Financial constraints and innovation: Why poor countries don't catch up*

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Abstract

We examine how financial constraints affect a firm's innovation and export activities. We test our theoretical predictions using the BEEPS firm survey which provides us with direct measures for innovations and firm-specific financial constraints and with information on shocks to firms' internal funds that can serve as firm-level instruments for financial constraints. Our results confirm that financial constraints play a significant role in explaining innovation, for domestic firms more so than for foreign firms. Furthermore, although innovation and export activities are considered to be complements, for financially constrained firms they may become effectively substitutes. This may help explain why poor countries don't catch up, despite increasing globalization.

JEL classification: O3, O16, F1, G3

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1 Introduction

One of the central questions in economic growth and development is why disparities in income and development across countries are large and persistent, despite increasing globalization. Much of empirical and theoretical research has been developed to identify factors that prevent less developed countries from catching up with developed countries. After decades of research, however, the question continues to puzzle the profession. Most of the difference in income across counties is attributed to differences in productivity which, in words of Zvi Griliches, is a measure of our ignorance. In this paper, we attempt to shed more light onto what determines variation in the level of productivity and hence income across countries by better understanding frictions that prevent firms from innovation.

Our analysis is motivated by several facts. First, in emerging markets and transition economies foreign owned firms tend to be more productive than domestically owned firms and these productivity differences between domestically and foreign owned firms do not seem to diminish over time (see e.g. Blomstrom (1988), Haddad and Harrison (1993), Aitken and Harrison (1999), Estrin et al. (2009)). Second, there is ample macroeconomic evidence (see Levine (2005) for a survey) that development of financial markets is strongly correlated with the development of a country. Although microeconomic channels for this relationship are an area of active research, many aspects of micro-level determinants remain unclear. Third, we know that financial frictions affect investment as well as research and development (R&D) spending made by firms at the microeconomic level (see Hall (2002) and Hall and Lerner (2009) for surveys). Fourth, recent research documents that the level of productivity at a country and firm level is related to trade in general

and to export status in particular (see e.g. Melitz (2003) or Bernard and Jensen (1999)), suggesting that trade liberalization should foster productivity growth.

We reconcile these facts in a stylized theoretical model where firms make decisions about whether to innovate and/or to export given financial constraints faced by the firms. We show that a firm's decision to invest into innovative activities is sensitive to financial frictions which can prevent firms from developing and adopting better technologies. Furthermore, we demonstrate that in a world without financial frictions, innovation and exporting goods are complementary activities. Thus, easing financial frictions can have an amplified effect on firms' innovation effort and consequently the level of productivity. However, as financial frictions become increasingly severe, these activities become effectively substitutes since both exporting and innovation rely on internal financing of firms.

We test predictions of our model using Business Environment and Enterprise Performance Surveys (BEEPS) which covers a broad array of sectors and countries in Eastern Europe and Commonwealth of Independent States (CIS). As we argue below, this data set has a number of advantages relative to data sets used in previous research. Most importantly, BEEPS collects direct measures of innovation and financial constraints so that we do not have to rely on indirect proxies for the key variables in our analysis. In addition, BEEPS provides information on shocks to firms' cash flow and internal funds which we can use as firm-level instrumental variables for our measures of financial constraints. Our preferred econometric results based on instrumental variable estimates unambiguously suggest that innovative activities of firms are strongly influenced by financial frictions. Moreover, we show that domestic firms are more likely to be affected by financial constraints than foreign firms, which helps explain why domestic firms do

not catch up. We also find that financial frictions affect export status and, consistent with our theoretical predictions, the joint incidence of export and innovation activities decreases in the severity of financial constraints. This may explain why the integration of product markets does not necessarily help domestic firms to catch up.

These findings point to clear policy prescriptions. To boost productivity at micro and macro levels, policymakers should focus on developing financial markets that ensure access to external funding for a broad array of firms. Reducing the cost of as well as enhancing access to external finance is likely to lead to more intensive innovation and exporting activities which, in turn, are likely to yield to a rapid development of new goods and technologies and adoption of frontier technologies and practices. Otherwise, costly external funding due to poor access or excessively high interest rates may significantly hamper convergence to the technological frontier.

Our analysis builds on and contributes to three broad strands of previous research. First, we contribute to a large literature documenting effects of financial frictions on R&D expenditures.[1] More recently this literature has started to shift focus on direct measures of innovation rather than indirect ones such as R&D spending. Ayyagari et al. (2007), which is the closest to our analysis, study the determinants of broadly defined innovation (i.e., innovation is not only product and process innovation, but also clos-

[1]Early papers in this literature exploited the idea that a change in available internal funds should not affect investment or R&D expenditure, if firms are not limited in their access to external funds. This hypothesis was tested by examining the sensitivity of investment and R&D spending to cash flow variables in the standard Euler-type investment regressions (The rationale of this approach has been challenged by Kaplan and Zingales (2000)). Himmelberg and Petersen (1994) were the first to find an economically large and statistically significant relationship between R&D expenditure and internal finance for a panel of small high-tech firms. Similarly, Mulkay et al. (2001) compare the cash flow sensitivity of both R&D expenditure and capital investment for US and French firms. They report that cash flow has a much larger impact on both R&D and investment in the US than in France. They also find no significant difference between the sensitivity of investment and R&D expenditure to measures of financial constraints. Bond et al. (2003) compare firm level panel data from the UK and Germany providing evidence that suggests that financial constraints are more relevant for British firms than for German firms.

ing plants, entering a joint venture, obtaining a new licensing agreement and others) using survey data from 47 developing countries. Similar to our results, Ayyagari et al. (2007) find a positive relationship between the use of external finance and the extent of innovation. Apart from considering the interplay between export and innovation, our analysis differs from Ayyagari et al. (2007) by employing finer definitions of innovation and a direct measure of financial constraints, and by using firm-level rather than country level instrumental variables to address potential endogeneity of access to external finance. The latter is important for two reasons. First, using country-level instruments is vulnerable to shocks affecting access to external finance at the country level. Second, firm-level variation dwarfs variation at the country level and hence using country-level instruments may capture only a small fraction of variation. Correspondingly, estimates may be imprecisely estimated and may measure the causal effect only due to country-level variation rather than quantitatively more important firm-level variation. Finally, we also provide a theoretical rationale why access to external finance may matter for innovation, even though most firms report to rely exclusively on internal finance for their innovation activities.

The second strand reports that financial frictions influence a firm's ability to export. For example, Chaney (2005) introduces financial constraints into Melitz (2003) model and predicts that financially constrained firms are less likely to cover the fixed costs of exporting and hence less likely to export. In line with Chaney's predictions, data on bilateral export flows imply that financially more developed countries are more likely to export and that the effect is more pronounced in financially vulnerable sectors (Manova (2008)). Micro-level data studies, which typically rely on firms' balance sheets and income statements to capture financial constraints, also broadly support these predictions.

For instance, Bellone et al. (2008) find that export starters enjoy better financial conditions while Greenaway et al. (2007) and Buch et al. (2009) report that financially healthy firms are more likely to export.[2]

The final strand is the nascent literature investigating the interaction between export and innovation. Most of this literature is theoretical (e.g., Atkeson and Burstein (2007), Constantini and Melitz (2008)) and aimed to show that adoption of new technologies in a country is more likely to occur after trade liberalization. Consistent with these theoretical models, Bustos (2007) finds that new entrants in the export market upgraded technology faster than other firms after trade and capital account liberalization in the early 1990s in Argentina. The dearth of empirical evidence in this literature makes our results particularly useful. We also emphasize in our theoretical model that if financial constraints are severe, innovation and export activities are less likely to be complements but may become substitutes instead.

The paper is organized as follows. Section 2 lays out a stylized model of a firm's decision to innovate and to export when faced with financial constraints. Section 3 describes the data and Section 4 presents the econometric specification. In Section 5 we report the main empirical findings. Section 6 discusses the interaction of export and innovation. Section 7 presents policy implications and concluding remarks.

2 Theoretical Framework

In this section we develop a stylized model to highlight the interaction between financial constraints, innovation and exporting activities. We abstract from many details to

[2]The micro-level evidence however is not unanimous. Stiebale (2008) finds no effect of financial constraints on a firm's export decision once observed and unobserved financial firm heterogeneity is accounted for.

present a clear picture of how these three phenomena are interconnected. We will use this prototypical model to derive a series of falsifiable implications which we will test later in the empirical sections of the paper.

2.1 Basic Setup

Consider an investor who has the opportunity to invest in innovation activities, at a fixed cost F_I.[3] The time structure of events is as follows. At stage 1, the investor decides whether to innovate or not. At stage 2, production takes place. At stage 3, profits are realized.

Since the focus of our analysis is on the impact of financial constraints on the investor's innovation activities, we need to specify in some detail how these activities are financed. We assume that at each stage, uncertain cash flows from previous activities are realized that can potentially be used as internal funds to finance current activities. In addition, the investor can turn to external funding to finance current expenditures. We assume that external funding is more expensive than internal due to asymmetric information problems, i.e. to finance one unit of credit the investor has to pay $\gamma > 1$ while the opportunity cost of internal financing is normalized to 1.

Consistent with the empirical evidence (see e.g. Ughetto (2008)), we assume that to finance innovation at stage 1, the investor has to rely on internal funds from positive cash flows. Intuitively, innovation is an activity which is particularly prone to asymmetric information problems and that cannot be easily collateralized. This rules out using external finance for innovation.

