1699
Metals and machinery	0.15	0.36	120.03	374.71	0.13	0.34	0.11	0.14	3677
Electronics	0.30	0.46	321.42	962.54	0.25	0.43	0.13	0.16	1043
Other transport equipment	0.19	0.39	149.04	396.47	0.17	0.37	0.16	0.12	646
Other manufacturing	0.17	0.37	94.68	379.53	0.12	0.33	0.22	0.17	1672

Mean statistics and t-test statistics for the test of mean differences reported.

Table B.8: Descriptive statistics by industry

Dependent variable:			ConstrCost					Exporter		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
FD	-0.168***	-0.261***	-0.233***	-0.262***	-0.262***	0.397	0.397	0.397	-0.002	0.101***
	(0.035)	(0.012)	(0.016)	(0.013)	(0.013)	(0.419)	(0.419)	(0.419)	(0.021)	(0.028)
GDPPC		0.018**					0.014			0.139***
		(0.008)					(0.016)			(0.030)
Law			0.028**					0.084**		0.019
			(0.010)					(0.028)		(0.022)
H/L									-0.129	-0.062
									(0.135)	(0.135)
K/L				0.020**	0.020**				-0.030	-0.165***
				(0.008)	(0.008)				(0.037)	(0.047)
N/L				0.000	0.000				0.059*	-0.013
				(0.012)	(0.012)				(0.028)	(0.027)
No. Obs.	11713	11713	11713	11713	11713	16525	16525	16525	16525	16525
R^2	0.168	0.168	0.168	0.168	0.168	0.311	0.311	0.311	0.311	0.311
			Email					ForeignTechnology		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
FD	-0.127***	-0.103***	-0.112***	-0.139***	-0.097***	0.010	0.050***	0.016**	-0.001	0.004
	(0.013)	(0.011)	(0.011)	(0.015)	(0.018)	(0.007)	(0.006)	(0.007)	(0.008)	(0.013)
GDPPC		0.039**			0.038***		0.061***			0.002
		(0.015)			(0.011)		(0.009)			(0.012)
Law			0.044***		0.025**			0.017***		0.009
			(0.011)		(0.011)			(0.002)		(0.005)
K/L				0.071**	0.011				0.090***	0.087***
				(0.024)	(0.034)				(0.012)	(0.018)
N/L				-0.028**	-0.013				-0.013*	-0.011*
				(0.012)	(0.009)				(0.007)	(0.006)
No. Obs.	13805	13805	13805	13805	13805	9429	9429	9429	9429	9429
R^2	0.355	0.355	0.355	0.355	0.355	0.162	0.162	0.162	0.162	0.162

Industry and year dummies. Standard errors clustered at the industry level in parentheses. Significance levels: *10%,**5%, ***1%.
Size, *Foreign* and *Skill* are positive and significant at the 1% level in Exporter, Email and ForeignTechnology. *Foreign* is negative and significant at the 1% level in ConstrCost. H/L omitted in Email and ForeignTechnology because of collinearity.

Table B.9: Financial development not interacted with sectoral financial dependence

Dependent variable:		Exporter		Email		ForeignTechnology
	(1)	(2)	(3)	(4)	(5)	(6)
FD × ExtDep	0.006*	-0.002	-0.009***	-0.017***	0.003*	0.009**
	(0.003)	(0.004)	(0.002)	(0.004)	(0.002)	(0.003)
q_1 × FD × ExtDep		0.011		0.029***		-0.009
		(0.006)		(0.009)		(0.006)
q_2 × FD × ExtDep		0.012***		0.022		-0.017***
		(0.004)		(0.013)		(0.005)
q_3 × FD × ExtDep		0.015***		0.010		-0.007**
		(0.003)		(0.007)		(0.003)
Foreign	0.163***	0.182***	0.075***	0.098***	0.236***	0.249***
	(0.016)	(0.016)	(0.013)	(0.012)	(0.023)	(0.023)
MNE	0.167***	0.184***	0.012	0.030	0.062***	0.071***
	(0.021)	(0.021)	(0.017)	(0.018)	(0.012)	(0.013)
Age	0.000	0.001*	-0.001***	-0.001***	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Skill			0.127***	0.124***	0.062***	0.061***
			(0.023)	(0.022)	(0.019)	(0.018)
q1		-0.476***		-0.432***		-0.131***
		(0.024)		(0.037)		(0.020)
q2		-0.377***		-0.285***		-0.106***
		(0.016)		(0.033)		(0.016)
q3		-0.214***		-0.129***		-0.067***
		(0.014)		(0.019)		(0.011)
Size	0.126***		0.112***		0.046***	
	(0.006)		(0.009)		(0.007)	
FD	-0.127	-0.126	-0.418***	-0.445***	-0.027	-0.021
	(0.082)	(0.100)	(0.072)	(0.076)	(0.020)	(0.021)
No. Obs.	14672	14672	11710	11710	5160	5160
R^2	0.311	0.301	0.303	0.296	0.177	0.169

