Financial constraints and the missing technology adoption

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Abstract

This paper develops a heterogeneous-firm model of international trade to study the impact of cross-country differences in financial market development on firms’ decision to export and to invest in technology adoption. Using the World Bank Enterprise Surveys, a rich cross-country, firm-level dataset that covers a large number of developing and emerging economies, I provide new firm-level evidence on the impact of financial development on growth-related investments. My results confirm the predictions of the model. First, they support the importance of financial market development for a firm’s decision to enter the export market found by previous literature. Second, I find that financial market development relaxes financial constraints and stimulates the use of more efficient production technologies. Financial market development thus reduces the "missing technology adoption". Finally I show that responses to financial market development are heterogeneous across the firm size distribution.

Keywords: International trade, Technology adoption, Financial constraints, Convergence

JEL: F1, O33, O16

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1. Introduction

A large strand of literature in economic growth shows that financial constraints prevent less developed countries from adopting advanced technologies and lead to persistent income differences across countries (e.g. Aghion, Howitt, and Mayer-Foulkes 2005). Another strand of literature studies the effect of financial constraints on firm-level investments in growth-related investments. This paper unites these two literatures and provides new firm-level evidence on the impact of cross-country differences in financial market development on investments in exporting and, most importantly, in 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 I call the missing technology adoption. This difference is likely to be larger in industries with high external financing needs. Indeed, I show that a higher level of financial development reduces the missing technology disproportionally in industries which are more dependent on external finance.

To guide my empirical analysis, I present an extension to multiple sectors of the heterogeneous-firm model developed in Peters and Schnitzer (2011). In the model, firms have the option to invest in a more expensive but more efficient production technology, as in Bustos (2011). An industry-specific fraction of the investment cost has to be financed externally. Firms in financially more dependent industries have higher costs of external finance. Moreover, 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 industries and across the firm size distribution. Large firms have sufficient access to external finance while small firms, which are financially constrained, have no incentive to pay the investment cost. 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 most affected by financial development.

I confirm 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 mostly developing countries. In addition to variation in financial development across countries, I exploit variation in financial dependence across industries for empirical identification. In particular, the main explanatory variable is an interaction between financial development
and dependence on external finance. This amounts to a difference-in-difference approach, that is a comparison of industries with different external financing needs across countries at different levels of financial development.\footnote{This approach has been proposed by \cite{RajanZingales1998}.}

First, I show that financial market development increases the access to external finance, especially in industries which require a lot of external funding. This is more important for smaller firms which, as assumed in the model, are the most financially constrained. Second, I find that the probability that a firm exports increases in financial market development (and disproportionally in financially dependent industries). My results thus confirm the existence of financial constraints in international trade found by previous literature (e.g. \cite{Chaney2005}). The positive effect of financial market development is driven by firms in the first quartile of the firm size distribution. Hence, financial constraints prevent primarily the smallest firms from serving foreign markets. Third, and most importantly, I provide evidence for the missing technology adoption. Given country and industry characteristics, a lower level of financial market development decreases the probability of using advanced technologies. This result is strongest in industries with high external financing needs. Moreover, financial development has the largest effect on firms in the second and third firm size quartile. As predicted by the model, firms in the middle of the size distribution are the missing technology adopters.

The Enterprise Surveys are ideal for the purpose of my study for two reasons. First, almost all countries which have been surveyed are developing and emerging economies. On the one hand, these countries are very likely to exhibit missing technology adoption. On the other hand, the cross-country variation is large enough to allow for robust results. Second, the survey questionnaire provides detailed questions about export behavior, technology choice, and access to external finance. Hence, I am able to construct direct measures of technology use and access to finance. The use of direct measures reduces measurement error and constitutes a major advantage over other studies that rely on indirect proxies, for example TFP estimations and balance-sheet data.

The identification strategy further strengthens the empirical results. Using an interaction between a country and an industry characteristic allows for the inclusion of country and industry dummies. Hence, I can correct for country and industry characteristics and avoid 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 challenge in most firm-level studies on financial constraints is to convince readers of the exogeneity of
the measure used.

My 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 progress at the country level. Aghion et al. (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. Manova, 2010; Buera, Kaboski, and Shin, 2009). The present paper brings the analysis to the firm level and shows that the impact of financial development differs across the firm distribution.

