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# R&D AND NON-R&D INNOVATORS DURING THE GLOBAL FINANCIAL CRISIS: THE ROLE OF BINDING CREDIT CONSTRAINTS

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This analysis identifies the effects of prevailing credit constraints on efforts of formal R&D innovators and (informal) non-R&D innovators in the manufacturing sector in Latin America and examines whether the global financial crisis aggravated these effects. It demonstrates that formal R&D innovators faced binding credit constraints that severely disturbed their innovative efforts, while non-R&D innovators remained unaffected. Furthermore, the global financial crisis put no additional strain on either R&D or non-R&D innovators. The analysis also identifies characteristics of R&D and non-R&D innovators and points to important differences in size, age, or ownership structure but similarities in international trading activities.

**JEL classification:** C35, G01, G32, O31

**Keywords:** Credit constraints, R&D and non-R&D innovators, financial crisis, Latin America

## 1. Introduction

Research and development (R&D) activities are one of the key engines of sustained economic growth and development, which puts them high on the policy agenda of all industrialized countries and increasingly of developing countries as well. Thus, concerted efforts are made, and specific science, technology, and innovation (STI) policies are devised and implemented to strengthen nations' innovative potential and technological capabilities and to foster the development and introduction of new or significantly improved products and/or processes.

As inherently uncertain and risky activities, innovative activities absorb substantial resources without guaranteeing that any marketable invention eventually materializes. In the face of insufficient own resources to fund innovative activities, entrepreneurs turn to capital markets to raise funds where they often face insurmountable financing constraints. Given innovators' reluctance to disclose sensitive

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information due to strong appropriability concerns, compounded by the absence of efficient institutions that could provide crucial firm- and project-specific information, the relationship between the debtor and potential outside investors is plagued by strong information asymmetries (Stiglitz and Weiss, 1981), which results in binding financing constraints. Moreover, the need to provide collateral in any credit transaction, but the inability of R&D to act as viable collateral, may also give rise to non-negligible financing constraints (Brown *et al.*, 2010). Hence, innovators may be forced to postpone or altogether abandon their innovative projects, stifling any impetus towards growth and development.

However, the scale and effects of financing constraints tend to differ by the type of innovator. Specifically, among OECD countries, a non-negligible share of firms is found to develop technological and non-technological innovations without carrying out any formal R&D (OECD, 2010). Similarly, Arundel *et al.* (2008) analyzed the 2007 Innobarometer for the EU-27 and demonstrated that slightly more than 50% of all innovative firms did not conduct any formal R&D. An important innovation strategy of these non-R&D innovators is to modify (or customize) products and processes obtained from other firms, which highlights that their innovations tend to be incremental in nature and predominantly new to the firm but not to its market. Furthermore, they stress that even though innovative firms that do not perform formal R&D spend less on innovation, possess poorer innovative capabilities, and are less likely to apply for or receive support from pubic innovation support programs, they are not outperformed—in terms of revenues—by innovative firms with formal R&D activities. Hence, given the particular nature of innovative activities they pursue in terms of degree of novelty, riskiness, scale, or objective and the significantly lower appropriability issues that arise as a consequence, non-R&D innovators are expected to face lower and less binding financing constraints than their formal R&D-based counterparts.

Moreover, in addition to binding financing constraints, both formal as well as non-formal R&D-based innovative activities of firms also sensitively respond to changes in economic conditions and environments in which they operate. Specifically, the recent global financial crisis robbed many entrepreneurs of the financial means to further pursue innovative activities, as global and local demand faltered, sales collapsed, and internal resources quickly melted away. Bereft of internal funds at their disposal, innovators may discontinue their innovative activities

until recovery sets in. However, R&D and non-R&D innovators may respond differently to the crisis. In the light of their significantly higher financial requirements, formal R&D innovators may see the need to discontinue some of their innovative activities, while the significantly lower cost of innovation allows non-formal R&D innovators to continue such activities, despite deteriorating financial market conditions.

In this context, the ensuing analysis focuses on formal R&D as well as non-R&D innovators and sheds light on (i) the presence and (ii) the effects of binding credit constraints as well as (iii) the effects of the global financial crisis on the two different types of innovators. It focuses on Latin America, which after Europe and Central Asia was strongest hit by the global financial crisis, and uses firm-level data for a large group of Latin American countries that was collected as part of the World Bank Enterprise Survey (WBES) component of the Latin American and Caribbean (LAC) Enterprise Surveys 2006 and 2010. As such, the study's contributions to the ongoing discussion are manifold. To begin with, it provides the first evidence on the different role of credit constraints for both R&D and non-R&D innovators, a distinction that has thus far been neglected in the literature. Ignoring innovative activities of non-R&D innovators would greatly underestimate the true extent of innovative activities in developing countries, where non-R&D innovators are a prime source of innovations. Secondly, this study explicitly accounts for the global financial crisis and its effects on financial constraints for both R&D and non-R&D innovators. Finally, it takes Latin America as its empirical platform and is therefore able to contribute to the discussion on a quickly developing and technologically vastly improving geographic region that has so far been under-researched in this line of literature.

Empirical findings point to fundamental differences between formal R&D and non-R&D innovators. First, formal R&D innovators face binding credit constraints, which strongly affect their innovative efforts, while non-R&D innovators—whose R&D activities are less resource intensive and risky and more likely the by-product of learning-by-doing—remain unrestricted by credit constraints. Interestingly, the global financial crisis of 2009 did not reinforce the negative effect of credit constraints on either type of innovator. Second, innovative efforts of R&D and non-R&D innovators are associated with entirely different firm characteristics: for *R&D innovators*, there is strong evidence in favor of the Schumpeterian "size-innovation" hypothesis, while his "competition-curbs-innovation" hypothesis finds no empirical

support. Furthermore, group membership—which offers group members easier access to group-internal technical knowledge, human resources, or funds, as well as international trading status, which encourages firms to innovate to maintain or gain a competitive edge over their competitors—proves conducive to formal R&D efforts. In contrast, the probability of performing *non-R&D-based* innovative activities is higher among smaller, more resource-deficient firms, whose innovative activities traditionally focus more strongly on informal activities in the areas of design and market research (Brouwer and Kleinknecht, 1997), and among younger firms with still-underexploited learning-by-doing potentials and deficient know-how. Furthermore, the probability of performing non-R&D-based innovative activities is also higher among firms with higher foreign ownership shares, which together with the insignificant effect for formal R&D innovators, suggests that formal R&D is still mainly home country based, probably due to insufficient indigenous technological capabilities (see, e.g., Belderbos *et al.*, 2013; Blomkvist *et al.*, 2011; Patel and Pavitt, 1991). Finally, international trading status is also conducive to non-R&D innovative activities, which suggests that stronger international competition encourages firms to more strongly pursue informal R&D to innovate and to remain competitive.

The remainder of the paper is structured as follows: section two discusses related empirical evidence on the role of financing constraints on firm-level innovative activities; section three provides an overview and description of the data used in the ensuing analysis; section four presents the empirical methodology used in the analysis; section five presents and discusses results; and finally, section six summarizes and concludes the analysis.

## 2. Related literature

Starting with the influential paper by Fazzari, Hubbard, and Petersen (1988), it has become a dominant procedure to divide samples of firms according to *a priori* measures of financing constraints and to analyze and compare emerging investment-cash flow sensitivities across sub-samples. Greater investment-cash flow sensitivities are then interpreted as evidence of stronger financing constraints. In essence, Fazzari *et al.* (1988) argued that retention practices like low dividend payments are reflective of the costs that external finance firms face: if internal cash flow is insufficient to fully finance planned investment

projects, firms may have to resort to paying low dividends to retain the lion's share of their income. And if external financing is costly, the sensitivity of investment to cash flow should therefore be highest among high-retention firms. However, this approach was heavily criticized by Kaplan and Zingales, who cast serious doubt on the fundamental, underlying assumption that investment-cash flow sensitivities increase monotonically with the degree of financing constraints (Kaplan and Zingales, 1997) and stressed that investment-cash flow sensitivities are bad indicators of financing constraints (Kaplan and Zingales, 2000).