[3] In principle, the innovation can take two forms, as product innovation or as process innovation. For the purpose of our analysis, however, it is not necessary to distinguish these two kinds of innovation. Thus, to fix ideas, we assume that both kinds of innovation increase the firm's profit potential by the same amount.

At stage 2, production needs to be financed. The firm prefers to use internal finance for production, if possible, but needs to turn to external sources, if internal funds are not sufficient. From an ex ante point of view, this is more likely to be the case if the investor has spent internal funds on innovation activities at stage 1, since less internal funds are left at stage 2.

Let π_i denote the profit if no innovation takes place where $i = 0$ if production is financed with internal funds and $i = \gamma$ if it is financed externally. We assume $\pi_0 > \pi_\gamma$. Similarly, let π_i^I denote the profit if the investor has carried out an innovation.

Without loss of generality, we assume that if no investment is made at stage 1, the firm has sufficient cash flow left at stage 2 such that the investor can finance production internally. Thus, from an ex ante point of view its expected payoff is

$$E(\pi) = \pi_0 \tag{1}$$

If the investor spends on innovation at stage 1, production can be financed internally at stage 2 with probability $q \leq 1$, while with probability $(1 - q)$ there is too little cash flow left and external finance has to be used. We can interpret changes in q as liquidity shocks (e.g., nonpayment from customers) experienced by firms. We will use this source of variation later as an instrumental variable. In case of innovation, the ex ante expected profit is

$$E(\pi|I) = q\pi_0^I + (1 - q)\pi_\gamma^I - F_I. \tag{2}$$

We can now determine the investor's incentive to innovate and how this is affected by the cost of external finance. His incentive to innovate is given by the difference in expected profits, $\Delta_I = E(\pi|I) - E(\pi)$.

$$\Delta_I = E(\pi|I) - E(\pi) \quad = \quad \pi_0^I - \pi_0 - (1 - q)(\pi_0^I - \pi_\gamma^I) - F_I. \tag{3}$$

Naturally, a firm decides to innovate if and only if $\Delta_I > 0$. To determine the impact of the cost of external finance, we take the first derivative of Δ_I with respect to γ.

$$\frac{d\Delta_I}{d\gamma} = (1-q)\underbrace{\frac{d\pi_\gamma^I}{d\gamma}}_{(-)} < 0. \tag{4}$$

Note that although innovation is always financed internally, the cost of external finance matters for the innovation incentive. This is due to the fact that external finance may play a role for the production cost and hence for the overall profitability of the firm. Thus, the larger the cost of external finance, i.e. the smaller π_γ, the smaller is the gain from innovating, i.e. the less likely it is that the firm will invest in innovation activities. Importantly, whether financial frictions are binding and whether a firm innovates are determined simultaneously. Furthermore, since innovation reduces the amount of internal funds, it increases the probability of hitting financial constraints and thus one may observe in the data that incidence of innovations and reported severity of financial constraints are positively correlated.

In the next step we examine how the impact of financial constraints is affected by other variables. Consider first the firm's financial status, as captured by the likelihood a firm will need to rely on external finance in stage 2. We find that

$$\frac{d^2\Delta_I}{d\gamma dq} = -\frac{d\pi_\gamma^I}{d\gamma} > 0. \tag{5}$$

Thus, the larger q, i.e. the smaller the likelihood of needing to rely on external finance, the less damaging is the effect of higher cost of external finance on the incentive to innovate. We can use variation in q to uncover the importance financial frictions as a decrease in q amplifies the importance of these frictions.

Consider next how financial constraints matter under different market conditions

which we collect in variable z so that the profit function is given by $\pi(z)$. We focus on z measuring the elasticity of substitution between different products which describes the market power and markup of the firm. This aspect of the model is interesting because the literature offers opposing views on the role of market power for innovation. The mainstream economic theory suggests that competition should lead to more innovations and hence there should be a negative relationship between markups and innovation. The other view is the Schumpeterian theory insisting that firms need resources to innovate and incentives to protect their market power by innovation. Having sufficient resources in part means that firms have enough internal funds to finance innovation activities which could not be collateralized. Thus examining how the sensitivity of innovation to financial constraints varies with market power can provide support for one of the views. In our model, we have

$$\frac{d^2\Delta_I}{d\gamma dz} = (1-q)\frac{d^2\pi_\gamma^I}{d\gamma dz} > 0 \tag{6}$$

if $\frac{d^2\pi_\gamma^I}{d\gamma dz} > 0$ which holds for a variety of different demand specifications. In the appendix, we provide an example with monopolistic competition and show under which conditions this is indeed the case. Intuitively, the less profitable the market, the less damaging is the effect of higher cost of external finance.

Although in this section we focus on innovation as a productivity enhancing activity which cannot be collateralized, we can extend our analysis to other types of activities which cannot be easily collateralized yet lead to improvements in measured productivity. A prominent example of such alternative activities is exporting goods. The sunk and flow cost of exporting goods often do not have a significant material component (e.g., a building or machine) and thus is similar to innovation in this respect. Likewise, exporting goods expands the market size so that overhead costs can be spread more widely and

hence an exporting firm can be more productive. Therefore, one may reasonably use our model to study exporting as well.

2.2 Interaction of export and innovation

In the this section we investigate how financial constraints affect the interaction of a firm's activities that draw on scarce financial resources. For this purpose, consider as a second activity the firm may be interested in the entry of a foreign market. As in Melitz (2003), setting up exporting facilities requires an upfront investment F_E.[4] Let π_i^{IE} denote the profit if both activities are carried out and π_i^E denote the profit if only exporting is chosen as a new activity, with $i = \{0, \gamma\}$, depending on how production is financed.

Since returns to innovation increase in the size of the market, exporting (i.e., entering a new market) makes innovation more attractive. On the other hand, a more productive firm (i.e., a firm which has innovated successfully) gains more from exporting than a less productive firm. Hence, innovation and entering a new market are complements. To capture this pattern, we assume that $\pi_i^{IE} - \pi_i^I > \pi_i^E - \pi_i$, i.e. the incentive to invest in starting export activities is larger if the firm invests in innovation activities as well. Likewise, we assume $\pi_i^{IE} - \pi_i^E > \pi_i^I - \pi_i$. In the appendix, we illustrate that these assumptions hold for a standard model of monopolistic competition.

Consider now the investor's incentive to invest in both, innovation and export. If both activities need to be financed with internal funds, it is even less likely to have internal funds left to finance production than if only one activity is financed. Thus, the

[4]These fixed cost of entering a foreign market are the reason why only the most productive firms are internationally active, because only the most productive firms are able to shoulder the fixed cost of market entry.

expected payoff is given by

$$E(\pi|IE) = q'\pi_0^{IE} + (1-q')\pi_\gamma^{IE} - F_I - F_E \tag{7}$$

with $q' < q$. The incentive to engage in both activities is captured by the following difference in profits.

$$\begin{aligned} E(\pi|IE) - E(\pi) &= [\pi_0^{IE} - \pi_0^I - F_E] + [\pi_0^I - \pi_0 - {}^F_I] - (1-q')(\pi_0^{IE} - \pi_\gamma^{IE}) \\ &> [\pi_0^E - \pi_0 - F_E] + [\pi_0^I - \pi_0 - {}^F_I] - (1-q')(\pi_0^{IE} - \pi_\gamma^{IE}) \end{aligned} \tag{8}$$

The last inequality holds if the two activities are complementary. However, note that the larger are the cost of external finance, i.e. the larger γ, the larger is the negative impact of $(\pi_0^{IE} - \pi_\gamma^{IE})$. Thus, it is theoretically possible to have

$$E(\pi|IE) - E(\pi) = [\pi_0^{IE} - \pi_0^I - F_E] + [\pi_0^I - \pi_0 - F_I] - (1-q')(\pi_0^{IE} - \pi_\gamma^{IE}) \tag{9}$$

$$< [\pi_0^E - \pi_0 - F_E] + [\pi_0^I - \pi_0 - F_I] \tag{10}$$

Hence, not only is complementary effect reduced in case of financial constraints, but it is also possible that if the negative impact of financial constraints is sufficiently large, observed innovation and export could behave as substitutes.

2.3 Empirical predictions

We can now turn to the predictions implied by our theoretical framework. From equation (4) above, we can establish the following hypothesis.

Hypothesis 1 *The more severe the financial constraints (larger γ), as captured by the cost of (or access to) external finance, the less likely it is that the firm engages in innovation or exporting activities.*

Hypothesis 1 is the central prediction of our model. Effectively it states that a drain of internal funds due to financing innovation or export activities, which could be paid only with internal funds, is likely to make other activities (e.g. production or purchases of new machines) more expensive and, therefore, firms may choose to do less innovation and exporting.

From equation (5) and (6), we derive the next two hypotheses.

Hypothesis 2 *The less likely it is that the firm needs to rely on external finance (larger q), the less negative is the impact of financial constraints on the firm's innovation activities.*

Hypothesis 2 suggests that financial constraints are likely to become more acute when firms are more likely to run into them. In other words, if we observe liquidity or payment shocks, firms are likely to become more sensitive to financial constraints and are more likely to report that they are financially constrained.