The second strand of literature empirically examines the effect of financial constraints on firm behavior. Beck, Demirguc-Kunt, and Maksimovic (2005) and Beck, Demirguc-Kunt, and Maksimovic (2008) use data from the World Bank Enterprise Surveys to study the effect of legal and financial constraints on firm growth. In line with my results, they show that smaller firms are 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: Minetti and Zhu (2011) for a sample of Italian firms, Muuls (2008) for Belgian firms, and Greenaway, Guariglia, and Kneller (2007) for firms in the UK. Berman and Hericourt (2010) study firms in nine developing countries using data from the Enterprise Surveys. A small number of papers analyzes the effect of financial constraints on innovative behavior of firms in different countries. Seker (2011) finds a positive correlation between access to finance and product and process innovation in a sample of firms taken from the Enterprise Surveys. Using BEEPS data (a subset of WBES), Gorodnichenko and Schnitzer (2010) establish a negative causal effect of financial constraints on innovative activity. However, none of these studies accounts for firm heterogeneity.

Finally, the paper probably most related to my study is Maskus, Neumann, and Seidel (2011). 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 et al. (2011) study the effect on R&D intensity in OECD countries, my focus is on the missing technology adoption in developing economies. Moreover, my analysis uses firm-level data and documents the importance of accounting for firm heterogeneity.

The paper is organized as follows. Section 2 presents the theoretical model and the resulting
empirical predictions. The data are described in Section 3. Section 4 explains the econometric approach and presents the results. Section 5 gives sensitivity tests and Section 6 concludes.

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). Furthermore, firms require external finance to cover the fixed investment cost. I consider two countries that differ with respect to financial market development: a country with a developed financial market, country $L$, and a country with a less developed financial market, country $H$.

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, a homogeneous good industry, which serves as numéraire, and $k = 1, ..., K$ differentiated good industry. Preferences. Preferences in the two countries are described by the quasi-linear quadratic utility function developed by Ottaviano, Tabuchi, and Thisse (2002):

$$U = q_0^c + \Pi k \left[ \alpha \int_{i \in \Omega_k} q_{ik}^c di - \frac{1}{2} \gamma_k \int_{i \in \Omega_k} (q_{ik}^c)^2 di - \frac{1}{2} \beta \left( \int_{i \in \Omega_k} q_{ik}^c di \right)^2 \right] \theta_k, \quad (1)$$

where $\alpha, \beta, \gamma > 0$. $q_0^c$ and $q_{ik}^c$ denote per capita consumption of the homogeneous good and of each variety $i$ of the differentiated good $k$. $\alpha, \beta$ characterize substitution between the differentiated and the homogeneous good $k$. $\gamma$ represents the degree of product differentiation with $\gamma = 0$ indicating perfect substitutability. The $\theta_k$ indicate the share of each differentiated good industry in total expenditure on differentiated goods and satisfy $\sum_k \theta_k = 1$ and $0 < \theta_k < 1$.

These preferences generate the linear demand system:

$$q_{ik} = S q_{ik}^* = \frac{\alpha S}{\gamma + \beta N_k} - \frac{S}{\gamma} p_{ik} + \frac{\beta N_k}{\gamma + \beta N_k} \frac{S}{\gamma} \bar{p}_k. \quad (2)$$

\footnote{The model readily extends to an arbitrary number of countries, different country sizes and different bilateral trade barriers.}

\footnote{The country subscript has been omitted for readability in this section.}
\( \tilde{p}_k = 1/N \int_{i \in \Omega} p_{ik} di \) is the average price and \( N_k \) the number of consumed varieties in industry \( k \).

Variety \( ik \) is consumed whenever \( p_{ik} \leq p_k^{\text{max}} \) where \( p_k^{\text{max}} \) 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. Assuming a positive demand for the homogeneous good, the wage in both countries equals unity.

The differentiated good industries are characterized by monopolistic competition and free entry. Production is at constant returns to scale with firm-specific labor requirement \( c_{ik} \). Firms are thus heterogeneous in their cost of production. Entry requires a fixed investment \( f_{Ek} \). 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 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 (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 \( f_k \) is paid upfront and can be thought of as a per-period fixed cost that comes with adopting a 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 \( t_k \); firms adopt a process innovation that reduces labor input requirement. An alternative interpretation of \( t_k \) is 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”. The advanced technology thus comes at a higher fixed cost but increases productivity.

**financial constraints.** Internal funds are not sufficient to cover the investment, that is firms need access to external finance. As in Rajan and Zingales (1998), the need for external finance is the same for all firms active in industry \( k \). In particular, only a fraction \( 1 - d_k \) of the fixed technology adoption cost \( f_k \) can be financed internally. The cost of obtaining external finance, \( f_{ikm}^{\text{ext}} \), depends on (i) financial market development in country \( m \), \( m = L, H \),
(ii) sectoral dependence on external finance \(d_k\) and (iii) firm size \(c_{ikm}\): more productive and hence larger firms have lower cost of external finance. This assumption is consistent with the data used for empirical analysis in the next section.