Country, industry, and year dummies. Standard errors clustered at the industry level in . parentheses. Significance levels: *10%,**5%, ***1%.

Table B.10: Additional regressors: Firm age, MNE dummy

Dependent variable:	Exporter		Email		ForeignTechnology	
	(1)	(2)	(3)	(4)	(5)	(6)
FD × ExtDep	0.008**	0.012***	0.000	-0.006	0.005	0.005
	(0.003)	(0.003)				
q_1 × FD × ExtDep		-0.001		0.013		-0.003
		(0.003)		(0.010)		(0.005)
q_2 × FD × ExtDep		-0.006***		0.013*		0.009*
		(0.001)		(0.006)		(0.004)
q_3 × FD × ExtDep		-0.003		-0.001		-0.010**
		(0.002)		(0.005)		(0.004)
Foreign	0.215***	0.224***	0.063***	0.076***	0.096***	0.097***
	(0.013)	(0.013)	(0.015)	(0.016)	(0.018)	(0.018)
Skill			0.129***	0.121***	0.031*	0.021
			(0.029)	(0.031)	(0.016)	(0.016)
q1		-0.455***		-0.357***		-0.101***
		(0.022)		(0.060)		(0.021)
q2		-0.328***		-0.184***		-0.093***
		(0.014)		(0.036)		(0.014)
q3		-0.174***		-0.078***		-0.074***
		(0.013)		(0.012)		(0.017)
Size	0.119***		0.092***		0.028***	
	(0.007)		(0.014)		(0.004)	
FD	-0.036	-0.037	0.035	0.032	-0.005	-0.005
	(0.031)	(0.031)	(0.026)	(0.025)	(0.016)	(0.017)
No. Obs.	6494	6494	6429	6429	5551	5551
R^2	0.315	0.304	0.274	0.270	0.135	0.137

Country, industry, and year dummies. Standard errors clustered at the industry level in parentheses. Significance levels: *10%,**5%, ***1%.

Table B.11: BEEPS data only

Dependent variable:	Exporter		Email		ForeignTechnology	
	(1)	(2)	(3)	(4)	(5)	(6)
FD × ExtDep	0.001	-0.003	-0.007**	-0.018**	0.004	0.010
	(0.003)	(0.004)	(0.003)	(0.007)	(0.004)	(0.007)
q_1 × FD × ExtDep		0.007		0.043**		-0.017**
		(0.006)		(0.019)		(0.006)
q_2 × FD × ExtDep		0.003		0.018		-0.013*
		(0.006)		(0.011)		(0.007)
q_3 × FD × ExtDep		0.007*		0.008		-0.010***
		(0.004)		(0.006)		(0.003)
Foreign	0.164***	0.185***	0.055***	0.075***	0.180***	0.195***
	(0.017)	(0.019)	(0.013)	(0.013)	(0.029)	(0.028)
Skill			0.164***	0.155***	0.080***	0.072***
			(0.043)	(0.045)	(0.022)	(0.022)
q1		-0.495***		-0.394***		-0.160***
		(0.018)		(0.031)		(0.013)
q2		-0.398***		-0.217***		-0.120***
		(0.010)		(0.026)		(0.014)
q3		-0.243***		-0.079***		-0.099***
		(0.015)		(0.012)		(0.009)
Size	0.137***		0.105***		0.054***	
	(0.005)		(0.009)		(0.004)	
FD	-0.494***	-0.459***	-0.271	-0.286	0.037	0.035
	(0.120)	(0.138)	(0.250)	(0.240)	(0.028)	(0.027)
No. Obs.	14020	14020	12960	12960	9343	9343
R^2	0.315	0.302	0.287	0.293	0.128	0.117

Country, industry, and year dummies. Standard errors clustered at the industry level in parentheses. Significance levels: *10%,**5%, ***1%.