Hypothesis 3 *The larger the elasticity (the smaller the mark up), the less negative is the impact of financial constraints on the firm's innovation activities.*

Hypothesis 3 contends that firms with more market power should be more sensitive to financial constraints, because they have a larger incentive to innovate and hence are more likely to report being financially constrained.

Finally, taking into account the firm's decision to enter foreign markets, we derive the following hypothesis.

Hypothesis 4 *The more severe the financial constraints experienced by a firm, the less complementary are the observed innovation and export activities, i.e. the relatively less the firm chooses both types of activities rather than only one of them.*

According to Hypothesis 4, activities competing for the same internal funds become substitutes as internal funds become scarcer even when these activities are complements in absence of frictions.

3 Data

To test the predictions outlined in the previous section, we use data from the 2002 and 2005 Business Environment and Enterprise Performance Survey (BEEPS), a joint initiative of the European Bank for Reconstruction and Development (EBRD) and the World Bank Group. These are large surveys of 6,500 firms in 2002 and 7,900 firms in 2005 in 27 transition countries.[5] An important feature of this data set is the inclusion of firms in the service sector, which is the new dynamic (yet understudied) sector in these economies. The surveys relied on the same sampling frames and used identical questionnaires in all countries. To ensure that the samples are representative of the relevant population of firms, the surveys used stratified random sampling. For example, in each country, the sectoral composition of the sample in terms of manufacturing versus services was determined by their relative contribution to GDP.[6] Firms that operate in sectors subject to government price regulation and prudential supervision, such as banking, electric power, rail transport, and water and waste water, were excluded from the sample. The sample includes very small firms with as few as two employees and

[5]In both years the surveys were administered to 15 countries from Central and Eastern Europe (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Serbia and Montenegro, Macedonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovak Republic, and Slovenia), 11 countries from the former Soviet Union (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Ukraine and Uzbekistan) and Turkey. In neither year could the survey be administered in Turkmenistan. Our estimation sample includes only about 11,500 firms due to missing observations on variables on interest.

[6]Manufacturing includes: Mining and quarrying, construction, manufacturing and agro-processing. Services includes: Transportation, storage and communications; wholesale, retail, repairs; real estate, business services; hotels and restaurants; other community, social and personal activities; and commerce.

firms with up to 10,000 employees. Moreover, the data include firms in the rural areas as well as large cities. Hence these data enable us to analyze diverse firms in a large number of countries. In addition, the data set contains a panel component, where 1,443 firms that were surveyed in 2002 were surveyed again in 2005.[7] While we use these panel data for robustness checks, our analysis relies primarily on the pooled 2002 and 2005 data since many variables of interest have a retrospective component in each survey date and because it is hard to detect robust relationships with a small panel of heterogeneous firms, especially when we use many control variables.

In addition to basic information about firm characteristics such as age, employment size and composition, and degree of competition, BEEPS collects information on self-reported measures of access to finance. Specifically, firms are asked to report on a 1 ("No obstacle") to 4 ("Major obstacle") scale how problematic access to financing (e.g., collateral required or financing not available from banks) is for the operation and growth of the firm's business. Similar information is collected for the cost of financing (e.g., interest rates and charges).

An important advantage of our data is that firms self-report various types of innovation activity. Hence, we are able to define innovation broadly as the development and upgrading of new products or adoption of new technologies. Specifically, we use binary variables based on answers to the question about whether firms have undertaken any of the following initiatives in the last three years: Developed successfully a major new product line or upgraded an existing product line - hereafter New Product; acquired new production technology – hereafter New Technology. These measures of innovation are an

[7]The relatively small size of the panel should not be associated with intensive exit of firms in these countries. The exit rate was about 8% (average across countries). The size of the panel is mainly brought about by a refusal of firms to participate in the new wave of the survey (42%) and inability to reach eligible responders within firms (25%).

improvement over the more commonly used measures of patents and R&D expenditures. Patents are generally viewed as having three weaknesses: 1) they measure inventions rather than innovations; 2) the tendency to patent varies across countries, industries and processes; and 3) firms often protect their innovations by using methods other than patents (maintaining technological complexity, industrial secrecy, and lead time over competitors). Using R&D expenditures may also be inappropriate because not all innovations are generated by R&D expenditures, R&D does not necessarily lead to innovation (it is an input rather than output), and formal R&D measures are biased against small firms (see e.g. Michie (1998), Archibugi and Sirilli (2001)). More important from the point of view of this paper is that these types of innovations are less likely to be observed in emerging market economies. Domestic firms are expected to engage more in imitation and adaptation of already created and tested technologies, rather than generating new inventions or expending resources on R&D. This is substantiated in our data where the vast majority (75%) of firms who answered that they acquired a new technology said that it was embodied in new machinery or equipment that was purchased or licensed from other sources. Only 17% said the technology was developed by the firm. Perhaps most importantly, the measures we use capture management innovations, which can be argued to be more important than inventions for improving a firm's competitiveness and efficiency.

To complement our analysis of innovation, we also consider two additional measures of innovation. First, we construct a dummy variable equal to one if a firm reports positive R&D spending and zero otherwise. We prefer using this measure of innovation to the volume of R&D spending because the distribution of R&D spending is highly skewed with a large mass of firms reporting zero R&D expenditures. Unfortunately, few

firms answer the question about R&D spending so that the sample size with non-missing responses shrinks by approximately 50%.

Second, we construct a measure of total factor productivity (TFP) which captures the *derived* effect of innovations. We compute TFP using the cost share for labor, material and capital (computed for each firm and aggregated for a given industry in each country and year) and adjust it for capacity utilization (CU):

$$logTFP_{isct} = logY_{isct} - s_{sc}^{L} logL_{isct} - s_{sc}^{M} logM_{isct} - s_{sc}^{K} logK_{isct} - logCU_{isct} \qquad (11)$$

where i, s, c, and t index firms, industries, countries and time, s_{sc}^{L},s_{sc}^{M},s_{sc}^{K} are labor, materials and capital cost shares, Y is sales, L is number of employees, M is the value of materials and K is the replacement value of capital.[8] Since only about one-half of the firms report sales revenue and even fewer report capital, the TFP-measure is available for less than 5,000 firms.

Because we lose so many observations with the R&D dummy and TFP-based measure of innovation, we use these alternative measures only as a robustness check. However, we can use TFP measures to check if self-reported measures of innovation are correlated with objectively measured productivity. Table 1 shows that self-reported measures of innovation are indeed positively related to measured productivity and thus they are meaningful indicators of innovative activities.

4 Econometric Specification

We estimate the following baseline probit specification with the pooled data in the 2002 and 2005 BEEPS for private domestically owned firms (i.e., with no foreign or state

[8]The interpretation of the measured productivity given by equation 11 should be careful. As argued by Gorodnichenko (2007) and others, measured productivity captures the revenue generating ability of firms (which includes both market power and technology level) rather than the technology level of firms.

ownership):

$$\begin{aligned} I_{isct} = \Phi\{\alpha_0 FC_{isct} &+ \beta_1 logL_{isc,t-3} + \beta_2 (logL_{isc,t-3})^2 + \beta_3 Edu_{isc,t-3} \\ &+ \beta_4 Skill_{isc,t-3} + \beta_5 Age_{isct} \\ &+ \beta_6 CMN_{isct} + \beta_7 Markup_{isct} \\ &+ \beta_8 SMNE_{isct} + \beta_9 Import_{isct} + \beta_{10} CU_{isct} \\ &+ \gamma Loc_{isct} + \lambda_s + \eta_c + \psi_t + error\} \end{aligned} \tag{12}$$

where I is a dummy variable equal to one if the firm reported an innovation, and zero otherwise; Φ denotes c.d.f. of a standard normal random variable; i, s, c, and t index firms, industry, country, and time, respectively. For continuous measures of innovation such as TFP we estimate the linear analogue of specification (12) with the same set of regressors. Variables dated with period are taken from retrospective questions about the firm's performance three years prior to the current date. In addition to industry (λ_s), country (η_c) and year (ψ_t) fixed effects, the following variables are included to control for a number of firm-specific factors deemed to be important in the literature:

FC, the main variable of our analysis, is a measure of financial constraints faced by firms. Our theory predicts that α_0 should be negative.

L (the number of employees) and L^2 measure the size of the firm. The argument for including size is that large companies have more resources to innovate and can benefit from economies of scale in R&D production and marketing.

EDU (the share of workers with a university education) and $SKILL$ (the share of skilled workers) capture human capital in the firm. These variables might be expected to be positively correlated with innovation if EDU reflects the involvement

of workers in R&D and more skilled workers ($SKILL$) are able to give feedback to the firm on how to improve a product.

Age of the firm is the log of the number of years since the firm began operations in the country. Two hypotheses are plausible: one suggesting that older firms developed routines that are resistant to innovation and another suggesting that older firms will accumulate the knowledge necessary to innovate. There is evidence for both hypotheses.

Variables CNM and $Markup$ capture competitive pressures. CNM is a dummy equal to one if the firm competes in the national markets and zero otherwise (e.g., when a firm only competes in a regional or local market). We expect CNM to have a positive effect on innovation, given that the firm operates in a larger market. $Markup$ (the price to cost ratio) is used as a proxy to estimate the effect of competition faced by each firm (see e.g., Nickell (1996); Aghion et al. (2005)). Gorodnichenko et al. (2009) show that both $Markup$ and CNM are positively related to the incidence of innovations.