The cost of external finance is formalized in the following way

\[
f_{ikm}^{\text{ext}}(f_k, d_k, \lambda_m, c_{ikm}) = \max \left\{d_k f_k - \lambda_m \left[\pi_{ikm}^A(c_{ikm}) - \pi_{ikm}(c_{ikm})\right], 0\right\}.
\]

(3)

\(\pi_{ikm}^A(c_{ikm})\) are the variable profits of firms using the advanced technology. \(\pi_{ikm}^A(c_{ikm}) - \pi_{ikm}(c_{ikm})\) is the net revenue from technology adoption. It increases in firm size, that is larger firms gain more from using the advanced technology. The idea is that this makes it easier for creditors to enforce repayment and hence lowers the cost of obtaining credit. Firms whose expected revenues from technology adoption are larger than \(d_k f_k/\lambda_m\) have an adoption cost equal to \(f_k\) while firms whose expected revenues from adopting are below \(d_k f_k/\lambda_m\) pay for obtaining outside finance. These extra cost of external finance are inversely related to firm size but are at most \(d_k f_k\). The parameter \(\lambda_m\), \(\lambda_m \in (0,1]\) and \(m = L, H\), indexes financial market development. In the country with a developed financial market, country \(L\) (\(\lambda_L = 1\)), no firm incurs extra cost of external finance. The total costs of technology adoption are thus equal to \(f_k\). In the country with the less developed financial market, country \(H\) (\(\lambda_H < 1\)), however, a subset of firms pays for obtaining outside finance, in addition to \(f_k\).

The total cost function of firms using the advanced technology, \(TC_{ikm}^A\), thus depends on the level of financial market development:

\[
TC_{ikm}(c_{ikm}) = c_{ikm} + q_{ikm} c_{ikm} \\
TC_{ikm}^A(c_{ikm}, d_k, \lambda_m) = (c_{ikm} - t_k) q_{ikm} + f_k + f_{ikm}^{\text{ext}}(f_k, d_k, \lambda_m, c_{ikm}).
\]

(4)

**Exporting.** Serving the foreign market involves variable trade costs of the iceberg form, \(\tau \geq 1\). The trade costs increase the production cost \(c_{ikm}\) but do not increase the return to technology adoption \(t_k\).
2.2. Firm decisions

In the following, the solution of the model is presented from the perspective of country H.

Prices and profits. Let \( p^D_{ikH} \), \( p^X_{ikH} \), \( p^{DA}_{ikH} \), \( p^{XA}_{ikH} \) 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:

\[
\begin{align*}
\frac{1}{2} (p^D_{ikH} + c_{ikH}) & , \\
\frac{1}{2} (p^X_{ikH} + \tau c_{ikH}) & , \\
\frac{1}{2} (p^{DA}_{ikH} + c_{ikH} - t_k) & , \\
\frac{1}{2} (p^{XA}_{ikH} + \tau c_{ikH} - t_k) & .
\end{align*}
\]

Prices charged by firms using the advanced technology are lower, \( p^{DA}_{ikH} = p^D_{ikH} - t_k/2 \) and \( p^{XA}_{ikH} = p^X_{ikH} - t_k/2 \). Accordingly, quantities sold are higher. Technology adoption increases thus variable profits but involves higher fixed cost. The profits of firms serving only the domestic market using the advanced and the baseline technology are given by:

\[
\pi^D_{ikH} = \frac{S}{4\gamma} (p^D_{ikH} - c_{ikH})^2 , \quad \pi^{DA}_{ikH} = \frac{S}{4\gamma} (p^{DA}_{ikH} - c_{ikH} + t_k)^2 - f_k - f^{ext}_{ikH} . \tag{5}
\]

Profits of firms serving also the foreign market are respectively

\[
\begin{align*}
\pi^T_{ikH} & = \pi^D_{ikH} + \pi^X_{ikH} = \frac{S}{4\gamma} [(p^{max}_{ikH} - c_{ikH})^2 + (p^D_{ikH} - \tau c_{ikH})^2] \\
\pi^{TA}_{ikH} & = \pi^{DA}_{ikH} + \pi^{XA}_{ikH} = \frac{S}{4\gamma} [(p^{max}_{ikH} - c_{ikH} + t_k)^2 + (p^{max}_{ikH} - \tau c_{ikH} + t_k)^2] - f_k - f^{ext}_{ikH} , \tag{6}
\end{align*}
\]

Firms’ sorting pattern. Denote with \( c^D_{kH} \), \( c^X_{kH} \), and \( c^A_{kH} \) the cost cutoffs below which firms in industry \( k \) in country \( H \) stay in the market and produce, serve the foreign market, and invest in technology adoption. In the data used for empirical analysis, only a subset of domestic producers serves the foreign market and/or uses an advanced production technology, that is \( c^X_{kH} < c^D_{kH} \) and \( c^A_{kH} < c^D_{kH} \). Furthermore, there are two possible sorting patterns (Figure XX). In the first case \( (c^A_{kH} < c^X_{kH}) \), serving 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 \( f_k \) is high. In the opposite case \( (c^X_{kH} < c^A_{kH}) \), the marginal technology adopter is a purely domestic firm, that is all exporters use the advanced technology (low \( f_k \)). In the following, I focus in the first case and consider the adoption of more expensive and
thus more significant technologies as these are more likely to foster growth and convergence. I provide the necessary parameter restrictions below.