More recently, however, the availability of new and better data that allows a more direct measurement of the presence of financing constraints has given fresh impetus to and revived the discussion regarding the presence and effects of financing constraints on firm investment behavior. Generally, a burgeoning empirical literature finds consistent evidence that prevailing financing constraints act as strong deterrents to R&D activities of firms. In that respect, Mancusi and Vezzulli (2010) used the 2004 Capitalia survey on Italian manufacturing firms to analyze the effects of financing constraints, both on the decision to conduct R&D as well as on the level of R&D investment. They found that the presence of financing constraints reduces the probability of doing R&D by around 23%. Männasoo and Meriküll (2011) reported similar negative effects for a diverse set of developed and transition economies covered by the Business Environment and Enterprise Performance survey (BEEPs). They found a nearly 70 percentage points lower probability that credit-constrained firms conduct R&D. Similarly, Hajivassilou and Savignac (2008) identified and shed light on prevailing direct as well as reverse effects between financing constraints and innovation. They applied a simultaneous bivariate probit framework with mutual endogeneity of financial constraints and innovation decisions of firms and demonstrated that binding financing constraints curtail innovation and that simultaneously, probably due to the higher uncertainty and riskiness innovators face, innovative firms are more likely encounter binding financing constraints. Mohnen *et al.* (2008) used the Dutch CIS 3.5 to study the effects of financing constraints on the probability to abandon, prematurely stop, seriously slow down, or not start an innovative project. They reported that almost every third innovative or potentially innovative firm in their sample felt hampered by one factor or another. They also found supportive evidence that prevailing financing constraints significantly increased the probabilities of prematurely stopping, seriously slowing down, or not starting any innovative project,

while no such effect emerged for altogether abandoning an innovative project. Moreover, prevailing financial constraints tended to reinforce (or, conversely, were reinforced by) other hampering constraints that further increased the likelihood of abandoning, seriously slowing down, or not starting innovative projects. Álvarez and Crespi (2011) have provided comparable empirical evidence in a developing-country setting: their study of some 10,000 Chilean firms in 2007 found conclusive evidence that innovative activities are less likely among financially constrained firms. Finally, the study by Czarnitzki and Hottenrott (2011b), which is most strongly related to our analysis, looked at the effects of financing constraints on different types of R&D investments of German product innovators, differentiating between original inventors who pursue cutting-edge R&D strategies to introduce market novelties on the one hand and imitators who implement routine R&D strategies to introduce products that are new only to the firm but not its market. Their analysis consistently demonstrated that financial constraints are binding restrictions only for original inventors who pursue riskier R&D but unbinding for inventors with routine R&D activities only.

In addition, specific firm characteristics have been found to be pivotal to a firm's decision to perform R&D. For instance, firm size has emerged as a key determinant, in that smaller firms have shown a significantly lower probability of performing R&D (Mancusi and Vezzulli, 2011; Hajivassilou and Savignac, 2008; Männasoo and Meriküll, 2011). However, the study by Álvarez and Crespi (2011) on Chilean firms also highlighted that this size effect is not universal. As shown by Santarelli and Sterlacchini (1990) for Italy, Brouwer and Kleinknecht (1997) for the Netherlands, or Felder *et al.* (1996) for Germany, smaller firms appeared more strongly engaged in informal R&D activities like design or market research and, to a large degree, introduced innovations without much formal R&D. In addition, the likelihood of conducting R&D was also critically associated with firm ownership: as an indication of prevailing centralization strategies of R&D activities, firm group headquarters were more likely to perform R&D (Mancusi and Vezzulli, 2011), while foreign ownership was of little importance (Mancusi and Vezzulli, 2011; Männasoo and Meriküll, 2011). Empirical evidence also has pointed to prevailing complementarities between R&D efforts and tangible investment activities (Mancusi and Vezzulli, 2011), rejected Schumpter's (1934) negative competition-innovation nexus, which rested on the assertion that since competition lowers the expected return from R&D, it tends to curb R&D efforts (Hajivassilou and

Savignac, 2008), or corroborated that exporters (Harris and Maffot, 2011; Männasoo and Meriküll, 2001), firms with a more educated and skilled workforce, or recipients of public subsidies showed a higher probability of conducting R&D (Männasoo and Meriküll, 2011). Likewise, the probability of performing R&D was found to be higher among entrants and younger firms (Huergo and Jaumandreu, 2003) or when sufficient internal resources were available (Álvarez and Crespi, 2011; Männasoo and Meriküll, 2011).

Similarly, the state of the economy strongly matters for a firm's decision to perform formal R&D and innovate. A case in point is the recent global financial crisis, which has strongly reduced the willingness of firms to invest in innovation. Archibugi *et al.* (2012) used the 2009 Innobarometer Survey and emphasized that in Europe, as a result of the crisis, the percentage of firms that increased innovation-related expenditures fell radically from 38% to 9%. In contrast, the percentage of firms that decreased innovation-related investment almost tripled, from around 9% before the crisis to 24% during the crisis. Similarly, business R&D spending dropped substantially during the crisis, though not all OECD countries were affected to the same extent (OECD, 2012). Likewise, findings from the 2010 InnovaLatino Survey[1] highlighted that as a result of the crisis, firms dropped some investments in innovation and that young firms were more likely to discontinue their innovation projects (Fundación Telefónica, 2011).

In addition, consistent evidence is emerging that binding financing constraints are unique to firms with very specific characteristics. In particular, there has been a long-standing debate on whether larger firms, with their superior abilities to generate internal funds, tend to face lower financing constraints. However, empirical evidence appears to suggest that the presence of financing constraints is independent of firm size, at least in a developed-country context (see, e.g., Mancusi and Vezzulli, 2011; Hajivassilou and Savignac, 2008). In contrast, Álvarez and Crespi (2011) in their study on Chilean firms or Czarnitzki and Hottenrott (2011b) in their analysis of the German manufacturing sector supported the negative size-constraint nexus and stressed that larger firms are less likely to be financially constrained. Moreover, there has been some indication that business-group affiliation is associated

1. Conducted by INSEAD and the Development Center of the OECD, this survey polled more than 1,500 manufacturing firms from eight countries, namely Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico, Peru, and Uruguay to shed light on Latin America's tech-readiness.

with lower financing constraints, since firms that are part of a business group are less dependent on external financing but may alternatively tap into internal capital markets and draw from internal group cash-flows and funds to finance their daily business operations as well as tangible fixed-asset and intangible R&D investment projects (Álvarez and Crespi, 2011). In addition, the available level of collateral—typically proxied by tangible assets—lowers the probability of being financially constrained (see, e.g., Álvarez and Crespi, 2011; Mancusi and Vezzulli, 2011). Since banks usually resort to physical assets to secure their loans or credits, asset-rich firms have more disposable means for banks to fall back on, which renders them less risky and therefore more attractive debtors. There is also evidence that firms that lack any alternative internal sources but strongly depend on external funds to finance their operations or projects are more likely to be financially constrained (Mancusi and Vezzulli, 2011). Mancusi and Vezzulli (2011) have also pointed to the potentially critical role of regionally differentiated credit or capital markets: probably due to inferior credit markets in the south or center of Italy, firms located in these regions face a higher probability of being credit constrained compared to their counterparts located in the more developed and industrialized north.

## 3. Data

The ensuing analysis applies firm-level data for a large set of Latin American countries comprising Argentina, Bolivia, Chile, Colombia, Ecuador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Peru, Paraguay, El Salvador, Uruguay, and Venezuela that were collected as part of the World Bank Enterprise Survey (WBES) component of the Latin American and Caribbean (LAC) Enterprise Surveys 2006 and 2010.[2] In particular, WBES-2006, which was conducted in calendar years 2006 and 2007 and refers to fiscal year 2005, is used to analyze the period prior to the onset of the global financial crisis, while WBES-2010, which was conducted between calendar years 2010 and 2011 and refers to fiscal year 2009, is used to analyze the crisis period.