$SMNE$ (the share of sales to multinational enterprises) and $Import$ (the share of imported inputs) capture vertical linkages or transfer of capabilities. Presumably exposure to foreign firms and markets is likely to stimulate more innovation as foreign firms and markets are likely to have better technologies, practices and products.

Location (*Loc*) is a set of dummies for size of population where the firm is operating or headquartered. This will control for potential differences in knowledge available in larger v. smaller cities.

Capacity Utilization (CU) is the percentage of a firm's output relative to maximum possible output. Although capacity utilization has been found to be a strong predictor of innovations (e.g. Becheikh et al. (2006)), the effect of CU on innovation is a priori indeterminate. If firms are too busy filling demand, they may be more interested in extending their current capacity than finding new ways of producing goods and services. At the same time, if firms are at capacity they may need to innovate.

Appendix Tables A1-A3 provide summary statistics for variables used in our analyses.

Estimating specification (12) by ordinary least squares or probit may lead to biased estimates of the key parameter α_0. For example, Canepa and Stoneman (2008*a*) report that firms from high tech industries and small firms in the U.K. are more likely to report a project being abandoned or delayed due to financial constraints. In other words, consistent with our model, firms that intend to innovate are more likely to hit a financial constraint than firms that do not even try. Hajivassiliou and Savignac (2007) make a similar observation based on French survey data. They illustrate the issue by estimating the sensitivity of innovation to financial constraints for two samples of firms: the full sample, which includes all firms, and a restricted sample. In the restricted sample, they include firms that are likely innovators and exclude firms that show no innovation activity despite being not financially constrained. Hajivassiliou and Savignac (2007) find that innovation and financial constraints are positively correlated in the full sample and negatively in the restricted sample. In summary, innovating firms are more likely to hit financial constraints and therefore one may find a positive relationship between financial constraints and incidence of successful innovations.

To correct for this endogeneity bias, we propose using instrumental variables which affect financial constraints but do not (directly) influence the intensity of innovative activities. Exogenous shocks to cash receipts for a firm appear to be a natural candidate as they can be interpreted as shocks to q in our model. Such shocks affect the amount of internal funds as well as attractiveness of firms to external creditors but do not influence innovations directly. This approach contrasts with previous analyses which use split-sample estimation (e.g., Hajivassiliou and Savignac (2007)).

Fortunately, BEEPS collects information about the structure of revenues as well as timeliness of payments from customers and to suppliers. We focus on variables which are most likely to be observed by external creditors and thus are likely to influence access to external finance. Specifically, we will use three variables. The first variable *Overdue* is the dummy variable equal to one if a firm has overdue payments to suppliers. Presumably, overdue payments to suppliers strongly signal that a firm experiences a financial difficulty. Since external creditors may be unable (e.g., due to asymmetric information) to differentiate insolvent vs. illiquid (but solvent) firms, availability of external financing is likely to fall for firms with overdue payments. The second variable $NTPcustomer$ is the share of payments from customers settled by debt swaps or offsets and exchange of goods for goods (barter). The third variable $NTPsupplier$ is the share of payments to suppliers settled by debt swaps or offsets and exchange of goods for goods (barter). Since debt swaps and barter are less likely to provide liquidity, firms engaged in these types of payment settlements are more likely to experience financial constraints.[9]

[9]As Marin and Schnitzer (2002) and Marin and Schnitzer (2005) show for transition economies, firms resort to barter if they are considered not creditworthy. But there is an additional mechanism which can make these types of payments exacerbate financial constraints. As discussed in Gorodnichenko and Grygorenko (2008), debt swaps or offsets and exchange of goods for goods were often employed by management to channel resources away from stakeholders. Since external creditors are particularly vulnerable to these types of looting, they may be more reluctant to provide credit to firms that engage

5 Empirical analysis of innovation

5.1 Productivity gap

We begin our empirical analysis by documenting that foreign owned firms are more productive than domestically owned firms in BEEPS. Table 2 shows that domestic firms are significantly (10 to 20 percent) less productive than companies under foreign ownership and that this productivity gap appears to widen over time, which is consistent with previous studies (see e.g. Sabirianova Peter et al. (2005), Sabirianova Peter et al. (2009)). Likewise we observe that foreign owned firms innovate more intensively than domestically owned firms. This large and persistent gap in measured productivity and innovation intensity is hard to reconcile with extensive reforms taken by BEEPS countries to accelerate growth and catching up with the technological frontier. As we conjecture above, a part of the gap could be explained by differential access of foreign and domestically owned firms to external credit. In particular, foreign firms may face milder financial frictions because they can often borrow in internal markets (e.g. from a mother company) than private domestically owned companies. In the rest of the section, we attempt to test this conjecture.

5.2 Main findings

In this section, we present estimates of equation (12), which tests the main hypotheses described in section 2. Our baseline specification for each measure of innovation is reported in Table 3. In addition to estimated coefficients and standard errors, we also report the elasticity of innovation with respect to financial constraints: $(\partial I/\partial FC)(\overline{FC}/\overline{I})$ where $(\partial I/\partial FC)$ is the marginal effect of financial constraint FC on a measure of inno-

in these forms of settling payments to suppliers and payments from customers.

vation I (evaluated at mean values), and $\overline{FC}$ and $\overline{I}$ are mean values of reported severity of financial constraint and reported innovation respectively. The advantage of using elasticity is that it makes the sensitivity of innovation to financial constraints comparable across regressions since mean innovation rates vary across samples and definitions. Our baseline sample includes only private domestically owned firms.

For all measures of innovation, we consistently find that a binding financial constraint is strongly negatively related to the incidence of innovations, as predicted by Hypothesis 1, according to instrumental variable estimates. At the same, in the regular probit, we do not find any significant relationship between innovations and access to external finance.[10] This pattern sharply contrasts with results in Ayyagari et al. (2007) who find very similar least squares and instrumental variable estimates. However, our estimates are in agreement with our theoretical prediction that endogeneity of innovation and financial constraints will bias estimates upward since more innovative firms are more likely to need external funding and hence more likely to hit financial constraints. Once the endogeneity bias is corrected, we find a strong negative causal effect of financial constraints on innovation. Specifically, the bottom panel of Table 3 shows that the elasticity of innovations with respect to financial constraints implied by estimates in the top panel of Table 3 is in -1.5 to -1 range for developing a new good or adopting a new technology, approximately -2 for the R&D spending, and -0.5 for TFP. These are economically significant magnitudes. For example, an one-standard deviation increase in the severity of financial constraints lowers the probability of a successful innovation by 18 percentage points for developing a new good, 24 percentage points for adopting a new technology, 28 percentage points for positive R&D spending, and 25 percentage

[10]We find similar results for linear probability models. Results are available upon request.

points for TFP.

Note that our instrumental variables have desirable properties such as being strong predictors of the endogenous variable (the F-statistics for the first stage fit is well above 10, a value commonly suggested as a sign of variables to be good instruments) and orthogonality to the error term (the p-value of the over-identifying restriction test is routinely above any standard significance level). We report first stage estimates in Appendix Table A4. Consistent with predictions of economic theory, positive $Overdue$, $NTPcustomer$ and $NTPsupplier$ raise the severity of financial constraints. However, $Overdue$ appears to be the strongest predictor of financial constraints.

There are a number of interesting findings with respect to the control variables in Table 3. First, larger firms tend to innovate more than smaller firms, which is consistent with the finding in the vast majority of studies on innovation (see e.g., Becheikh et al. (2006) and the Schumpeter (1943)) hypothesis. The size effect is concave for both types of innovations. Second, the effect of human capital varies by how it is measured. Having a higher share of skilled workers does not affect the probability of developing a new product and acquiring new technology. On the other hand, as the share of workers with a university education rises, all types of innovation are boosted. These findings stress the need for a highly educated labor force to improve the capabilities of the product or service. Third, older (more mature) firms are not as likely to innovate with respect to product and technology as new firms. Fourth, firms that compete/operate in national markets are more likely to innovate in any of the three areas than firms that only compete/operate in a local or regional market. This may reflect both the capability of the firms operating in the larger national market, as well as the characteristics of the national as opposed to local environment. Fifth, lower competition, proxied by markup, has a

positive effect on innovation, which is consistent with the results in Carlin et al. (2006) and Gorodnichenko et al. (2009) who use a similar econometric framework. Sixth, consistent with Gorodnichenko et al. (2009), linkages to foreign firms ($SMNE$ and $Import$) are positively associated with the success of innovation. Finally, more intensive capacity utilization is associated with less intensive innovative activities.

5.3 Analysis of subsamples

To investigate possible heterogeneity of causal effects of financial constraints on innovation across types of firms, we re-estimate specification (12) for a series of sub-samples. In these sample splits, we focus only on the incidence of acquiring new technology and developing a new good since for these two measures of innovation we have the largest number of observations. For two other measures of innovation (TFP and positive R&D spending), we have too few observations for certain cells which makes statistical analysis imprecise and sensitive to a handful of observations. Table 4 reports our results for various sub-samples which differentiate firms by sector, age, size, ownership, region and level of competition and debt.