Upon entry, there are thus four types of firms. Firms with a cost drawn above \(c_{kH}^D\) immediately exit the market. Firms with marginal cost between \(c_{kH}^D\) and \(c_{kH}^X\) are purely domestic producers and those with costs between \(c_{kH}^X\) and \(c_{kH}^A\) also serve the foreign market. The most productive firms with production cost below \(c_{kH}^A\) adopt the advanced technology and 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 \(\pi^D_{ikH}\) are non-negative:

\[
\pi^D_{ikH}(c_{kH}^D) = 0 \iff c_{kH}^D = p_{kH}^{\text{max}}.
\]

(7)

Firms export if they can profitably serve the foreign market. This is the case if their production costs are below the export cutoff \(c_{kH}^X\) where

\[
\pi^X_{ikH}(c_{kH}^X) = 0 \iff c_{kH}^X = \frac{c_{kL}^D}{\tau}.
\]

(8)

Exporters invest in technology adoption if their total profits are higher when using the advanced technology, that is if \(\pi^{TA}_{ikH}(c_{ikH}) \geq \pi^T_{ikH}(c_{ikH})\). In particular,

\[
\frac{S}{4\gamma} \left[ \left( c_{kH}^D - c_{ikH} + t_k \right)^2 + \left( c_{kL}^D - \tau c_{ikH} + t_k \right)^2 \right] - f_k - f_{ikH}^{\text{ext}} \geq \frac{S}{4\gamma} \left[ \left( c_{kH}^D - c_{ikH} \right)^2 + \left( c_{kL}^D - \tau c_{ikH} \right)^2 \right]
\]

\[
\iff c_{kH}^A = \frac{1}{1 + \tau} \left( c_{kH}^D + c_{kL}^D + t_k - \frac{1 + d_k}{1 + \lambda H} \frac{2\gamma f_k}{S t_k} \right)
\]

(9)

The technology adoption cutoff \(c_{kH}^A\) depends on the total costs of technology adoption, \(f_k + f_{ikH}^{\text{ext}}\). Firms in country \(L\) only pay the fixed cost of technology adoption \(f_k\). Hence, firms in \(L\) need to be less productive to have an incentive to invest in technology adoption. This is reflected by a higher technology adoption cutoff: \(c_{kL}^A(\lambda_L = 1) > c_{kH}^A(\lambda_H < 1)\).

The most productive and hence largest firms in country \(H\) have no extra costs of external

\[\text{For } c_{kH}^A < c_{kH}^X, f_k \text{ must thus be larger than } \left( c_{kH}^D + t_k - c_{kL}^D / \tau \right) S t_k (1 + \lambda H) / 4\gamma(1 + d_k), \text{ where both } c_{kH}^D \text{ and } c_{kL}^D \text{ depend on } \tau, k, t_k, f_k, d_k, \gamma, S, f_{E}, c_M.\]
Note that $c_{kH}^{NC} \leq c_{kL}^A$: all financially unconstrained firms in country $H$ adopt the advanced technology. The marginal technology adopter is thus a financially constrained firm. It follows that firms with cost draws $c_{ikH} \in [(c_{kH}^A, c_{kL}^A)$ would invest in technology adoption in country $L$ but are prevented from doing so by $f_{ikH}^H > 0$. The probability of being in that cost interval is what I call the missing technology adoption.

2.3. Industry equilibrium

Free entry ensures that, in each industry $k$, firms enter until expected profits are equal to the fixed entry cost $f_E$. The resulting free entry condition for industry $k$ and country $H$ is

$$f_{Ek} = \int_{0}^{c_{kH}^{NC}} \left[ \pi_{kH}^T (c_{ikH}) + f_{ikH}^{ext} \right] dF(c_{ikH}) + \int_{c_{kH}^{NC}}^{c_{kH}^A} \pi_{kH}^T (c_{ikm}) dF(c_{ikm})$$

$$+ \int_{c_{kH}^{A}}^{c_{XkH}} \pi_{kH}^T (c_{ikH}) dF(c_{ikH}) + \int_{c_{XkH}}^{c_{kH}^D} \pi_{kH}^D (c_{ikH}) dF(c_{ikH}).$$