The Enterprise Surveys are conducted by means of face-to-face interviews with managers, owners, or directors of establishments on a three- to

2. Officially available panel data are used except for Honduras, Mexico, and Nicaragua for which data on individual survey waves were matched by means of constant panel identifiers. Belize, Brazil, Suriname, and Guyana were excluded from the analysis, since data are available for 2010 only, while Costa Rica was excluded due to incompatibility of data across survey waves.

four-year rotation in order to collect information on the quality of individual firms' business environment, how it is perceived by them and how it changes over time, identifying various constraints or obstacles to firm performance and growth, and capturing the effects a country's business environment has on firms' international competitiveness. It focuses on the private, non-agricultural sector of an economy.

To obtain representative final samples and unbiased estimates, each country sample is selected using random sampling, stratified by size, region, and industry classification. From a sectoral perspective, all manufacturing sectors (group D), construction (group F), services (groups G and H), transport, storage, and communications (group I), and IT (from group K) are covered (based on the ISIC revision 3.1 classification). The primary sampling unit of each survey was an establishment with five or more full-time employees, located in major urban centers, which engaged in non-agricultural activities. This particular sampling methodology generates country samples that are representative of the whole non-agricultural private sector. Furthermore, the standardized sampling strategy and survey instruments used in collecting the data guarantee that survey data from different countries are comparable.

Country samples are adjusted to account for items that elicit non-responses—questions with missing responses—which is a problem the Enterprise Survey shares with other surveys, since some data, particularly accounting data, are considered too sensitive to share. Item non-responses are accounted for by factoring in a rate of 25% for non-responses *per stratum*. This automatically increases the number of necessary interviews but guarantees that enough valid responses are available to compute indicators with the required precision.

In all, 10,930 firms were covered by the WBES-2006 and 9,536 firms by the follow-up WBES-2010. A total of 3,426 firms were covered in both surveys, of which 2,242 manufacturing firms are subject to the ensuing analysis since information on R&D expenditures and the introduction of new or improved products and/or processes are unavailable for the remaining service firms in the sample. As for sample characteristics, around 37% of all manufacturing firms analyzed are either micro or small firms with up to 19 employees, 40% are medium-sized with between 20 and 99 employees, while the remaining 23% are large firms with more than 99 employees. Around 13% of all manufacturing firms are part of a group, while only around 8% are either majority foreign-owned or young. Finally, in terms of trading status, around 8% are exporters only,

around 25% are importers only, while another 10% are both exporters and importers. The remaining 57% of all manufacturing firms have no international trade relations but cater to domestic markets only.

The ensuing analysis seeks to shed light on the effects of prevailing credit constraints on firms' innovative activities. To account for the often neglected but non-negligible role of innovators that do not perform formal R&D, two different groups of innovators are analyzed: so-called *R&D innovators,* which assign resources to R&D development activities performed in-house, as well as *non-R&D innovators,* which do not perform any formal R&D but still introduce new or significantly improved products and/or processes. Hence, in the analysis, R&D innovators refer to all firms in the sample that introduced new or significantly improved products and/or processes and reported positive formal R&D expenditures, while non-R&D innovators refer to all firms that introduced new or significantly improved products and/or processes but reported zero formal R&D expenditures. This sizeable group of non-R&D innovators typically uses occasional, unstructured, and less systematic informal R&D activities (Santarelli and Sterlacchini, 1990) that are not explicitly planned and budgeted and frequently customizes or modifies products and processes obtained from other firms (Arundel *et al.*, 2007) to produce incremental innovations that are predominantly new to the firm but not to its market.

The analysis uses a self-reported credit-constraint indicator ($CC_{ikt}$) to identify whether and to what extent financing constraints affected the probability of being either a formal R&D innovator or a non-R&D innovator, both before and during the global financial crisis of 2009. Specifically, at time $t$ firm $i$ in country $k$ is considered to be credit constrained ($CC_{ikt} = 1$) if it did not apply for loans or lines of credit since either i) application procedures were considered too complex, ii) interest rates were considered too unfavorable, iii) collateral requirements were unattainable, iv) the size of the loan and maturity were insufficient, v) it did not think the credit line would have been approved, or vi) due to other reasons not specified in the survey. In contrast, $CC_{ikt} = 0$ if the firm successfully applied for a line of credit or loan (as reference group).[3] Table A.2 in the Appendix highlights that credit constraints were non-negligible since approximately every fifth firm in the manufacturing sector faced credit constraints.

3. This approach is in contrast to Beck *et al.* (2008), who used a broader Likert-scale-based constraint indicator, reflecting whether financing obstacles affected the operation and growth of firms.

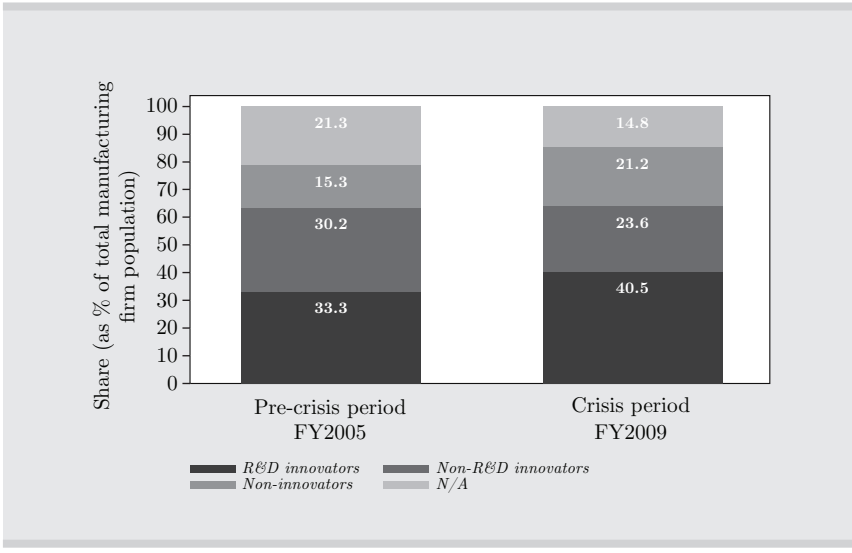
Furthermore, it sheds light on the effects of the global financial crisis regarding the ease with which external funds can be accessed in Latin America. In particular, after the bankruptcy of Lehman Brothers in September 2008, Latin America was quickly drawn into the swiftly and globally spreading crisis. Between 2008 and 2009, growth collapsed the most in Central America (by 6.8 percentage points), followed by South America (with 5.6 percentage points), and the Caribbean (with 1.8 percentage points only) (Savescu, 2014). However, the crisis had a varied effect on Latin American countries, sending many into short-lived recessions only. Mexico, with its strong economic ties with the United States, was hit the hardest by the crisis, followed by Paraguay, El Salvador, and Venezuela, which were hit almost equally hard. In contrast, a number of Latin American countries avoided recessions. With real GDP growth of almost 3.5% in 2009, Bolivia and Guyana weathered the crisis very well, followed by Uruguay, Nicaragua, Suriname, and Panama with real GDP growth of around 2.5% in 2009 (Savescu, 2014). And while the real economy stumbled, no Latin American economy experienced a financial crisis since, thanks to profound central bank and financial market reforms of the 1990s, the region entered the crisis with solid financial fundamentals.

In addition, in the face of the crisis, monetary policies were implemented that helped weather the fierce storms that swept through global financial markets and banking sectors: most Latin American central banks implemented monetary-easing policies to stimulate investments and pave the way for an early and quick recovery; some also provided foreign currency liquidity to the private sector in the form of foreign exchange spot, repo, and swap transactions to avoid any disruptions in foreign exchange markets and to make external financing available (Winograd and Brei, 2009), while others (Brazil, Peru, and Colombia) significantly reduced their (marginal) reserve requirements to mobilize extra capital for additional bank loans (Jara *et al.*, 2009). Overall, the monetary policy mix appears to have been effective since the decline in bank credits in Central and South American emerging market economies was moderate when compared to emerging market economies in Europe (Guo and Stepanyan, 2011).