Table B.12: Narrower industry classification

B.5 Data Appendix

Variable list

Age is the firm's age, which is computed as the year of the survey minus the year in which the firm began operations in its country. The corresponding question is "In what year did your firm begin operations in this country?"

ConstrAcc is a dummy based on the question "Please tell us if access to financing (e.g., collateral) is a problem for the operation and growth of your business." The answer can take the values "No obstacle", "Minor obstacle", "Moderate obstacle", "Major obstacle", or "Very severe Obstacle". The dummy takes the value one if the answer is "Moderate obstacle", "Major obstacle", or "Very severe Obstacle"; it takes the value zero if the answer is "No obstacle" or "Minor obstacle".

ConstrCost is a dummy based on the question "Please tell us if the cost of financing (e.g., interest rates) is a problem for the operation and growth of your business." The answer can take the values "No obstacle", "Minor obstacle", "Moderate obstacle", "Major obstacle", or "Very severe Obstacle". The dummy takes the value one if the answer is "Moderate obstacle", "Major obstacle" or "Very severe Obstacle'; it takes the value zero if the answer is "No obstacle" or "Minor obstacle".

Email is a dummy variable equal to one if the firm responds "Yes" to the question "Does your enterprise regularly use e-mail [...] in its interactions with clients and suppliers?"

Exporter is a dummy variable that takes the value one if the firm reports a positive magnitude for the following question "What percent of your establishment's sales are exported directly?"

Expr is the LaPorta, Lopez-de Silanes, Shleifer, and Vishny (1998) measure of the risk of expropriation. It is provided on a zero to ten scale with higher scores for greater risks of expropriation (LaPorta, Lopez-de Silanes, Shleifer, and Vishny, 1998, see p. 1125).

ExtDep captures the sectoral demand for credit. ExtDep is computed using the information about US firms in the Compustat North America database. For each firm, we sum the use of external finance (i.e., capital expenditures minus cash flow from operations) over the period 1996–2005 and divide by the sum of the capital expenditures over the same time period. Then, we take the median for each NAICS 3-digit industry. Finally, we calculate a weighted average to match these values to the industries in the World Bank Enterprise Surveys.

FD measures the country's level of financial development. FD is the sum of "private credit by deposit money banks and other financial institutions / GDP" and "stock market capitalization / GDP", both taken from Beck, Demirgüç-Kunt, and Levine (2009).

Foreign is a dummy variable equal to one if at least 10% of the firm is owned by the foreign private sector.

ForeignTechnology is a dummy variable that takes the value one if the firm responds "Yes" to the question "Does your establishment use technology licensed from a foreign-owned company?"

H/L is the human capital per worker. We set $H/L = \exp\{\phi(s)\}$, where s is the average number of years of schooling in the population over 25 years old from Barro and Lee (2010). $\phi(s)$ is a piecewise linear function with slope 0.13 for $s \leq 4$, 0.10 for $4 < s \leq 8$, and 0.07 for $8 < s$ (Caselli, 2005, p. 687). The Barro and Lee (2010) measure is available for the years 2000 and 2005. For countries surveyed in 2002, we use the human capital in 2000, and for those surveyed after 2002, we use the human capital in 2005.

Law is the LaPorta, Lopez-de Silanes, Shleifer, and Vishny (1998, p. 1124) measure of the rule of law. It is provided on a zero to ten scale with higher scores for stronger traditions of law and order.

Liqu is a sectoral measure of the liquidity ratio. It is taken from Felbermayr and Yalcin (2011), who construct the liquidity ratio as the current liabilities over the current assets for a large number of NACE 1.1 sectors, using the Amadeus database for Germany. we match these data with the World Bank Enterprise Surveys using the ISIC classification of the firm's main product line.

N/L is the (log) of the natural resources per worker. In order to measure a country's natural resources endowment, we use data from World Bank (1997). In particular, we take the difference between "natural capital" and "protected areas". The population data is from the Penn World Tables Version 7.0.