First, by and large the strength of the causal effect is somewhat larger for service than for manufacturing, although in many cases we cannot reject the null of equality for these two sectors. The stronger responses for services probably reflect the fact that it is easier for firms in the manufacturing sector to collateralize (e.g., pledge a new piece of equipment as collateral for a loan) borrowing from external creditors than for firms in the service sector which tends to be more intensive in labor and possibly intangible assets such as loyalty of customers and customer base.

Second, we also find that new firms are more sensitive to financial constraints than

old firms. This finding is consistent with the idea that new firms may have shorter credit history which makes access to external financing harder and that they have had less opportunities to accumulate internal funds and hence need to rely more on external finance, which is in agreement with Hypothesis 2. Our finding is also consistent with previous studies (e.g., Brown et al. (2009)) reporting that R&D spending of mature firms is much less sensitive to cash flow and external equity than that of young firms.

Third, the strength of the response strongly varies with the firm size. Small firms (2 to 10 employees) have the elasticity of innovation with respect to financial constraints two to three times larger than the elasticity of large firms (100 and more employees). This result is consistent with many previous studies documenting that small firms are more likely to experience lack of external funds and several informational frictions than large firms (see e.g. Harhoff (1998), Canepa and Stoneman (2008*b*) and Ughetto (2008).

Fourth, the sensitivity can also vary with the level of development of financial markets. Generally, more developed financial markets are more likely to overcome asymmetric information and other impediments for access to external credit. To examine this hypothesis, we split countries into four regions commonly used in the analysis of Eastern European and CIS countries: Central European and Baltic countries which became new EU members; South-East European (SEE) countries (mainly Balkans); Western CIS (WCIS) countries (Belarus, Russia, Ukraine); Eastern CIS (ECIS) countries (Caucasus and Central Asia). The ranking of financial market development typically runs from new EU members (most developed) to SEE to WCIS to ECIS (least developed). Therefore, we should expect that the sensitivity of innovation to financial constraints should be the lowest in new EU member countries and the highest in the Eastern CIS countries. Our results strongly support this prediction. We find a relatively monotonous increase in

sensitivity as we move from more to less financially developed economies.[11]

Fifth, it is possible that the sensitivity to financial constraints varies across industries with the level of debt and market power in the industry. We split all industry-country-year cells into high debt (high markup) and low debt (low markup) groups according to the average level of debt (markup) in the industry. If an industry-country-year cell is above the mean across industries, we classify this cell as high debt (high markup) industry.[12] Information of the level of debt We find no discernable difference in the sensitivity of innovation to financial constraints for high and low debt industries. This finding suggests that the sensitivity to financial constraints is mostly determined by firm rather than industry characteristics. This finding can also mean that observed level of debt and access to external credit are jointly determined in such a way that a high level of debt is positively correlated with financial constraints.

On the other hand, we find that innovations in high markup industries tend to exhibit stronger sensitivity to financial constraints than innovation in low markup industries. As we have observed above in the discussion of coefficients on control variables, we do find that firms with more market power tend to innovate more. Thus, they are more likely to report hitting a financial constraint. However, these differences are not statistically significantly different from zero and therefore we have only partial support for Hypothesis 3 in our theoretical predictions.

Finally, we re-estimate specification (12) for state owned and foreign owned firms. Both types of firms are less likely to experience financial constraints since they can

[11]Our ranking of the countries is also consistent with the ranking of venture capital deals across countries, as documented by e.g. VentureXpert. Specifically, new EU member countries have the largest number of venture capital deals while ECIS countries have the lowest.

[12]Firms were asked to report their debt only in 2002 wave of BEEPS and, consequently, we use only 2002 wave to classify industries into low and high debt industries. We use both 2002 and 2005 waves of BEEPS to classify industries in low and high markup industries.

borrow funds internally either from an appropriate level of government (directly or using a guarantee from the government) or from a mother company. Therefore, according to Hypothesis 2, we should expect a weaker (if any) effect of financial constraints on innovation.[13] This conjecture is supported by our results: only state owned firms exhibit some sensitivity to financial constraints when we measure innovation as the incidence of acquiring a new technology; in all other cases, we find no significant sensitivity. In particular, foreign firms do not show to be financially constrained in their innovation activities. Thus, we can identify financial constraints as one important reason for why domestic firms innovate less than foreign firms do, why domestic firms are less productive than foreign firms and why they do not catch up over time. In short, our analysis suggests that one important channel leading from financial constraints to unsatisfactory firm performance is the lack of innovation activity.

5.4 Robustness checks

Financial constraints can have many dimensions. Typically, financial constraints are measured along (i) whether firms have access to external credit and (ii) the price firms have to pay for external credit if they have access to it. We have focused on whether firms have access to credit. In Table 5, we examine if our results also extend to the price of credit. We use the self-reported measure of the cost of financing which runs on 1 ("No obstacle") to 4 ("Major obstacle") scale. We find that results are largely the same as for the access to credit and thus we do not report all sample splits to preserve space.

In another robustness check, we examine if additional instrumental variables affect our estimate of innovation sensitivity to financial constraints. Specifically, we use a dummy

[13]For example, Harrison and Mcmillan (2003) report for firms in Côte d'Ivoire that domestic firms are more credit constrained in their investment than foreign firms.

variable which is equal to one if a firm had to resolve non-payment from customers in court. As shown in Table 5, we find results similar to our baseline.

6 Interaction of export and innovation

Previous research documents that financial constraints affect the export status of firms (see Berman and Héricourt (2008), Buch et al. (2009), Bellone et al. (2008), Greenaway et al. (2007)). It is also firmly established that exporting firms have higher level of productivity and innovate more than non-exporting firms (see e.g. Aw and Hwang (1995), Bernard and Jensen (1995), Bernard and Jensen (2004)), Bernard and Wagner (1997)).[14] However, the interplay between how exporting firms acquire these advantages over non-exporters is less clear. Causation may flow from export status to productivity (e.g., due to learning by doing as argued in Grossman and Helpman (1991), World Bank (1991) and World Bank (1993)) or from productivity to export status (e.g., Melitz (2003)). In this section, we try to tie together effects of financial constraints on export status and productivity differences and shed new light on the direction of causation in the export-productivity link.

Our theoretical model suggests that measured productivity and innovation are jointly determined with export status. Furthermore, export status and innovation depend on whether a firm faces financial constraints. Specifically, for mild financial constraints, it is always optimal for firms to engage in both exporting and innovation since both activities are complementary. However, for sufficiently binding financial constraints, the activities become substitutes. Intuitively, both activities must rely on internal financing since neither activity can be collateralized. With mild financial constraints, both activities

[14]For a survey of empirical studies on this issue see Wagner 2000.

can be funded with internal resources and since one activity reinforces the other it is optimal for firms to do both activities. With a binding financial constraint, only one activity can be funded and, hence, export and innovation become substitutes. In what follows, we examine formally this testable implication of our theoretical model.

Table 6 reports the estimates for specification (12) where we replace innovation dummy with an export dummy. In our analysis we consider two measures of export status. The first is the dummy variable ($Export$) equal to one if a firm exports any of its goods directly or indirectly and zero otherwise. The second is the dummy variable ($ExportNew$) equal to one if a firm has started to export in the last 3 years and zero otherwise. Consistent with the fact that starting new export involves larger expenses than maintaining export status (Das et al. (2007)), we find that $ExportNew$ is more sensitive to financial constraints than $Export$. Thus, consistent with previous work, we confirm that exporting is affected by financial constraints.

To study the interplay between export and innovation, we construct two additional variables. The first variable ($E\&I$) is the dummy variable equal to one if a firm both exports and innovates. The second variable ($EorI$) is the dummy is equal to one if a firm either export or innovates but does not do both activities. $E\&I$ captures the complementary nature of export and innovation. $EorI$ reflects the substitutable nature of export and innovation. As we discussed above, the incidence of $E\&I$ relative to $EorI$ should be a decreasing function in the severity of financial constraints. This means, in practice, that if we use specification (12) with $E\&I$ and $EorI$ as the dependent variables, the elasticity of $E\&I$ with respect to financial constraint should be greater than the elasticity of $EorI$ with respect to financial constraint. We look for this pattern by

estimating the $E\&I$ and $EorI$ regressions separately (i.e. IV probit for each regression).[15] We find that the elasticity for $E\&I$ is 3 to 5 times larger in the $E\&I$ regression than it is for $EorI$ in the $EorI$ regression, thus confirming Hypothesis 4. This difference is economically and statistically significant.

This finding clearly indicates that firms may be forced to a suboptimal behavior when financial frictions are severe. In particular, firms may fail to fully materialize gains from complementary export and innovation activities. Inability to jointly innovate and export can considerably slow down technological catching up to the frontier and thus can lead to persistent gaps between domestic firms and foreign firms.

7 Policy implications and concluding remarks

There are a number of policy implications to be drawn from this analysis. First of all, evidence presented in this paper may help to understand why the productivity of domestically owned firms in emerging economies catches up slowly to the technological frontier. Specifically, we argue that domestic firms may find it difficult to finance the innovation necessary to increase their productivity. We also offer a more detailed perspective for policymakers. We document that financial frictions are particularly detrimental for small or young firms. Policies aimed to help these types of firms are likely to have the biggest effect. We also find that firms in the service sector are more sensitive to financial constraints probably because it is harder to collateralize investment and innovation in this sector. Since the service sector has been underdeveloped in emerging market economies and, consequently, there is an acute need to expand the size and quality of the service sector, public policy should provide support to firms in the service sector so that they

[15] We find similar results when we estimate the causal effects joints using bivariate IV probits. Results are available upon request.

can overcome financial frictions and catch us faster to world standard. More broadly, our cross-country analysis of firms' behavior at the micro level strongly indicates that the strength of financial frictions faced by firms is decreasing in the level of development of financial markets. Since financial frictions slow down improvements in technology and the welfare costs of delayed productivity catch up are probably enormous, policy should also be directed toward establishing a framework for deep credit markets and a strong banking sector willing to provide access to external financing for a broad range of firms.