Figure 1 sheds light on the prevalence of different types of innovators and depicts the shares of formal R&D innovators, non-R&D innovators, and non-innovators in the total sample of manufacturing firms before as well as during the crisis. It highlights that the share of R&D innovators increased from around 33% in 2005 to 41% in 2009. In

contrast, the share of non-R&D innovators declined between 2005 and 2009 from around 30% to only 24%. Hence, there is some indication that firm-level activities that entail lower fixed costs—like activities of non-R&D performers—may more easily be discontinued or postponed once external conditions worsen and demand plunges. In contrast, due to the generally high fixed costs of formal R&D, R&D innovators are less likely and inclined to discontinue their formal R&D activities.

**Figure 1. Share of formal R&D innovators, non-R&D innovators, and non-innovators in manufacturing: Pre-crisis and crisis periods**

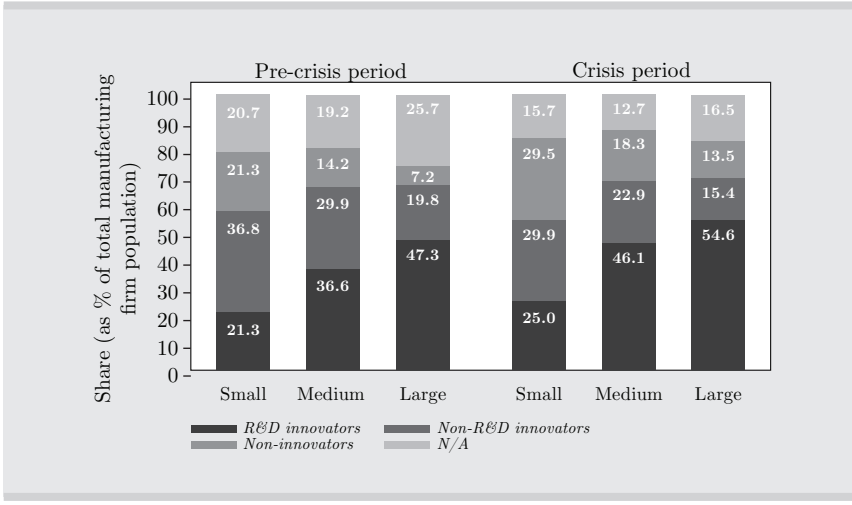



Source: WBES 2006 and 2010, own calculations.
Note: *R&D innovators* refers to firms that reported non-negative formal R&D expenditure and introduced new or improved products and/or services. *Non-R&D innovators* refers to firms that did not perform any formal R&D but still introduced new or significantly improved product and/or process. *Non-innovators* refers to firms that neither performed any formal R&D nor introduced new or significantly improved product and/or process. N/A means to "not available."

Additionally, to shed light on the relationship between firm size and the type of innovator, Figure 2 shows the prevalence of formal R&D innovators, non-R&D innovators, and non-innovators in the pre-crisis and crisis periods by firm size. It highlights that, irrespective of period considered, formal R&D innovators are more prevalent among larger firms, while both non-R&D innovators as well as non-innovators are more prevalent among smaller firms. Hence, in line with empirical evidence for some European countries (Santarelli and Sterlacchini, 1990;

Brouwer and Kleinknecht, 1997; Felder *et al.*, 1996), smaller firms in Latin America also more strongly engage in informal R&D activities.

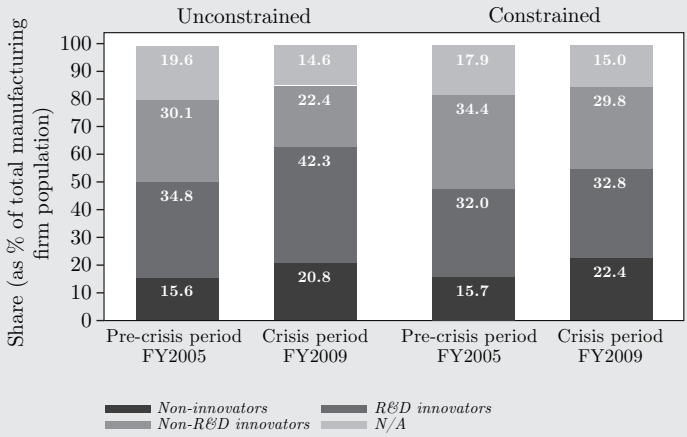
**Figure 2. Share of R&D innovators, non-R&D innovators, and non-innovators in manufacturing by firm size: Pre-crisis and crisis periods**




Source: WBES 2006 and 2010, own calculations.
Note: *Small* refers to firms with up to 19 employees, *Medium* refers to firms with more than 19 but less than 99 employees, and *Large* refers to firms with 99 employees and more. *R&D innovators* refers to firms that reported non-negative formal R&D expenditure and introduced new or improved products and/or services. *Non-R&D innovators* refers to firms that did not perform any formal R&D but still introduced new or significantly improved product and/or process. *Non-innovators* refers to firms that neither performed any formal R&D nor introduced new or significantly improved product and/or process. *N/A* means "not available."

Furthermore, the relationship between credit constraints and the type of innovator is depicted in Figure 3 both for the pre-crisis year of 2005 as well as the crisis year of 2009. It points to important differences between the different types of innovators. First, it stresses that irrespective of period considered, relative to their unconstrained counterparts, credit-constrained firms were more likely to be non-R&D innovators but less likely to be formal R&D innovators. Hence, credit constraints appear to discourage formal R&D innovative activities. Second, it indicates that the effects of credit constraints were stronger during the crisis period, rendering credit-constrained R&D innovators even less likely to pursue formal R&D activities but credit-constrained non-R&D innovators even more likely to innovate without spending on formal R&D than in the pre-crisis period.

**Figure 3 Prevalence of type of innovator by credit constraint: Pre-crisis and crisis periods**




Source: WBES 2006 and 2010, own calculations.
Note: *R&D innovators* refers to firms that reported non-negative formal R&D expenditure and introduced new or improved products and/or services. *Non-R&D innovators* refers to firms that did not perform any formal R&D but still introduced new or significantly improved product and/or process. *Non-innovators* refers to firms that neither performed any formal R&D nor introduced new or significantly improved product and/or process. *N/A* means "not available." Firms face credit constraints if, in a particular year, they did not apply for a line of credit or loan due to one of the following six reasons: i) the application procedure was too complex, ii) interest rates were unfavorable, iii) collateral requirements were too high, iv) size of loan and maturity were insufficient, v) the entrepreneur did not think that loan would have been approved, and vi) other (unspecified) reasons. No credit constraint prevailed if, due to sufficient own capital, the firm did not apply for a loan.

## 4. Credit constraints and the propensity to innovate

Methodologically, a recursive multinomial probit model with endogenous credit constraints is applied to identify whether and to what extent credit constraints affect the probability of being either an R&D innovator or a non-R&D innovator (relative to non-innovators). In particular, *R&D-innovators* refers to innovators that perform formal R&D activities in-house to develop new or modified products and/or processes, while *non-R&D innovators* refers to innovators that do not pursue any formal R&D activities but still manage to develop new or modified products and/or processes. The potential endogeneity of the credit constraint indicator stems from two different sources: first, latent heterogeneous factors (like entrepreneurial behavior) may affect

both the probability of being credit constrained and the probability of being a particular type of innovator, and second, the decision to pursue innovative activities and how to finance them (that is by means of internal or external sources) may be simultaneous. The model is recursive to guarantee coherency of such limited dependent variable models with endogeneity and correlated unobservable error terms, which implies that binding credit constraints are allowed to affect a firm's probability of being innovative while, on the contrary, a firm's innovativeness is not allowed to simultaneously affect its probability of facing credit constraints. This approach therefore differs from the one developed by Hajivassilou and Savignac (2008), who demonstrate that through prior sign restrictions on model parameters, simultaneous bivariate probit models with mutual endogeneity fulfill the traditionally violated coherency condition.