MNE is a dummy variable that takes the value one if the firm responds "Yes" to the question "Does your firm have holdings or operations in other countries?"

K/L is the (log) of the physical capital per worker. We compute K/L according to the perpetual inventory method, setting $K_t = I_t + \delta K_{t-1}$, where I_t is the investment in the year t and $\delta = 0.06$ is the depreciation rate. For details, see Caselli (2005, p. 685). The population data is from the Penn World Tables Version 7.0.

Productivity is computed as (log) of the sales per (permanent) worker.

Repud is the LaPorta, Lopez-de Silanes, Shleifer, and Vishny (1998, p. 1125) measure of the repudiation of contracts by the government. It is provided on a zero to ten scale, with higher scores for greater risks of the repudiation of contracts.

Size The firm size is measured as the (log) of the number of (permanent) workers.

Skill is the fraction of the total workforce of the firm constituted by its non-production workers, and captures the average skill level of the firm's workforce.

State is a dummy variable equal to one if at least 10% of the firm is owned by the government / state.

Tang is the ratio of the tangible assets to the total assets, and provides a sectoral measure of asset tangibility. This measure is taken from Felbermayr and Yalcin (2011), who compute asset tangibility for a large number of NACE 1.1 sectors using the Amadeus database for Germany. We match these data with the World Bank Enterprise Surveys using the ISIC classification of the firm's main product line. *Tang* is time invariant.

TrCr is accounts payable over turnover and provides a sectoral measure of trade credit received. It is taken from Felbermayr and Yalcin (2011), who compute trade credit received for a large number of NACE 1.1 sectors using the Amadeus database for Germany. We match these data with the World Bank Enterprise Surveys using the ISIC classification of the firm's main product line.

Appendix C

Appendix to Chapter 3

C.1 Figures

Figure C.1: Correlation between GDP per capita and the share of credit constrained firms, 2005, 2008, 2009.

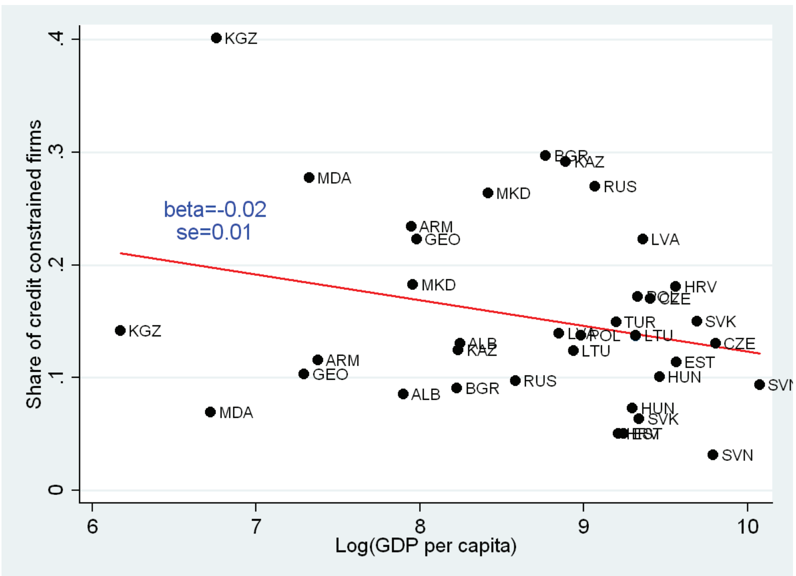


Figure C.2: Correlation between private credit to GDP and the share of credit constrained firms, 2005, 2008, 2009.