Secondly, financial constraints may force firms to choose between innovation and internationalization strategies, thus losing out on the complementary effects of both strategies. This could explain why domestic firms in emerging economies benefit less from trade liberalization than should a priori be expected. The problem may be that they lack the finance to take advantage of new export opportunities, while being confronted with increased import competition. Thus, the integration of international product markets does not have the desired effects of pushing domestic firms towards the technology frontier if it is not accompanied by complementary financial market reforms.

Although our partial equilibrium analysis provides a number of useful insights, it may miss some general equilibrium effects which can amplify or attenuate factors highlighted in our analysis. For example, foreign multinationals may ease local credit constraints by bringing foreign capital into the economy. On the other hand, to the extent that foreign firms borrow locally, the can crowd out domestic borrowers and exacerbate financial constraints faced by domestic firms (see Marin and Schnitzer (2006) and Harrison and Mcmillan (2003) for further discussion and evidence). We leave analysis of these general equilibrium effects to future research.

8 Mathematical Appendix

Basic Setup

Consider the following example of a firm that is competing in a monopolistic competition environment à la Dixit Stiglitz. Consumers have a preference for variety and hence there are total expenditures E on a diversified bundle of goods. Solving the utility maximization problem of a representative consumer, we can derive derive the demand function for the firm as

$$x = \frac{Ep^{-\sigma}}{P^{1-\sigma}}, \tag{13}$$

where p is the price charged by the firm, P is the price index of all varieties' prices, and σ is the elasticity of substitution.

Firms produce at a constant marginal cost c. If the firm innovates, it reduces this marginal cost to $c' < c$. If production is financed with external funds, the cost of each unit is increased to $\gamma c'$, with $\gamma > 1$. Profits are given by

$$\pi_0^I = px - \gamma c' x - F_I \tag{14}$$

if internal funds are used and π_γ^I if external funds are needed. Firms set prices to maximize their profits. Consider the first order condition

$$\frac{d\pi_0^I}{dp} = x + (p - c')\frac{dx}{dp} = 0 \tag{15}$$

From 13 we can derive

$$\frac{dx}{dp} = -\sigma \frac{Ep^{-\sigma-1}}{P^{1-\sigma}} \tag{16}$$

using the fact that the price index does not change if a single firm changes its price, due to the continuum of firms.

Plugging 16 and 13 into 15, we can solve for the optimal price

$$p = c' \frac{\sigma}{\sigma - 1} \tag{17}$$

Now, using 27 and 13, we can determine the profit as

$$\pi_0^I = \frac{E}{\sigma} \left(\frac{p}{P} \right)^{1-\sigma} \tag{18}$$

Consider next the case where external finance is used. The only difference with respect to π_0^I is that now the constant marginal cost is multiplied by γ and so is the optimal price set by the firm. Hence

$$\pi_\gamma^I = \gamma^{(1-\sigma)} \pi_0^I \tag{19}$$

We can now determine the marginal profit with respect to γ, the cost of external finance.

$$\frac{d\pi_\gamma^I}{d\gamma} = \frac{E}{\sigma} \underbrace{(1-\sigma)}_{(-)} \gamma^{-\sigma} \left(\frac{p}{P} \right)^{1-\sigma} < 0 \tag{20}$$

Furthermore, we can determine how the marginal profit is affected by changes of the elasticity of substitution, σ.[16]

$$\begin{aligned}
\frac{d^2\pi_\gamma^I}{d\gamma d\sigma} &= \frac{-\sigma - (1-\sigma)}{\sigma^2} E\gamma^{-\sigma} \left(\frac{p}{P} \right)^{1-\sigma} + \frac{E(1-\sigma)}{\sigma} \gamma^{-\sigma} \left(\frac{p}{P} \right)^{1-\sigma} [-\ln\gamma - ln(\frac{p}{P})] && (21) \\
&= E\gamma^{-\sigma} \left(\frac{p}{P} \right)^{1-\sigma} \left[-\frac{1}{\sigma^2} + \frac{\sigma - 1}{\sigma} (ln\gamma + ln(\frac{p}{P})) \right] && (22) \\
&= E\gamma^{-\sigma} \left(\frac{p}{P} \right)^{1-\sigma} \underbrace{\left[\sigma(\sigma-1)(ln\gamma + \ln(\frac{p}{P})) - 1 \right]}_{(a)} && (23)
\end{aligned}$$

[16] For the ease of exposition, we assume here that the ratio p/P does not change with σ, as is the case for symmetric firms.

Thus, for any given $\sigma > 1$ and price ratio p/P we can determine a lower bound of $\gamma > 1$ such that the sign of $a > 0$ and vice versa, for any given $\gamma > 1$ we can determine a lower bound of $\sigma > 1$ for this to hold.

Interaction of export and innovation

To see that our assumptions

$$\pi_i^{IE} - \pi_i^I > \pi_i^E - \pi_i \tag{24}$$

$$\pi_i^{IE} - \pi_i^E > \pi_i^I - \pi_i \tag{25}$$

are reasonable, consider again

$$\pi_0^I = \frac{E}{\sigma}\left(\frac{p}{P}\right)^{1-\sigma} \tag{26}$$

as determined above, with

$$p = c'\frac{\sigma}{\sigma - 1} \tag{27}$$

and π_γ^I likewise.

Note that the firm's profit without innovation differs only in the marginal cost and hence the price to be charged by the firm. Let $c' = \delta c < c$. Then we can write

$$\begin{aligned}
\pi_0^I &= \frac{E}{\sigma}\left(\frac{p}{P}\right)^{1-\sigma} && (28)\\
&= \frac{E}{\sigma}\left(\frac{c'}{P}\frac{\sigma}{\sigma-1}\right)^{1-\sigma} && (29)\\
&= \frac{E}{\sigma}\left(\frac{\delta c}{P}\frac{\sigma}{\sigma-1}\right)^{1-\sigma} && (30)\\
&= \delta^{1-\sigma}\pi_0 > \pi_0 && (31)
\end{aligned}$$

Consider next the firm's payoff in case of exporting. To simplify notation, suppose that the foreign market is symmetric to the domestic market, such that the exporting

firm is now confronted with an increase in demand, represented by an increase in total expenditures $mE > E$. Thus, we can write

$$\pi_0^E = m\pi_0 = \frac{mE}{\sigma}\left(\frac{c}{P}\frac{\sigma}{\sigma-1}\right)^{1-\sigma} \tag{32}$$

and

$$\pi_0^{IE} = m\pi_0^I = \frac{mE}{\sigma}\left(\frac{c'}{P}\frac{\sigma}{\sigma-1}\right)^{1-\sigma} = m\delta^{1-\sigma}\pi_0 \tag{33}$$

Then it is straightforward to see that

$$\pi_0^{IE} - \pi_0^I = (m\delta^{1-\sigma} - \delta^{1-\sigma})\pi_0 = \delta^{1-\sigma}(m-1)\pi_0 > (m-1)\pi_0 = \pi_0^E - \pi_0 \tag{34}$$

and similarly

$$\pi_0^{IE} - \pi_0^E = (m\delta^{1-\sigma} - m)\pi_0 = m(\delta^{1-\sigma} - 1)\pi_0 > (\delta^{1-\sigma} - 1)\pi_0 = \pi_0^I - \pi_0 \tag{35}$$

and similarly for π_γ^{IE}, π_γ^E and π_γ^I.

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Table 1. The link between Solow residual and innovations.

	Total factor productivity (Solow residual)				
	(1)	(2)	(3)	(4)	(5)
New technology	0.038**			0.032*	0.032
	(0.018)			(0.018)	(0.021)
New good		0.036**		0.033*	0.018
		(0.017)		(0.018)	(0.021)
Positive R&D spending			0.145***		0.119***
			(0.024)		(0.026)
Observations	6,861	6,922	4,733	6,829	4,677
R-squared	0.397	0.388	0.433	0.408	0.455

Notes: *Solow residual* measures log total factor productivity computed as log sales minus log capital, log employment, and log material input weighted by cost shares of each input. Total factor productivity is adjusted for differences in capacity utilization. Cost shares are allowed to vary by industry and country. *New technology* is the dummy variable equal to one if the firm reports successful development and/or adaption of new technology and zero otherwise. *New good* is the dummy variable equal to one if the firm reports successful introduction of a new good or service and zero otherwise. *Positive R&D spending* is the dummy variable if the reports positive research and development spending and zero otherwise. Dummy variables for interactions between year, country, and industry are included but not reported. Robust standard errors are in parentheses. ***, **, * denote significance at 0.01, 0.05, and 0.10 levels.