The recursive system is specified as follows, where equation (1) is the outcome equation that explains the probability that a firm is either a formal R&D-innovator or a non-R&D innovator, while equation (2) is the structural equation that specifies the probability that a firm is credit constrained:

$$type^{*}_{ijkt} = \alpha_1 CC_{ikt} + \alpha_2 crisis_t + \boldsymbol{x}_{ijkt}\,\boldsymbol{\beta'} + e_{ijkt} \tag{1}$$

$$CC^{*}_{ikt} = \boldsymbol{y}_{ikt}\,\boldsymbol{\theta'} + \delta_1 crisis_t + u_{ikt}\,, \tag{2}$$

where $type^{*}_{ijkt}$ and $CC^{*}_{ikt}$ are latent variables and $type_{ijkt}$ is an unordered categorical variable that describes whether at time $t$ firm $i$ in country $k$ is either a formal R&D-innovator ($j = 1$), a non-R&D innovator ($j = 2$), or a non-innovator ($j = 0$, as base category). It is linked with its latent counterpart as follows:

$$type_{ikt} = \begin{cases} j \text{ if } type^{*}_{ijkt} = \max(type^{*}_{i1kt}, type^{*}_{i2kt}) \\ 0 \quad \text{otherwise} \end{cases},$$

which implies that the probability of choosing category is given by:

$$P(type_{ikt} = j \Big| \alpha_1, \beta, x_{ijkt}) = \frac{\exp(\alpha_1 CC_{ikt} + \boldsymbol{x}_{ijkt}\boldsymbol{\beta}')}{\sum_{k=1}^{p} \alpha_1 CC_{ikt} + \boldsymbol{x}_{ijkt}\boldsymbol{\beta}' + e_{ijkt}}.$$

Furthermore, $CC_{ikt}$ is a dichotomous variable defined as follows: $CC_{ikt} = 1$ if $CC^*_{ikt} > 0$ and $CC_{ikt} = 0$ otherwise.

Methodologically, since the analysis uses panel data, with all firms being observed twice (once in fiscal year 2005 and then again in fiscal year 2009), panel data techniques are used to shed light on the role of credit constraints for a firm's decision about which particular innovation strategy to pursue. In particular, a random-effects regression approach is used, which explicitly accounts for unobserved firm heterogeneity. In contrast, a fixed-effects regression approach is infeasible since many of the key explanatory variables used in the estimation are time-invariant and would therefore drop in a fixed-effects approach, which uses deviations from the mean to account for unobserved firm heterogeneity.

$CC_{ikt}$ is the main variable of interest. As highlighted above, it is a self-reported credit constraint indicator that is equal to 1 if at time $t$ firm $i$ in country $k$ abstained from applying for a credit since either i) application procedures were considered too complex, ii) interest rates were considered too unfavorable, iii) collateral requirements were unattainable, iv) the size of the loan and maturity were insufficient, v) it did not think the credit line would have been approved, or vi) due to other reasons not specified in the survey, and 0 otherwise. It therefore refers to situations when, due to the above-mentioned reasons, firms are discouraged from applying for credits and is intended to capture the effect of prevailing credit constraints on a firm's probability to pursue a particular innovation strategy. This particular indicator is suited for the analysis as it directly captures the presence of financial constraints and therefore avoids any shortcomings associated with investment-cash flow sensitivities that, following Fazzari *et al.* (1988), have been used traditionally in this line of research. However, as an indicator of subjective perceptions, it is more subjective than other indicators that have been used so far to proxy financial constraints. For instance,

Czarnitzki and Hottenrott (2011a, 2011b) use a standardized credit rating index from Creditreform to capture credit constraints among German firms. This index is particularly informative and relevant as it is also widely used by lenders like banks for loan decisions or suppliers to obtain reliable information on potential business partners, thereby reducing prevailing information asymmetries. Männasoo and Meriküll (2011) likewise use a more objective proxy and identify credit constraints also on the basis of rejected bank loan applications. Moreover, unlike other proxies, ours is not a direct measure of financial constraints for innovative activities. For instance, Álvarez and Crespi (2011), Hajivassilou and Savignac (2008), or Mohnen *et al.* (2008) all used financial constraint indicators that were either considered obstacles to innovation projects or that led to serious delays, abandonment of, or failure to start such projects. However, these financial constraint indicators are again rather subjective and strongly based on perception. Based on the empirical evidence presented in section two on the prevalence of financing constraints among formal R&D innovators in general and the different types of R&D innovators in particular (Czarnitzki and Hottenrott, 2011b) and the very nature of innovative activities of non-R&D innovators in terms of resource intensity, riskiness, scale, or objective, we therefore hypothesize that:

*H1: Credit constraints are harmful to R&D innovators but of little effect for non-R&D innovators.*

$Crisis_t$ is a time-specific dummy variable that is equal to 1 for fiscal year 2009, and 0 otherwise. Since it is included in both equations, it captures (i) whether credit constraints were more prevalent during the crisis, and (ii) how different types of innovators adjusted their innovation strategies to the crisis (relative to non-innovators). Figure 1 above implies that non-innovators and formal R&D innovators became more prevalent, while non-R&D innovators became less prevalent during the crisis. Hence, we expect the following crisis effects on the propensity of being either a formal R&D innovator or a non-R&D innovator:

*H2: The financial crisis has a discouraging effect on non-R&D innovators, rendering them less prevalent.*

Moreover, in one specification, we also test whether the negative effect of credit constraints was significantly stronger during the global financial crisis of 2009. Hence, $CC_{ikt} * Crisis_t$ is also included as an interaction term between the credit constraint dummy and the crisis dummy. As

indicated in Figure 3, the financial crisis tended to further intensify the effects of credit constraints, so we hypothesize that:

*H3: The financial crisis further amplifies the effects of credit constraints, rendering credit-constrained R&D innovators even less likely to pursue formal R&D activities but credit-constrained non-R&D innovators even more likely to innovate without spending on formal R&D.*

Furthermore, $\boldsymbol{x}_{ijkt}$ in equation (1) is a vector of the following firm characteristics:

**Firm size:** Following Schumpeter's (1942) seminal work, a lively debate has erupted concerning the role of firm size for firm innovative activities. Since then, various hypotheses have been suggested supporting Schumpeter's proposition that larger firms are more innovative than smaller ones. In that respect, prevailing *capital market imperfections* may favor larger firms and their superior capabilities to generate internal funds. Specifically, in light of capital market imperfections, smaller firms face restrictive barriers to essential financial resources, while larger firms may still be able to fund their R&D projects from internal funds. Alternatively, Cohen and Klepper (1996) developed a *cost-spreading* argument and emphasize that since appropriability conditions confine firms to exploiting their innovations predominantly through their own output, large firms can typically average the fixed costs of R&D over a greater level of output so that R&D efforts tend to increase with output and firm size. While their specific findings are diverse, Crépon *et al.* (1998), Mancusi and Vezzulli (2011), Hajivassilou and Savignac (2008), and Männasoo and Meriküll (2011) all found a positive relationship between size and the probability of pursuing formal R&D. In contrast, Santarelli and Sterlacchini (1990), Brouwer and Kleinknecht (1997), and Felder *et al.* (1996) stressed that smaller firms appear more strongly engaged in informal R&D activities. Hence, in line with above theoretical considerations and previous empirical insights, we hypothesize that:

*H4: Larger firms are more likely to pursue formal R&D-based innovative activities while, due to their limited resources, smaller firms are more likely to pursue less resource-demanding non-R&D-based, informal innovative activities.*

Firm size is included as a dummy variable for either medium-sized firms (with between 20 to 99 employees) or large firms with more than 99 employees, with the group of micro and small firms with up to 19 employees as reference group.