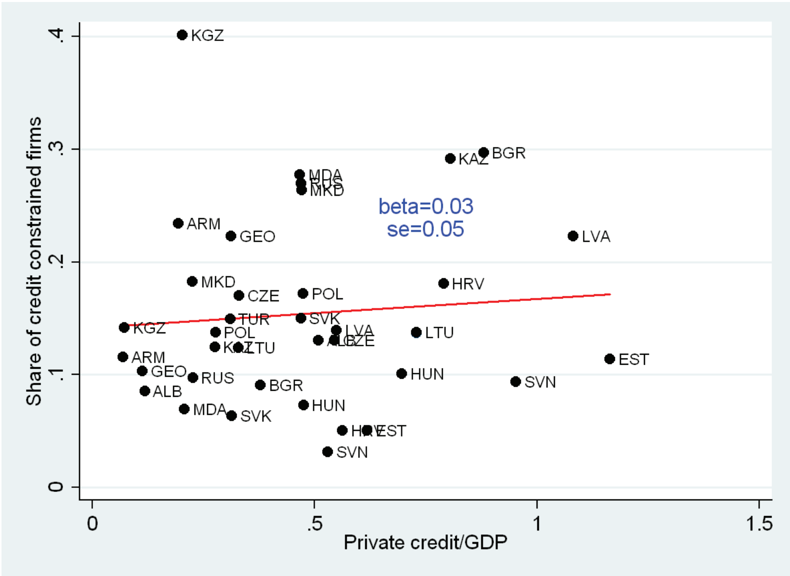
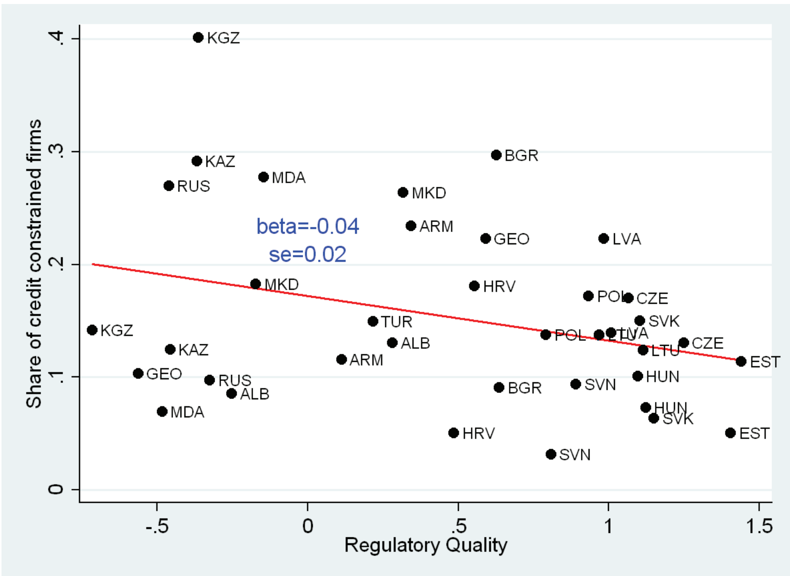


Figure C.3: Correlation between regulatory quality and the share of credit constrained firms, 2005, 2008, 2009.



C.2 Tables

Country	2005	2008	2009	Total
Albania	129	0	23	152
Armenia	268	0	256	524
Bulgaria	198	0	212	410
Croatia	158	0	83	241
Czech Republic	270	0	153	423
Estonia	179	0	211	390
FYROM	93	0	273	366
Georgia	136	229	0	365
Hungary	454	0	238	692
Kazakhstan	402	0	374	776
Kyrgyz Republic	148	0	162	310
Latvia	151	0	193	344
Lithuania	153	0	204	357
Moldova	217	0	321	538
Poland	719	0	262	981
Russia	340	0	641	981
Slovakia	142	0	173	315
Slovenia	189	0	245	434
Turkey	0	818	0	818
Total	4346	1047	4024	9417

Table C.1: Baseline regression sample by country and year

Variable	Obs.	Mean	Std. Dev.	Min	Max
Credit Constrained	3704	0.162	0.368	0	1
Exporter	3698	0.392	0.488	0	1
Importer	2864	0.418	0.493	0	1
Size	3704	3.686	1.562	0	9.048
Productivity	3704	10.178	1.725	1.204	16.478
Foreign	3704	0.120	0.325	0	1
Overdue	3704	0.043	0.202	0	1
Disclosure × ExtDep	3704	6.549	9.886	0	66.092
RegQu × FinDev	3704	88.916	66.170	7.418	379.076