And, solving the integral,

$$\frac{(c_{kH}^D)^{k+2} + \tau^{-k}(c_{kL}^D)^{k+2}}{k+2} + t_k(1+\tau) \left[ (1 + \lambda_H)(c_{kH}^A)^{k+1} - \lambda_H (c_{kH}^{NC})^{k+1} \right] = \frac{f_{Ek} 2\gamma (c_{M})^k (k+1)}{S},$$

where $c_{AH}$ and $c_{kH}^{NC}$ are given by (9) and (10). The free entry condition for industry $k$ in country $L$ is analogous. For each industry $k$, (11) is a thus system of two equations with two unknowns, $c_{kL}^D$ and $c_{kH}^D$. It can be shown that there is a unique equilibrium pair $c_{kL}^D < c_{kH}^D$ (see Mathematical Appendix). From (9), the ex-ante probability of technology adoption is higher in country $L$. Hence, expected profits are larger and more firms pay the entry cost $f_{Ek}$ driving down the entry cutoff. $c_{kL}^D < c_{kH}^D$ implies, by (8) and (9), that the export and technology adoption cutoffs are higher in the country with a developed financial market, $c_{kL}^X > c_{kH}^X$ and $c_{kL}^A > c_{kH}^A$. The difference in the probabilities, that is the missing technology adoption, decreases in financial market development of country $H$ and increases in the need for outside finance.

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8In country $L$, $c_{kL}^{NC} = c_{kL}^A$.
2.4. Predictions

Probability of being financially constrained. Define a dummy variable, \(\text{constr}_{ikH}\), that takes value one if firm \(i\) active in industry \(k\) in country \(H\) is financially constrained and value zero otherwise. The probability of being financially constrained is expressed by

\[
\Pr (\text{constr}_{ikH} = 1|\text{observables}) = \Pr (c_{ikH} \geq c^{NC}_{kH}) = \Pr (c_{ikH} - c^{NC}_{kH} \geq 0) .
\]

From the free entry condition in (11) follows that an increase in financial market development \(\lambda_H\) leads \textit{ceteris paribus} to a lower entry cutoff in \(H\) and a higher entry cutoff in \(L\). \(c^{NC}_{kH}\) thus increases in \(\lambda_H\). Therefore:

\textit{Prediction 1. Given industry and (other) country characteristics, the probability that firm \(i\) active in industry \(k\) in country \(H\) is financially constrained decreases in financial market development.}

Export market participation. Define a dummy variable, \(\text{exp}_{ikH}\), that takes value one if firm \(i\) in industry \(k\) exports. The probability that the firm exports is then

\[
\Pr (\text{exp}_{ikH} = 1|\text{observables}) = \Pr (c_{ikH} \leq c^X_{kH}) = \Pr \left( \frac{c^D_{kH}}{\tau} - c_{ikH} \geq 0 \right) .
\]

(11) implies that a higher level of financial market development increases the export cutoff. Hence:

\textit{Prediction 2. Given industry and (other) country characteristics, the probability that firm \(i\) active in industry \(k\) in country \(H\) exports increases in financial market development.}

Technology adoption. Define a dummy variable, \(\text{ta}_{ikH}\), equal to one if if firm \(ikH\) uses an advanced technology. Then:

\[
\Pr (\text{ta}_{ikH} = 1|\text{observables}) = \Pr (c_{ikH} \leq c^A_{kH}) = \Pr (c^A_{kH} - c_{ikH} \geq 0) .
\]

From (11) follows that an increase in financial market development leads to a higher technology adoption cutoff, provided that

\[
4\gamma(1 + d_k)f_k/\text{St}_k \left(1 + \lambda_H\right)^2 + dc^D_{kL}/d\lambda_H > dc^D_{kH}/d\lambda_H .
\]

\footnote{This holds provided that

\[
2\gamma d_k f_k/\text{St}_k \left(\lambda_H\right)^2 + dc^D_{kL}/d\lambda_H > dc^D_{kH}/d\lambda_H .
\]}

10
In this case:

**Prediction 3.** Given industry and (other) country characteristics, the probability that firm \(i\) active in industry \(k\) in country \(H\) invests in technology adoption increases in financial market development.

3. Data

In order to test the predictions of my model, I 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 World Bank in a large number of mostly developing and emerging countries. I focus here on the surveys conducted between 2002 and 2006 as these contain detailed information on technology use\(^{10}\). While a third of the countries have been surveyed more than once in this time period, the empirical analysis is based on the pooled data. In order to improve upon 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)\(^{11}\). Firms that are fully government/state owned are excluded. The data include firms active in manufacturing, retail and other services. However, I restrict my analysis to manufacturing as the model outlined above best applies to this sector.