**Firm age:** As emphasized by Schumpeter (1934), new entrants are vital sources of novel and technologically superior products and processes, which renders younger firms also more likely to be innovative than older ones. Some supportive empirical evidence comes from the study by Huergo and Jaumandreu (2003) for Spanish manufacturing firms at different life stages. This study analyzed the role of age for a firm's probability of introducing process innovations and emphasized that entrants tend to show the highest innovation probability, while older firms have considerably lower innovation probabilities. However, with their still underexploited technical and commercial learning-by-doing potentials, younger firms may initially more strongly rely on informal innovative activities. Hence, we expect the following:

*H5: Younger firms are more likely to pursue non-R&D-based innovative activities than older ones.*

Age is accounted for in terms of the log of age (as the difference between the fiscal year and the year the firm began its operations).

**Firm ownership:** Thanks to easier access to knowledge, human resources, and internal funds[4] together with more effective and widespread risk-diversification strategies, innovative efforts—both formal and informal—may be higher among firms that are either foreign owned or part of a group. Empirical evidence on the role of ownership for the propensity to innovate exclusively focuses on formal R&D only and is rather mixed and inconclusive. With respect to *foreign ownership*, Balcet and Evangelista (2005) found that the propensity to innovate is relatively high among foreign affiliates in Italy (a finding that is, to a great degree, explained by the size and over-representation of foreign affiliates in science-based industries), while Falk (2008) emphasized that the higher propensity to innovate observable among foreign-owned firms is mainly due to differences in firm characteristics (particularly size). Furthermore, with respect to *group membership status*, Frenz and Ietto-Gillies (2007) demonstrated that while the propensity to innovate is not higher among firms that are part of a group, the positive impact on the propensity to innovate observable among UK-based MNCs predominantly stems from multinationality *per se* and not from foreignness. In contrast, no significant differences in the propensities to innovate were found by Johansson *et al.* (2008) in a study on four Nordic countries or Dachs

4. Specifically, as emphasized by Shin and Park (1999) and confirmed by Beck *et al.* (2006), business group affiliation is associated with lower funding obstacles, while Schiantarelli and Sembenelli (2000) and Beck *et al.* (2006) demonstrate that foreign-owned firms indeed enjoy easier access to funds.

and Ebersberger (2009) in a study on Austria. Since, easier access to knowledge, human resources, and internal funds should apply to all innovative firms that are either foreign-owned or part of a group, we hypothesize that:

*H6: Foreign ownership and group membership are both conducive to R&D-based and non-R&D-based innovative activities.*

A dummy variable is included which is 1 for firms that are part of a group and 0 otherwise. Additionally, the percentage of a firm owned by private foreign individuals, companies, or organizations is included to capture the degree of foreign ownership.

**Internationally trading firms:** Firms that move on the international stage and trade products and/or services internationally and consequently face fiercer and more merciless competition may be more inclined to continuously innovate—both formally and informally—to maintain or gain a leading edge over their competitors than purely domestically oriented firms. This perception was corroborated by Harris and Moffat (2011), who stressed that in UK manufacturing and service sectors, exporting increased the probability of spending on formal R&D, and by Männasoo and Meriküll (2011), who analyzed a set of more advanced Central and Eastern European Countries and showed that exporting is associated with a higher propensity to conduct formal R&D. Moreover, internationally trading firms also benefit from their exposure to international technology and the ensuing technology transfer that may take place. This can either take place in a disembodied form, which requires stronger domestic technological capabilities to properly assimilate and utilize foreign technology (see, e.g., Aw *et al.*, 2007), or in an embodied form through investments in productivity-enhancing leading-edge machinery and equipment, which is particularly relevant for technologically lagging economies with underdeveloped or altogether lacking capital goods markets. These considerations should hold for both types of innovators, since (i) fiercer international competition forces both to innovate, and (ii) technology transfer is beneficial to both, to different degrees though since non-R&D-based innovators typically also possess weaker technological capabilities. Hence, we hypothesize that:

*H7: Internationally trading firms that export goods and services and/or import inputs are more likely to innovate and to pursue R&D-based and non-R&D-based innovative activities than firms that cater to or source from domestic markets only.*

For the analysis, instead of lumping internationally trading firms together, the analysis explicitly differentiates between different types of trading firms: firms that are exporters only, firms that are (direct) importers only, and firms that both export and import. Each trading status is captured by means of an individual dummy variable with firms sourcing from or catering to domestic markets only as a reference group.

**Product market competition:** In his seminal work, Schumpeter (1934) advocated a negative relationship between product market competition and R&D, since competition lowers the expected return from R&D and therefore tends to lower R&D efforts. On the contrary, Aghion and Howitt (1999) demonstrated how some model modifications result in a positive relationship between competition and R&D efforts. While empirical evidence is mixed and inconclusive, a postulated negative relationship was found by Horowitz (1962) and Gustavsson and Poldahl (2003), while for a broad sample of developing countries, Ayyagari *et al.* (2007) found that the propensity to innovate is higher, the higher the number of competitors. Others (see, e.g., Scherer, 1967; Levin *et al.*, 1985; and more recently, Aghion *et al.*, 2005) have pointed to an inverted-U relationship between the degree of competition and innovativeness, stressing the conduciveness of a minimum amount of competition but the destructive effects of excessive competition. There is no *a priori* reason to believe that competition affects both types of innovators differently. Hence, in line with the Schumpeterian competition-curbs-innovation hypothesis, we hypothesize that:

*H8: Competition deters innovative efforts, rendering R&D-based and non-R&D-based innovators less likely to be innovative.*

The survey asks respondents to indicate "*for the main market in which this establishment sold its main products, how many competitors did this establishment's main product/product line face? i) None* (taken as a reference group)*, ii) one, iii) two to five, or iv) more than five.*" Correspondingly, three individual dummy variables are included for each response option with 0 as the reference group.

**Informal sector practices:** Competitive pressures may also emanate from the informal sector, which is often a substantial part of the economy, particularly in developing or emerging economies. For example, Vuletin (2008) estimated the size of the informal economy in Latin America and the Caribbean and emphasized that it varies widely among Latin American countries: with around 30% of GDP,

Mexico, Brazil, and Chile have the smallest informal sectors, while Nicaragua and Paraguay have the largest informal economies, with almost 70% of GDP. And while informal sector establishments tend to spend less on formal R&D, they may avail of particular business practices that significantly improve their competitive position *vis-à-vis* formal sector establishments. These informal sector practices may spur innovative efforts—both formal and informal—if they result in higher competitiveness but may also curb such efforts if they prove detrimental to formal establishment performance in terms of, for instance, lower profits. The latter hypothesis is supported by Demirbas *et al.* (2011), who found a detrimental effect of a large or growing informal economy on formal R&D per employee in Turkish SMEs. The role of informal sector practices is accounted for by a Likert-scale variable that captures the response to the survey question whether "*...practices of competitors in the informal sector were 'no obstacle'* (coded 0)*, a 'minor obstacle'* (coded 1)*, a 'moderate obstacle'* (coded 2)*, a 'major obstacle'* (coded 3)*, or a 'very severe obstacle'* (coded 4) *to the current operations of the establishment.*" Hence, based on the limited empirical evidence, we hypothesize that:

*H9: Higher obstacles from practices of competitors in the informal sector are detrimental and render both R&D-based and non-R&D-based innovators less likely.*

**Human capital:** It goes beyond mere speculation that the endowment of firm-specific human capital is pivotal to any R&D efforts. For example, Janz *et al.* (2003) and Männasoo and Meriküll (2011) have demonstrated that firms with higher human capital endowment have a higher propensity to innovate, while Silva *et al.* (2008) emphasized that a lack of qualified personnel significantly reduced the propensity to innovate among Spanish firms. To account for the skill bias in innovation activities, the non-production labor share as the ratio of non-production workers to production workers is included. Since skills are particularly relevant for more systematic, cutting-edge formal R&D activities relative to less organized informal innovative activities, we hypothesize that:

*H10: Firms with more skilled human resources are more likely to purse R&D-based innovative activities while firms with less skilled human resources are more likely to pursue non-R&D-based innovative activities.*

Furthermore, in the absence of any sector characteristics, a set of manufacturing sector dummies is included to account for sector-specific

characteristics,[5] while country characteristics are captured by means of country dummies.