Table C.2: Summary statistics, Manufacturing

Variable	Obs.	Mean	Std. Dev.	Min	Max
Credit Constrained	4718	0.160	0.367	0	1
Exporter	4715	0.165	0.371	0	1
Importer	2222	0.273	0.446	0	1
Size	4718	2.901	1.543	0	9.810
Productivity	4718	10.156	2.226	1.504	19.543
Foreign	4718	0.104	0.306	0	1
Overdue	4718	0.036	0.185	0	1
Disclosure × ExtDep	4718	5.102	3.578	0	26.904
RegQu × FinDev	4718	112.700	81.507	7.418	379.076

Table C.3: Summary statistics, Services

Table C.4: Difference between two-way traders, importers, exporters, and purely domestic firms, Manufacturing firms

	(1) Sales	(2) Employment	(3) Productivity	(4) Credit Constr.	(5) R&D	(6) Foreign Techn.
Import Only	0.763***	0.298***	0.465***	-0.018	0.118***	0.029**
	(0.087)	(0.057)	(0.062)	(0.018)	(0.019)	(0.013)
Export Only	1.627***	1.177***	0.450***	-0.057***	0.205***	0.042**
	(0.116)	(0.077)	(0.090)	(0.022)	(0.027)	(0.020)
Two-Way Trade	2.190***	1.631***	0.559***	-0.099***	0.272***	0.114***
	(0.083)	(0.060)	(0.057)	(0.016)	(0.020)	(0.014)
Constant	12.930***	3.086***	9.844***	0.112	0.294**	0.442***
	(0.473)	(0.351)	(0.296)	(0.093)	(0.118)	(0.097)
No. Obs.	3704	3704	3704	3704	3409	3582
R^2	0.432	0.322	0.456	0.052	0.155	0.147
F	99.565	58.794	118.598	6.381	23.341	18.442

OLS regressions. Year, country, sector dummies. Robust standard errors in parentheses. (d) for discrete change of dummy variable from 0 to 1. Significance levels: *10%,**5%, ***1%.

Table C.5: Difference between two-way traders, importers, exporters, and purely domestic firms, Service firms

	(1) Sales	(2) Employment	(3) Productivity	(4) Credit Constr.	(5) R&D	(6) Foreign Techn.
Import Only	0.433***	0.281***	0.152***	-0.031**	0.046***	0.008*
	(0.094)	(0.072)	(0.058)	(0.015)	(0.014)	(0.004)
Export Only	0.850***	0.553***	0.297***	-0.052***	0.130***	0.017*
	(0.095)	(0.074)	(0.061)	(0.016)	(0.021)	(0.010)
Two-Way Trade	1.331***	0.830***	0.500***	-0.066***	0.098***	0.005
	(0.124)	(0.103)	(0.066)	(0.015)	(0.024)	(0.005)
Constant	14.015***	2.860***	11.155***	0.205***	0.110**	0.606***
	(0.287)	(0.202)	(0.166)	(0.048)	(0.052)	(0.137)
No. Obs.	4718	4718	4718	4718	4319	2311
R^2	0.460	0.123	0.604	0.051	0.099	0.269
F	127.323	23.155	203.146	11.642	14.377	

OLS regressions. Year, country, sector dummies. Robust standard errors in parentheses. (d) for discrete change of dummy variable from 0 to 1. Significance levels: *10%,**5%, ***1%.

	Exporter			Importer		
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	2SLS-First	2SLS	OLS	2SLS-First	2SLS
Credit Constr. (d)	-0.024**		-0.336*	0.016		-1.902**
	(-2.469)		(-1.820)	(0.855)		(-2.427)
Size	0.062***	-0.033***	0.052***	0.031***	-0.029***	-0.025
	(21.374)	(-13.298)	(7.589)	(7.259)	(-10.182)	(-1.054)
Productivity	0.011***	-0.011***	0.009***	-0.009*	-0.010**	-0.021**
	(4.479)	(-3.830)	(2.981)	(-1.957)	(-2.377)	(-2.252)
Foreign (d)	0.191***	-0.026**	0.183***	-0.002	-0.037***	-0.075*
	(12.574)	(-2.421)	(11.285)	(-0.081)	(-3.267)	(-1.830)
Disclosure × ExtDep		-0.005***			-0.004**	
		(-3.086)			(-1.995)	
Overdue (d)		0.068***			0.020	
		(3.259)			(0.830)	
RegQu × FinDev		-0.001***			-0.001**	
		(-4.117)			(-2.082)	
No. Obs.	9408	9408	9408	5542	5542	5542
R^2	0.275	0.067	0.208	0.113	0.055	-1.543
F	103.170	16.043	93.680	20.971	7.482	6.818
F (first stage)		12.49***			3.04**	
Hansen J		0.207				0.113

Year, country, sector dummies. Robust standard errors in parentheses. (d) for discrete change of dummy variable from 0 to 1. Significance levels: *10%,**5%, ***1%.