Table 2. Differences in productivity between foreign and domestic private firms.

	all years	2002	2005
	(1)	(2)	(3)
Total factor productivity	0.115***	0.096**	0.135***
	(0.024)	(0.042)	(0.028)
Observations	6,266	2,236	4,030
R-squared	0.158	0.213	0.210
Labor productivity	0.258***	0.245***	0.266***
	(0.022)	(0.038)	(0.027)
Observations	10,587	4,205	6,382
R-squared	0.582	0.501	0.621
New good	0.072	0.073	0.064
	(0.011)	(0.016)	(0.015)
Observations	14,513	5,701	8,812
R-squared	0.073	0.100	0.073
New technology	0.036***	0.029**	0.046***
	(0.011)	(0.015)	(0.015)
Observations	14,395	5,689	8,688
R-squared	0.087	0.095	0.094
Positive R&D spending	0.110***	0.047***	0.146***
	(0.012)	(0.013)	(0.018)
Observations	7,032	2,055	4,977
R-squared	0.538	0.561	0.153

Notes: *Total factor productivity* (*Solow residual*) measures log total factor productivity computed as log sales minus log capital, log employment, and log material input weighted by cost shares of each input. Total factor productivity is adjusted for differences in capacity utilization. Cost shares are allowed to vary by industry and country. *Labor productivity* is computed as log of sales to employment ratio. Fixed effects for year, country, and industry are included but not reported. Robust standard errors are in parentheses. ***, **, * denote significance at 0.01, 0.05, and 0.10 levels.

Table 3. Baseline results.

	New good		New technology		Positive R&D spending		Total Factor Productivity	
	IV probit	Probit	IV probit	Probit	IV probit	Probit	IV	OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Access to finance	-0.421***	0.019	-0.589***	-0.008	-0.721***	0.010	-0.222***	0.006
	(0.090)	(0.012)	(0.068)	(0.013)	(0.077)	(0.026)	(0.066)	(0.007)
Share of sales to MNE	0.130*	0.182***	0.090	0.174**	0.149	0.310**	0.036	0.040
	(0.068)	(0.070)	(0.067)	(0.071)	(0.117)	(0.146)	(0.047)	(0.043)
Share of imported inputs	0.256***	0.235***	0.254***	0.241***	0.263***	0.299***	-0.011	-0.038
	(0.037)	(0.038)	(0.038)	(0.041)	(0.066)	(0.084)	(0.028)	(0.025)
ln(Labor)	0.204***	0.256***	0.228***	0.328***	0.159**	0.333***	0.101***	0.115***
	(0.038)	(0.035)	(0.041)	(0.038)	(0.074)	(0.097)	(0.026)	(0.024)
$\ln(\text{Labor})^2$	-0.019***	-0.021***	-0.020***	-0.024***	0.006	0.010	-0.008**	-0.008**
	(0.005)	(0.005)	(0.005)	(0.005)	(0.009)	(0.013)	(0.004)	(0.003)
Share of skilled labor	0.032	0.031	0.016	0.020	-0.083	-0.142	0.008	0.036
	(0.044)	(0.047)	(0.044)	(0.050)	(0.077)	(0.102)	(0.035)	(0.031)
Share of labor with university degree	0.147***	0.195***	0.120**	0.200***	0.022	0.084	0.073*	0.094**
	(0.053)	(0.054)	(0.055)	(0.059)	(0.095)	(0.128)	(0.043)	(0.039)
Markup	0.229**	0.246**	0.428***	0.523***	0.485***	0.608***	0.023	-0.006
	(0.106)	(0.103)	(0.098)	(0.103)	(0.158)	(0.207)	(0.066)	(0.060)
Log(age)	-0.091***	-0.093***	-0.064***	-0.068***	-0.076**	-0.088**	-0.017	-0.016
	(0.020)	(0.021)	(0.019)	(0.021)	(0.033)	(0.045)	(0.016)	(0.014)
Capacity utilization	-0.349***	-0.244***	-0.382***	-0.263***	-0.460***	-0.382***	-1.369***	-1.303***
	(0.063)	(0.064)	(0.061)	(0.067)	(0.104)	(0.137)	(0.050)	(0.042)
Compete in national markets	0.131***	0.146***	0.191***	0.241***	0.213***	0.356***	0.009	0.007
	(0.034)	(0.035)	(0.037)	(0.037)	(0.069)	(0.076)	(0.022)	(0.020)
Elasticity with respect to access to finance	-1.016***	0.045	-1.650***	-0.021	-1.988***	0.023	-0.492***	0.013
	(0.224)	(0.027)	(0.221)	(0.032)	(0.304)	(0.056)	(0.146)	(0.015)
Observations	10,660	10,660	10,591	10,591	5,263	5,263	4,668	4,668
Over-id p-val	0.663		0.425		0.192		0.295	
1st stage F-stat	58.09		57.17		19.26		28.53	

Note: *Total factor productivity* measures log total factor productivity computed as log sales minus log capital, log employment, and log material input weighted by cost shares of each input adjusted for capacity utilization. Cost shares are allowed to vary by industry and country. *New technology* is the dummy variable equal to one if the firm reports successful development and/or adaption of new technology. *New good* is the dummy variable equal to one if the firm reports successful introduction of a new good or service. *Positive R&D spending* is the dummy variable if the reports positive research and development spending. Robust standard errors are in parentheses. ***, **, * denote significance at 0.01, 0.05, and 0.10 levels. *Over-id p-val* is the p-value for the overidentifying restrictions test. *Elasticity* is the marginal effect divided by the mean value of the dependent variable and multiplied by the mean value of access to finance. *1st stage F-stat* is the value of the F statistic for the hypothesis that instrumental variables have jointly zero coefficients in the first stage regression. Only private domestically owned firms are included in the estimation sample.

Table 4. Sample splits by properties of firms.

	New good			New technology		
	Estimate	Elasticity	Obs.	Estimate	Elasticity	Obs.
	(1)	(2)	(3)	(4)	(5)	(6)
Sector						
Manufacturing	-0.402***	-0.795***	3,628	-0.567***	-1.264***	3,605
	(0.139)	(0.275)		(0.108)	(0.245)	
Services	-0.462***	-1.245***	5,687	-0.736***	-2.816***	5,628
	(0.159)	(0.466)		(0.078)	(0.462)	
Firm age						
New	-0.454***	-1.100***	8,276	-0.653***	-1.895***	8,233
	(0.117)	(0.292)		(0.075)	(0.264)	
Old	-0.387***	-0.926***	2,356	-0.382**	-0.971***	2342
	(0.147)	(0.360)		(0.161)	(0.430)	
Firm Size						
2-10	-0.668***	-1.999***	4,889	-0.766***	-3.162***	4,906
	(0.084)	(0.300)		(0.058)	(0.399)	
11-49	-0.578***	-1.303***	3,349	-0.697***	-1.811***	3,318
	(0.153)	(0.354)		(0.101)	(0.294)	
50-99	-0.423*	-0.854*	986	-0.604*	-1.316*	980
	(0.263)	(0.532)		(0.369)	(0.824)	
100+	-0.381**	-0.728**	1,381	-0.457***	-0.907***	1,380
	(0.185)	(0.355)		(0.173)	(0.344)	
Ownership						
State	-0.209	-0.502	1,831	-0.323**	-0.795**	1,467
	(0.170)	(0.413)		(0.155)	(0.395)	
Foreign	-0.289	-0.504	1,840	-0.297	-0.634	1,824
	(0.290)	(0.505)		(0.271)	(0.591)	
Region						
New EU members	-0.027	-0.068	3,260	-0.335	-0.974	3,238
	(0.244)	(0.606)		(0.242)	(0.773)	
South-East Europe	-0.425**	-0.897**	2,214	-0.572***	-1.467***	2,202
	(0.167)	(0.353)		(0.128)	(0.350)	
Western CIS	-0.810***	-1.793***	2,112	-0.765***	-2.122***	2,094
	(0.104)	(0.238)		(0.122)	(0.404)	
Eastern CIS	-0.886***	-2.557***	2,324	-0.889***	-2.410***	2,310
	(0.049)	(0.178)		(0.046)	(0.167)	
Industries by the level of debt						
High	-0.463***	-0.999***	4,620	-0.661***	-1.679***	4,583
	(0.143)	(0.313)		(0.094)	(0.263)	
Low	-0.399***	-1.049***	6,018	-0.538***	-1.617***	5,980
	(0.120)	(0.331)		(0.095)	(0.343)	
Industries by the level of markup						
High	-0.527***	-1.244***	5,262	-0.688***	-1.904***	5,232
	(0.109)	(0.269)		(0.069)	(0.227)	
Low	-0.341**	-0.839**	5,379	-0.503***	-1.436***	5,337
	(0.141)	(0.354)		(0.112)	(0.363)	

Note: *New technology* is the dummy variable equal to one if the firm reports successful development and/or adaption of new technology and zero otherwise. *New good* is the dummy variable equal to one if the firm reports successful introduction of a new good or service and zero otherwise. *Elasticity* is the marginal effect divided by the mean value of the dependent variable (unconditional probability of success) and multiplied by the mean value of access to finance. Robust standard errors are in parentheses. ***, **, * denote significance at 0.01, 0.05, and 0.10 levels. The sample includes only private domestically owned firms unless stated otherwise. Industries with high (low) debt and high (low) markup are defined as industries where the reported level of debt and markup is above (below) average reported across industries and countries. All other sample splits are done at the firm level.