The Enterprise Surveys collect information on firm characteristics such as number of workers, skill composition, balance-sheet data, ownership, and age. From these data, I construct \(size_{ikH}\) as the log number of permanent workers. \(productivity_{ikH}\) is measured as log value added per worker if balance-sheet data are available and log sales per worker otherwise\(^{12}\). Ownership information is captured by two dummy variables, \(for_{ikH}\) and \(state_{ikH}\), that take value one if more than 10% of the firm are owned by the foreign private sector and the government/state. Finally, the skill level of the workforce is proxied by the fraction of non-production workers (\(skill_{ikH}\)).

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\(^{10}\)As these surveys have been conducted by different units within the World Bank, the respective questionnaires have been standardized for a joint analysis only later on. Therefore, not all questions have been asked in all countries. In a robustness check, I use the BEEPS data (a subset of the WBES) based on identical questionnaires in all countries.

\(^{11}\)For more information on the sampling scheme, see http://www.enterprisesurveys.org/Methodology/.

\(^{12}\)In robustness checks that are available upon request, I show that the measurement of productivity does not influence the results.
Furthermore, and most important for my purpose, the Enterprise Surveys provide information on export behavior, technology use and access to external finance. Specifically, firms are asked what percentage of [their] sales are exported directly. I classify a firm as an exporter ($\text{exp}_{ikH} = 1$) if it exports a positive share of its sales. 31% of all firms export (standard deviation: 0.46) with a minimum of 1% in Angola and a maximum of 100% in Lao PDR.

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 only have an incentive to use foreign technology 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 the above assumption about firms’ sorting pattern (high $f_k$). Indeed, in almost all countries, the share of firms using foreign technology is lower than the share of exporters. Therefore, a firm is considered a technology adopter ($\text{ta}_{ikH} = 1$) if it reports to use foreign technology. 13% of all firms that answered the question use a licensed foreign technology (standard deviation: 0.34) with a minimum of 2% in Benin and a maximum of 35% in Cambodia. However, firms might use technology from a foreign-owned firm without a license or a formal agreement. In this case, $\text{ta}_{ikH} = 0$ while, in reality, the firm is a technology adopter. Furthermore, holding a license might be a substitute for purchasing new machinery or equipment. I therefore use a second measure of technology adoption in the robustness checks. A firm is considered a technology adopter if it has introduced new technology that has substantially changed the way that the main product is produced in the preceding three years. There are two minor differences with respect to the foreign technology measure above. First, the interpretation is slightly different: the first measure captures the use and the second measure the introduction of a more efficient technology. Furthermore, the second measure is associated with lower costs of technology adoption ($f_k$): in the majority of the countries, the share of exporters is lower than the share of firms having introduced a new production technology.

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. I classify firms as being financially constrained ($\text{constr}_{ikH} = 1$) if (i) access to financing, (ii) the cost of financing are at least a moderate obstacle (2 on the four-point scale). 55% 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 indirect proxies used in other studies (e.g. total debt/total assets and cash flow/total assets in Berman and Hericourt (2010)). However, self-reported measures might be influenced by the subjective assessment of the respondents. Following Gorodnichenko and Schnitzer (2010), I thus show that the percentage of firms reporting to be financially constrained is negatively related to financial market development (Figure XX).

**Financial market development.** In the model, financial market development captures the overall access of firms to external finance. My 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, 2010). 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 a minimum of 4% in the Kyrgyz Republic and a maximum of 325% in Jordan. In the median country, Turkey, private credit amounts to 45% of GDP. As private credit is an outcome-based measure, I consider two alternative sets of measures that capture markets constraints in my robustness checks. In the first set of measures are repudiation of contracts, expropriation risk and accounting standards from LaPorta, Lopez-de Silanes, Shleifer, and Vishny (1998). These data are for the year 1996 and thus do not vary over time. Therefore, I also use World Bank Doing Business measures of “Getting credit”: strength of legal rights, depth of credit information index and public registry coverage. These measures are available since 2004.

**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” and is computed using Standard and Poor’s Compustat Northamerica. This database contains financial information of all publicly listed US-based firms. I 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.

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13 Unfortunately, these data are not available for all countries (see Appendix).
14 It is convenient to use US data because (i) this country has the most developed financial market worldwide and (ii) is not included in the sample.
15 The results are equivalent to those in Chor and Manova (2011).
I then calculate a weighted average to match these values to the ten, very broadly defined, industries in the Enterprise Surveys. The surveys also provide the ISIC 3-digit industry classification of firms’ main product line. As a robustness check, I match the Compustat measure to each of those industries using the concordance table provided by the US Census Bureau. As the dependence on external finance measure might be endogenous to investment in technologies, I use asset tangibility as an alternative measure of access to external finance (cf. Manova 2010).