The credit-constrained equation (2) controls for all firm characteristics included in equation (1) plus three exclusion restrictions, such as: (i) the share of working capital financed by internal funds as a proxy for the availability of internal funds and collateral that should render a firm less likely to face credit constraints; (ii) whether a firm currently has an overdraft facility to indicate longer-standing relationships and a stronger reputation with banks; and (iii) the log of sales per employee (in US$) three years ago as a proxy for past productivity. Again, country and industry dummies are included.

However, with respect to relevant determinants of credit constraints, our analysis is unfortunately restricted by data availability. In particular, the Enterprise Survey data we employ lacks crucial financial information as usually contained in balance sheets and profit and loss accounts, which makes it almost impossible to relate financing constraints to the financial situation of firms which other research has proven to be relevant. For instance, Ferrando and Mulier (2013) showed for a large set of euro-area firms that more profitable firms and firms with more working capital or lower leverage ratios are less likely to be financially constrained. Similarly, we also lack information on firms' patenting activities, which carry an important signaling value—particularly for small firms—and therefore help mitigate financing constraints on R&D of established firms (see, e.g., Czarnitzki *et al.*, 2014).

## 5. Findings

Table 1 presents results of the analysis for two different model specifications. Model 1 includes all the relevant control variables and serves as the base model. Furthermore, Model 2 also includes a crisis-credit constraint interaction term to test whether the effect of credit constraints on the different types of innovators was significantly stronger during the global financial crisis.

5. Given the partly low number of observations per industry, some industries were grouped together in homogenous groups: 15: Food products; 17-19: Textiles, garments, and leather; 20-22: Wood products, paper products, publishing, etc.; 23-24: Chemicals and chemical products and coke, refined petroleum; 25: Rubber and plastic products; 26: Other non-metallic mineral products; 27-28: Basic metals, fabricated metal products; 29: Machinery and equipment n.e.c.; 31-33: Electrical machinery and apparatus, medical, precision, and optical instruments; 34-35: Motor vehicles, trailers, and semi-trailers and other transport equipment; 36-37: Furniture, manufacturing n.e.c., recycling.

Results for Model 1, columns (1) and (2), highlight that credit constraints posed substantial obstacles to the propensity of being an R&D innovator: firms that faced credit constraints had a significantly lower probability of performing any formal R&D. Generally, this finding is in line with similar empirical analyses that find a strong and negative relationship between the presence of financing constraints and a firm's likelihood to conduct formal R&D (Álvarez and Crespi, 2011; Hajivassilou and Savignac, 2008; Mancusi and Vezzulli, 2010; Männasoo and Meriküll, 2011). In contrast, non-R&D innovators were unaffected by credit constraints. Hence, in support of Hypothesis 1, there is evidence that binding credit constraints affected R&D innovators only while non-R&D innovators, whose innovative activities are less costly and resource intensive but more of a by-product of daily business operations and learning-by-doing dynamics, remained financially unrestricted and unaffected. Furthermore, and as suggested by Figure 1, the crisis had a non-negligible discouragement effect on non-R&D innovators that only became less prevalent—relative to non-innovators—during the crisis, lending support to Hypothesis 2. However, as shown in Model 2, columns (3) and (4), there is no evidence of a stronger crisis-effect of credit constraints on the different types of innovators. While the coefficients show the expected signs, they fail to be significant. Hence, the financial crisis put no additional strain on both R&D and non-R&D innovators, which leads us to reject Hypothesis 3 formulated above.

Moreover, the analysis identifies several firm characteristics that are pivotal to any R&D-based or non-R&D-based innovative activities. In particular, due to richer and more comprehensive internal funds, the propensity to perform formal R&D was significantly higher among larger firms. Hence, in accordance with previous empirical analyses (see, e.g. Pavitt *et al.*, 1987; Crépon *et al.,* 1998), there is evidence in favor of the Schumpeterian-size R&D nexus, but this only holds for formal R&D innovators. On the contrary, and as suggested by Brouwer and Kleinknecht (1997), non-R&D-based innovative activities are in the domain of smaller and relatively resource-deficient firms. These size-related findings are in support of Hypothesis 4.

Partly in line with Hypothesis 6, the analysis also demonstrates that group membership and foreign ownership were of vital importance, though with different effects. Firms that were part of a group had a higher probability of performing formal R&D activities. Hence, comparatively easy access to vital group-internal technical knowledge, human resources, or funds appears to be conducive to R&D-based

## Table 1. Probability of being an R&D or non-R&D innovator

| Variables | Model 1 | | Model 2 | |
|---|---|---|---|---|
| | R&D innovator (1) | Non-R&D innovator (2) | R&D innovator (3) | Non-R&D innovator (4) |
| Credit constrained (yes=1): *H1* | -0.658*** | 0.046 | -0.558** | 0.049 |
| | (-2.831) | (0.212) | (-1.999) | (0.195) |
| Crisis: *H2* | -0.065 | -0.441*** | -0.029 | -0.448*** |
| | (-0.567) | (-4.572) | (-0.230) | (-4.162) |
| Credit constrained*crisis: *H3* | | | -0.194 | 0.019 |
| | | | (-0.696) | (0.082) |
| Medium-sized (yes=1): *H4* | 0.845*** | 0.223** | 0.840*** | 0.224** |
| | (6.282) | (2.035) | (6.247) | (2.046) |
| Large (yes=1): *H4* | 1.285*** | 0.191 | 1.284*** | 0.192 |
| | (6.673) | (1.131) | (6.665) | (1.138) |
| Log age: *H5* | -0.032 | -0.148** | -0.031 | -0.148** |
| | (-0.422) | (-2.344) | (-0.417) | (-2.340) |
| Part of a group (yes=1): *H6* | 0.426** | 0.160 | 0.427** | 0.160 |
| | (2.321) | (0.971) | (2.324) | (0.969) |
| Foreign ownership share (%): *H6* | 0.001 | 0.006** | 0.001 | 0.006** |
| | (0.217) | (2.264) | (0.204) | (2.274) |
| Exporter only (yes=1): *H7* | 1.105*** | 0.581** | 1.103*** | 0.584** |
| | (3.628) | (2.086) | (3.621) | (2.093) |
| Importer only (yes=1): *H7* | 0.907*** | 0.433*** | 0.906*** | 0.434*** |
| | (5.900) | (3.250) | (5.894) | (3.263) |
| Exporter & importer (yes=1): *H7* | 1.114*** | 0.377 | 1.115*** | 0.379 |
| | (4.116) | (1.491) | (4.116) | (1.500) |
| Competition: minor: *H8* | -0.038 | -0.797*** | -0.043 | -0.792*** |
| | (-0.129) | (-3.103) | (-0.145) | (-3.082) |
| Competition: moderate: *H8* | -0.173 | -0.378 | -0.166 | -0.382 |
| | (-0.591) | (-1.520) | (-0.568) | (-1.536) |
| Competition: strong: *H8* | 0.174 | 0.063 | 0.175 | 0.062 |
| | (1.392) | (0.593) | (1.402) | (0.580) |
| Informal sector practices: *H9* | 0.198*** | 0.099*** | 0.199*** | 0.099*** |
| | (4.403) | (2.646) | (4.415) | (2.638) |
| Non-production labor share (%): *H10* | -0.030 | 0.008 | -0.030 | 0.008 |
| | (-0.768) | (0.267) | (-0.766) | (0.268) |
| Country dummies | Yes | Yes | Yes | Yes |
| Industry dummies | Yes | Yes | Yes | Yes |
| Constant | 0.194 | 0.894*** | 0.177 | 0.896*** |
| | (0.582) | (3.214) | (0.529) | (3.204) |
| No. of observations | 3,163 | 3,163 | 3,163 | 3,163 |
| Log likelihood | -4060 | -4060 | -4059 | -4059 |

Note: Robust z-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Columns (1) and (3) refer to formal R&D innovators, while columns (2) and (4) refer to non-R&D innovators. Non-innovators serve as base category.

innovative activities. On the contrary, while a higher foreign-ownership share rendered firms more likely to be innovative without performing any formal R&D, it failed to translate into a higher propensity of R&D innovators to perform formal R&D. This finding is in contrast to previous empirical evidence on the propensity to innovate in studies on different European countries and appears to suggest that possibly due to substantial risks and costs of decentralized R&D activities (in terms of a loss of control or of non-negligible coordination costs) paired with insufficient or poor indigenous technological capabilities, formal R&D-based innovative activities are still predominantly home country and headquarter based (Belderbos *et al.*, 2011). Hence, as predominantly production-oriented entities with deficient technological capabilities to successfully pursue formal R&D and probably scarce or no resources to fund formal R&D, foreign-owned firms in Latin America appear to rely on or resort to non-R&D-based innovative activities to develop new or significantly improved products and/or processes.