Table 5. Robustness checks.

	New good			New technology		
	Coefficient	Elasticity	Obs.	Coefficient	Elasticity	Obs.
	(1)	(2)	(3)	(4)	(5)	(6)
Financial cost	-0.695***	-1.608***	10,665	-0.502***	-1.222***	10,739
	(0.061)	(0.172)		(0.089)	(0.226)	
Additional instrument	-0.421***	-1.016***	10,660	-0.589***	-1.650***	10,591
	(0.090)	(0.224)		(0.068)	(0.221)	
Fixed effects	-0.227	-1.387	1,542	-0.120	-0.877	1,542
(linear regression)	(0.160)	(0.979)		(0.133)	(0.972)	

Note: *Financial cost* is the self-reported measure of the cost of credit on scale from 1 to 4. *Alternative instrument* is based on being plaintiff and resolving overdue payments (combine with overdue payments to supplier). The fixed effects regression in the probit specification has similar results but the estimates are not consistent in probit with fixed effects. *New technology* is the dummy variable equal to one if the firm reports successful development and/or adaption of new technology and zero otherwise. *New good* is the dummy variable equal to one if the firm reports successful introduction of a new good or service and zero otherwise. *Elasticity* is the marginal effect divided by the mean value of the dependent variable (unconditional probability of success) and multiplied by the mean value of access to finance. Only private domestically owned firms are included in the estimation sample except for the foreign and state owned firms. Robust standard errors are in parentheses. ***, **, * denote significance at 0.01, 0.05, and 0.10 levels.

Table 6. Financial constraints, export and innovation.

	Export			Start new export		
	Coefficient	Elasticity	Obs.	Coefficient	Elasticity	Obs.
	(1)	(2)	(3)	(4)	(5)	(6)
Export	-0.282**	-0.682**	10,596	-0.429***	-1.081*	10,174
	(0.126)	(0.351)		(0.137)	(0.617)	
Export AND new good	-0.589***	-2.303**	10,613	-0.665***	-3.765**	10,174
	(0.095)	(0.901)		(0.082)	(1.744)	
Export AND new technology	-0.764***	-5.110***	10,495	-0.746***	-5.880***	10,152
	(0.045)	(1.144)		(0.059)	(2.191)	
Export OR new good	-0.334***	-0.795***	10,636	-0.457***	-1.139***	10,182
but not both	(0.096)	(0.232)		(0.083)	(0.216)	
Export OR new technology	-0.384***	-0.981***	10,543	-0.449***	-1.218***	10,108
but not both	(0.092)	(0.245)		(0.089)	(0.262)	

Note: *Export* is the dummy variable equal to one if the firm reports positive export sales and zero otherwise. *Start new export* is the dummy variable equal to one if the firm started exporting goods over last three years and zero otherwise. *New technology* is the dummy variable equal to one if the firm reports successful development and/or adaption of new technology and zero otherwise. *New good* is the dummy variable equal to one if the firm reports successful introduction of a new good or service and zero otherwise. *Elasticity* is the marginal effect divided by the mean value of the dependent variable (unconditional probability of success) and multiplied by the mean value of access to finance. Only private domestically owned firms are included in the estimation sample. Robust standard errors are in parentheses. ***, **, * denote significance at 0.01, 0.05, and 0.10 levels. Over-id p-val is the p-value for the overidentifying restrictions test.

Appendix Tables

Appendix table A1. Descriptive statistics.

	Mean	St.Dev.
Innovation Variables		
New Product	0.562	0.496
New Technology	0.302	0.459
Positive R&D spending	0.370	0.482
Total factor productivity	1.668	0.710
Vertical Transfer of Capability		
Share of sales to MNEs	0.066	0.196
Share of imported inputs	0.258	0.359
Controls		
ln(Labor)	3.000	1.604
ln(Labor)^2	11.577	11.530
Share of skilled workers	0.487	0.309
Share of workers with university education	0.272	0.290
Log(age)	2.367	0.777
Compete in national markets	0.667	0.471
Markup	0.209	0.118
Capacity utilization	0.794	0.177
Location		
Capital	0.313	0.464
Other, over 1 million	0.060	0.237
Other, 250,000-1,000,000	0.157	0.364
Other, 50,000-250,000	0.224	0.417
Under 50,000	0.241	0.428

Appendix table A2. Unconditional probabilities of innovation.

	New technology (1)	New good (2)	R&D expenditure (3)
Sector			
Manufacturing	0.492	0.431	0.431
Services	0.314	0.227	0.302
Firm age			
New	0.300	0.375	0.336
Old	0.329	0.372	0.459
Firm Size			
2-10	0.207	0.298	0.188
11-50	0.333	0.395	0.351
51-100	0.376	0.440	0.450
100+	0.430	0.459	0.695
Ownership			
Private domestic	0.299	0.366	0.307
State	0.309	0.320	0.561
Foreign	0.352	0.463	0.582
Region			
New EU members	0.262	0.357	0.355
South-East Europe	0.361	0.456	0.353
Western CIS	0.322	0.417	0.500
Eastern CIS	0.326	0.314	0.309
Industries by the level of debt			
High	0.359	0.439	0.418
Low	0.266	0.323	0.323
Industries by the level of markup			
High	0.320	0.389	0.372
Low	0.290	0.365	0.362

Appendix table A3. Unconditional probabilities of innovation and export status by types of financial constraints.

	Access to finance									
	No obstacle		Minor obstacle		Moderate obstacle		Major obstacle		Total	
	prob.	N obs	prob.	N obs	prob.	N obs	prob.	N obs	prob.	N obs
Export										
Export	0.202	3,889	0.212	2,395	0.202	2,900	0.211	2,442	0.206	11,626
Export AND new good	0.097	3,878	0.094	2,391	0.104	2,898	0.105	2,439	0.100	11,606
Export AND new technology	0.081	3,848	0.090	2,375	0.084	2,883	0.078	2,418	0.083	11,524
Export OR new good but not both	0.351	3,878	0.392	2,391	0.372	2,898	0.401	2,439	0.375	11,606
Export OR new technology but not both	0.331	3,848	0.338	2,375	0.346	2,883	0.357	2,418	0.342	11,524
Start new export										
Export	0.093	3,774	0.099	2,328	0.096	2,791	0.103	2,283	0.097	11,176
Export AND new good	0.056	3,765	0.048	2,325	0.060	2,788	0.056	2,281	0.055	11,159
Export AND new technology	0.046	3,736	0.047	2,306	0.050	2,773	0.042	2,258	0.046	11,073
Export OR new good but not both	0.322	3,765	0.365	2,325	0.352	2,788	0.391	2,281	0.352	11,159
Export OR new technology but not both	0.290	3,736	0.312	2,306	0.308	2,773	0.324	2,258	0.306	11,073

Appendix table A4. First stage regression.

	New good	New technology	Positive R&D spending	Total Factor Productivity
	(1)	(2)	(3)	(4)
Overdue dummy	0.290***	0.288***	0.295***	0.302***
	(0.031)	(0.031)	(0.042)	(0.046)
NTPcustomer dummy	0.055	0.088	-0.018	-0.172
	(0.122)	(0.121)	(0.169)	(0.184)
NTPsupplier dummy	0.232**	0.206*	0.248	0.395**
	(0.108)	(0.107)	(0.154)	(0.165)
Share of sales to MNE	-0.052	-0.056	-0.042	0.006
	(0.057)	(0.057)	(0.083)	(0.086)
Share of imported	0.146***	0.148***	0.152***	0.159***
inputs	(0.033)	(0.033)	(0.047)	(0.049)
ln(Labor)	-0.041	-0.036	-0.055	-0.064
	(0.027)	(0.027)	(0.040)	(0.044)
$\ln(\text{Labor})^2$	-0.003	-0.004	-0.001	-0.000
	(0.004)	(0.004)	(0.005)	(0.006)
Share of skilled labor	0.011	0.003	0.000	-0.128**
	(0.039)	(0.039)	(0.057)	(0.061)
Share of labor	-0.029	-0.029	-0.007	-0.075
with university degree	(0.045)	(0.045)	(0.067)	(0.073)
Markup	0.038	0.045	0.138	0.114
	(0.088)	(0.088)	(0.115)	(0.125)
Log(age)	-0.024	-0.022	-0.027	-0.009
	(0.017)	(0.017)	(0.024)	(0.026)
Compete in national markets	0.003	0.000	-0.036	0.011
	(0.029)	(0.029)	(0.040)	(0.043)
Capacity utilization	-0.279***	-0.281***	-0.306***	-0.273***
	(0.054)	(0.055)	(0.078)	(0.084)
Observations	10,690	10,622	5,271	4,678
R-squared	0.085	0.085	0.095	0.105

Notes: The table reports the first stage estimation results for estimates reported in Table 3. *Overdue dummy* is the dummy variable equal to one if a firm has overdue payments to suppliers. *NTPcustomer dummy* is the share of payments from customers settled by debt swaps or offsets and exchange of goods for goods (barter). *NTPsupplier dummy* is the share of payments to suppliers settled by debt swaps or offsets and exchange of goods for goods (barter). Only private domestically owned firms are included in the estimation sample. Robust standard errors are in parentheses. ***, **, * denote significance at 0.01, 0.05, and 0.10 levels.