Table C.6: Linear Probability and 2SLS Models – All Firms

	Exporter			Importer		
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	2SLS-First	2SLS	OLS	2SLS-First	2SLS
Credit Constr. (d)	-0.023		-0.536*	0.044*		-1.449**
	(-1.273)		(-1.783)	(1.738)		(-2.349)
Size	0.116***	-0.040***	0.096***	0.046***	-0.035***	-0.006
	(23.801)	(-9.488)	(7.340)	(7.631)	(-7.771)	(-0.248)
Productivity	0.021***	-0.018***	0.013*	0.026***	-0.014**	0.009
	(4.066)	(-3.701)	(1.767)	(3.866)	(-2.502)	(0.809)
Foreign (d)	0.226***	-0.024	0.214***	-0.001	-0.028*	-0.044
	(10.136)	(-1.452)	(8.779)	(-0.051)	(-1.695)	(-1.102)
Disclosure × ExtDep		-0.005***			-0.004**	
		(-2.859)			(-2.296)	
Overdue (d)		0.071**			0.041	
		(2.117)			(1.112)	
RegQu × FinDev		-0.001**			-0.001**	
		(-2.052)			(-2.024)	
No. Obs.	3698	3698	3698	2864	2864	2864
R^2	0.325	0.076	0.186	0.185	0.067	-0.864
F	84.957	8.659	69.268	27.367	5.770	10.553
F (first stage)		5.62***			3.52**	
Hansen J		0.275				0.115

Year, country, sector dummies. Robust standard errors in parentheses. (d) for discrete change of dummy variable from 0 to 1. Significance levels: *10%,**5%, ***1%.

Table C.7: Linear Probability and 2SLS Models – Manufacturing Firms

	Exporter			Importer		
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	2SLS-First	2SLS	OLS	2SLS-First	2SLS
Credit Constr. (d)	-0.025**		-0.129	-0.061*		0.448
	(-2.111)		(-0.509)	(-1.900)		(0.760)
Size	0.028***	-0.029***	0.025***	0.031***	-0.018***	0.041***
	(7.273)	(-8.476)	(2.994)	(4.680)	(-4.657)	(3.156)
Productivity	0.018***	-0.005	0.018***	0.091***	-0.021**	0.102***
	(5.969)	(-1.292)	(5.793)	(6.314)	(-2.269)	(5.066)
Foreign (d)	0.127***	-0.016	0.125***	0.201***	-0.033**	0.218***
	(5.881)	(-1.021)	(5.675)	(6.536)	(-2.196)	(5.841)
Disclosure × ExtDep		-0.003			0.002	
		(-0.732)			(0.681)	
Overdue (d)		0.060**			-0.004	
		(2.026)			(-0.127)	
RegQu × FinDev		-0.001***			0.006	
		(-3.376)			(1.635)	
No. Obs.	4715	4715	4715	2222	2222	2222
R^2	0.170	0.066	0.161	0.184	0.051	0.094
F	28.948	11.201	28.459			120.007
F (first stage)		5.48***			1.05**	
Hansen J		0.187				0.000

Year, country, sector dummies. Robust standard errors in parentheses. (d) for discrete change of dummy variable from 0 to 1. Significance levels: *10%,**5%, ***1%.

Table C.8: Linear Probability and 2SLS Models – Service Firms

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Curriculum Vitae

10/2008-10/2012	Promotion in Volkswirtschaftslehre Munich Graduate School of Economics Ludwig-Maximilians-Universität München
03/2011-06/2011	Forschungsaufenthalt Stanford University, USA
10/2003-09/2008	Studium der Volkswirtschaftslehre Eberhard-Karls-Universität Tübingen
06/2003	Abitur Ricarda-Huch-Gymnasium Krefeld