The final dataset includes slightly over 43,000 firm-country-year observations. Descriptive statistics are given in Table XX in the Appendix.

4. Empirics

This section provides an empirical test of the predictions developed in section 2.4. First, I outline the econometric strategy used for identification. Then, I study the impact of cross-country differences in financial market development on export market participation and the missing technology adoption.

4.1. Econometric specification

A difference-in-difference approach. In order to establish causality, I 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. I thus compare firms in the same industry across countries and firms in the same country across industries. From my model follows that firms active in the same industry are more likely to have access to external finance (Prediction 1), export (Prediction 2), and use advanced technologies (Prediction 3) if they operate in a financially more developed country. Similarly, the effect of financial development on firm behavior is more pronounced in industries that depend more on the use of external finance. 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 the use of advanced technologies, and especially so in industries that are more dependent on external finance. This is the difference-in-difference approach first proposed in Rajan and Zingales (1998). The argument is formalized in the following index
where \(X_{ikmt} = \{\text{constr}_{ikmt}, \text{exp}_{ikmt}, \text{ta}_{ikmt}\}\) is a dummy variable equal to one if firm \(i\) active in industry \(k\) in country \(m\) and surveyed in in year \(t\) reports to be financially constrained (Prediction 1), to export (Prediction 2), and to use an advanced technology (Prediction 3). \(\text{Prod}_{ikmt}\) is the logarithm of firm productivity and \(\text{U}_{ikmt}\) is a vector of firm-level controls including \(\text{size}_{ikH}\), \(\text{for}_{ikH}\) and \(\text{skill}_{ikH}\) (Prediction 3)\(^{15}\). These variables are expected to have a negative effect on the probability of being financially constrained (\(\beta_2 < 0\), \(\beta_3 < 0\)) and a positive effect on the incidence of exporting and advanced technology use (\(\beta_2 > 0\), \(\beta_3 > 0\)).

The main variable of interest is the interaction between financial development and external financing needs \(\text{FD}_{mt} \times \text{ExtDep}_k\). It 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, \(\beta_1\) is expected to be positive in the test of Prediction 2 and 3 and negative when testing Predictions 3. A major advantage of this difference-in-difference approach is that it allows to control for country and industry characteristics. This makes the analysis robust to criticism about omitted variable bias. In addition to country and industry dummies \(D_m, D_k\), I include year dummies \(D_t\) to control for the fact that countries have been surveyed in different years.

I estimate equation (13) using a probit model. However, in nonlinear models, the sign and magnitude of the interaction effect depends on the value of the covariates and does thus not necessarily equal the marginal effect of the interaction term. As suggested by Ai and Norton (2003), I therefore estimate a linear probability model in my robustness checks.

**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. The largest firms sell profitably abroad and have an incentive to use advanced technologies. However, these firms are the least likely to be financially constrained. The smallest firms, which most often do not have access to external finance, are not productive enough to serve
the foreign market or to invest in technology adoption. It is thus the firms in the middle of the firm size distribution which are most affected by an increase in financial market development.

In order to study these heterogeneous effects, I define a set of dummies \( q_j, j = 1, ..., 4 \) and a set of triple interactions \( q_j \times FD_{mt} \times ExtDep_k ; j = 1, ..., 4 \). \( q_j \) takes value one if the firm is in the \( j \)th quartile of the firm size distribution. I estimate the following equation:

\[
X_{ikmt} = \beta_1 FD_{mt} \times ExtDep_k + \sum_{j=1}^{4} \beta_j q_j \times FD_{mt} \times ExtDep_k + \beta_2 Prod_{ikmt} + \beta_3 U_{ikmt} + D_m + D_k + D_t + \epsilon_{ikmt},
\]

where \( U_{ikmt} \) now includes the quartile dummies \( q_1, ..., q_4 \) instead of \( size_{ikH} \).

4.2. Results

I now present the results of the empirical test described in section 4.1.

Access to external finance. Table 1 presents the estimation of equation (13) where \( X_{ikmt} \)

<table>
<thead>
<tr>
<th>Dependent variable:</th>
<th>Access to financing</th>
<th>Cost of financing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small</td>
<td>Large</td>
</tr>
<tr>
<td>FD \times ExtDep</td>
<td>-0.004*</td>
<td>-0.007***</td>
</tr>
<tr>
<td>(0.002)</td>
<td>(0.003)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Productivity</td>
<td>-0.013***</td>
<td>-0.008*</td>
</tr>
<tr>
<td>(0.004)</td>
<td>(0.005)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>Size</td>
<td>-0.014***</td>
<td>0.005</td>
</tr>
<tr>
<td>(0.005)</td>
<td>(0.010)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>Foreign</td>
<td>-0.114***</td>
<td>-0.108***</td>
</tr>
<tr>
<td>(0.019)</td>
<td>(0.028)</td>
<td>(0.016)</td>
</tr>
<tr>
<td>No. obs.</td>
<td>12,251</td>
<td>6,167</td>
</tr>
<tr>
<td>Pseudo R²</td>
<td>0.12</td>
<td>0.09</td>
</tr>
</tbody>
</table>

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

is a dummy taking value one if the firm reports to be financially constrained. This is the test of Prediction 1. In columns (1)-(3) the measurement of financial constraints is based on access to financing and in columns (4)-(6) on cost of financing. Columns (1) and (4) contain the results for the full sample and Columns (2), (3), (5), and (6) divide the sample in small (below median size) and large (above median size) firms. The reported coefficients are marginal effects measured at the mean for continuous regressors.

The coefficient on the interaction term is negative and significant in the full sample whether...
financial constraints are measured by access to financing or cost of financing. Financial
development reduces financial constraints and especially so in industries that depend more
on the use of external finance. As postulated in the theoretical model, this effect is driven
by smaller firms: the effect of the interaction term is weaker in the large firms sample in
columns (3) and (6). The estimated coefficients of the firm-level controls show the expected
signs. More productive, larger and foreign-owned firms are less likely to be financially con-
strained.

Entry into export markets. The empirical test of Prediction 2 is reported in Table 2. Columns

<table>
<thead>
<tr>
<th>Table 2: Entry into the export market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variable:</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>FD × ExtDep</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>$q_2 \times FD \times ExtDep$</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>$q_3 \times FD \times ExtDep$</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>$q_4 \times FD \times ExtDep$</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Productivity</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Size</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>$q_2$</td>
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<tr>
<td></td>
</tr>
<tr>
<td>$q_3$</td>
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<tr>
<td></td>
</tr>
<tr>
<td>$q_4$</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Foreign</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>No. obs.</td>
</tr>
<tr>
<td>Pseudo $R^2$</td>
</tr>
</tbody>
</table>

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

(1)-(3) report the results for the full sample and for the split in small and large firms. The
interaction between financial development and use of external finance has a positive and
highly significant effect in all estimations. Financial market development disproportionately
increases export market participation in industries that have strong external financing needs.
The firm-level determinants of export behavior show the expected sign. More productive,
larger and foreign owned firms have a higher probability of exporting. This is in line with existing studies of firms’ export behavior.

Column (4) presents the analysis by quartile of the firm size distribution. The dummy for the first quartile (\(q_1\)) and the corresponding triple interaction (\(q_1 \times FD \times ExtDep\)) have been omitted and serve as a reference group. The interactions with the second, third, and fourth quartile dummies are negative and highly significant at the one-percent level. Financial market development thus has the largest effect on the smallest firms which, at a lower level of financial market development, are not able to profitably serve the foreign market.

*Use of advanced technologies.* Table 3 presents the empirical test of Prediction 3. Columns (1)-(4) report estimations for the full sample, small and large firms, and by quartile of the firm size distribution. Productivity and size have a positive and highly significant effect on firms’ use of advanced technology. The largest firms are indeed the most likely to invest...
in more efficient production technologies. This follows from the coefficients of the quartile dummies in column (4). 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. And a larger fraction of non-production workers makes it easier to adapt more advanced and hence more complex technologies. The estimated coefficient of the interaction term is positive and highly significant in columns (1)–(3). Hence, financial market development increases the likelihood of using advanced technologies and especially so in more financially dependent industries. A higher level of financial development, by increasing firms’ access to external finance, reduces the missing technology adoption and allows previously constrained firms to invest in better technologies. These are the firms in the middle of the firm size distribution. This follows from the coefficients of the triple interactions in the by-quartile analysis. The smallest firms do not have an incentive to pay the high fixed cost of technology adoption and the largest firms have sufficient access to external finance to invest even at lower levels of financial development. These results, together with the results in Table 2, strengthen the assumption of exporting being relatively cheaper than technology adoption made above.

5. Sensivity tests

[...]

6. Conclusion

This paper presents a model of financially constrained firms to derive predictions on the effect of cross-country differences in financial development. Using data from the World Bank Enterprise Surveys, I provide new firm-level evidence on the impact of financial market development on the decision to invest in more efficient production technologies. In particular, I show that barriers to external financing, which follow from a lack of financial development, explain cross-country differences in the use of advanced production technologies. Financial market development thus reduces the missing technology adoption. This has important policy implications as the adoption of more efficient production technologies is considered to be an engine of economic growth.

References

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