Furthermore, in line with findings by Harris and Moffat (2011) or Männasoo and Meriküll (2011), there is supportive evidence that a firm's probability to innovate is affected by its trading status. Particularly, in support of Hypothesis 7, our results emphasize that relative to their purely domestically oriented counterparts, internationally trading firms show a significantly higher probability of performing formal R&D activities as well as non-R&D-based innovative activities (except for firms that both export and import). This finding suggests that internationally trading firms face stronger competition than firms that solely source from or cater to domestic markets, which induces them innovate—either in terms of formal R&D activities or non-R&D-based innovative activities—and develop new or significantly improved products or processes to become or remain competitive and profitable.

The degree of competitive pressures firms face on their main product markets also affected their probability to innovate. In particular, contrary to the Schumpeterian "competition-curbs-R&D" hypothesis (Hypothesis 8), formal R&D efforts were independent of the degree of product market competition. In contrast, product market competition mattered for non-R&D-based innovative activities: firms that faced only *minor* competition in their main product markets were less likely to pursue non-R&D-based innovative activities.

Similarly, firms' innovative efforts also responded to practices of competitors in the informal sector. In particular, firms were more likely

to pursue either formal R&D activities or non-R&D-based innovative activities if informal sector practices were more of an obstacle to their current business operations. This finding contradicts Hypothesis 9 and stresses that in the light of obstructive informal sector practices, stronger (formal and informal) innovative efforts may be exerted to gain a competitive edge over informal sector firms and to guarantee firm survival and growth.

However, in contrast to recent findings on barriers to innovation and to our expectations (Hypothesis 10), the existence of human capital that should matter the most for formal R&D innovators played no significant role in the propensity to pursue either R&D-based or non-R&D-based innovative activities.

Finally, Table 2 presents results on the probabilities of being credit constrained (equation (2), above) for both models separately. The results highlight that in line with findings by Álvarez and Crespi (2011) for Chilean firms or Czarnitzki and Hottenrott (2012b) for German firms, larger, more resource-abundant, and more collateral-rich firms were less likely to face credit constraints. Similarly, internationally trading firms—in particular, importers only as well as firms that both export and import—that are typically more productive and competitive and firms that had an overdraft facility and, therefore, a longer-standing relationship with potential outside creditors, like banks, all proved more creditworthy and were, therefore, significantly less likely to be credit constrained. In contrast, informal sector practices that were considered more of an obstacle to current business operations rendered firms more likely to be credit constrained. This finding is probably the result of lower profits that resulted from obstructive informal sector practices and rendered firms less creditworthy.

**Table 2. Probability of being credit constrained**

| Variables | Model 1 Credit constrained (1) | Model 2 Credit constrained (2) |
|---|---|---|
| Crisis | -0.054 | -0.057 |
| | (-0.884) | (-0.936) |
| Medium-sized (yes=1) | -0.193*** | -0.193*** |
| | (-2.850) | (-2.854) |
| Large (yes=1) | -0.412*** | -0.410*** |
| | (-3.969) | (-3.952) |
| Log age | 0.013 | 0.013 |
| | (0.330) | (0.333) |
| Part of a group (yes=1) | -0.081 | -0.083 |
| | (-0.802) | (-0.821) |
| Foreign ownership share (%) | -0.000 | -0.000 |
| | (-0.043) | (-0.043) |
| Exporter only (yes=1) | -0.078 | -0.078 |
| | (-0.529) | (-0.527) |
| Importer only (yes=1) | -0.179** | -0.178** |
| | (-2.166) | (-2.164) |
| Exporter & importer (yes=1) | -0.412*** | -0.415*** |
| | (-2.603) | (-2.619) |
| Informal sector practices (Likert scale) | 0.083*** | 0.083*** |
| | (3.497) | (3.516) |
| Competition: minor | 0.099 | 0.098 |
| | (0.609) | (0.602) |
| Competition: moderate | -0.004 | -0.003 |
| | (-0.025) | (-0.019) |
| Competition: strong | -0.006 | -0.005 |
| | (-0.092) | (-0.071) |
| Non-production labor share | -0.015 | -0.014 |
| | (-0.534) | (-0.511) |
| Working capital financed by internal funds (%) | 0.000 | 0.000 |
| | (0.520) | (0.513) |
| Overdraft facility (yes=1) | -0.662*** | -0.663*** |
| | (-9.538) | (-9.557) |
| Log sales per employee | -0.038 | -0.038 |
| | (-1.249) | (-1.267) |
| Country dummies | Yes | Yes |
| Industry dummies | Yes | Yes |
| Constant | 0.319 | 0.326 |
| | (0.918) | (0.935) |
| No. of observations | 3,163 | 3,163 |
| Log likelihood | -4060 | -4059 |

Note: Robust $z$-statistics in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

## 6. Summary and conclusion

Due to the very nature of innovative activities, innovators frequently encounter binding financing constraints in the course of tapping into (new) external funding sources. Consequently, bereft of crucial resources, many R&D projects are postponed or abandoned altogether, robbing economies of a strong and reliable engine towards sustained growth and development.

Against this backdrop, the analysis sheds light on whether and to what extent prevailing credit constraints affected a firm's probability of being an innovator and how that changed as a result of the global financial crisis of 2009. It studies separately the group of formal R&D innovators, which assign resources to R&D development activities performed in-house, and the group of non-R&D innovators, which do not perform any formal R&D but still develop and introduce new or significantly improved products and/or processes, a distinction that has so far been neglected in this line of research. It focuses on Latin America, which was the world region second-most affected by the recent global financial crisis, and applies firm-level data for a large set of Latin American countries that was collected as part of the World Bank Enterprise Survey (WBES) component of the Latin American and Caribbean (LAC) Enterprise Surveys 2006 and 2010.

The results point to the presence of non-negligible credit constraints, demonstrating that approximately every fifth innovative firm in the sample faced credit constraints, and emphasize their detrimental but differentiated effect on innovators. In particular, while formal R&D innovators faced binding credit constraints, which render them less likely to perform formal R&D, non-R&D innovators, whose R&D activities are less resource-intensive and risky and more likely the by-product of learning-by-doing, remained unaffected by credit constraints. Hence, in light of innovation's important role for growth, there is a need for policy intervention to reduce existing financing constraints, subject to compliance with financial prudence, to allow for unhindered innovative efforts, particularly of formal R&D innovators. Moreover, there is no evidence that credit constraints became more prevalent during the global financial crisis nor that the crisis aggravated the negative effects of credit constraints on innovative efforts of either R&D or non-R&D innovators. Hence, while the crisis had some strong adverse effects on the real economy and sent some Latin American economies into deep recessions, it barely affected their financial sectors, thanks to

lower financial and corporate sector vulnerabilities and better policy fundamentals on the eve of the crisis (Savescu, 2014) and to effective monetary policy interventions in the course of the crisis (Winograd and Brei, 2009; Jara *et al.*, 2009).

In addition, the analysis identified specific firm characteristics that were conducive or obstructive to either formal R&D or non-R&D innovative activities. It demonstrates that innovative efforts of R&D and non-R&D innovators were associated with different firm characteristics. For *R&D innovators*, there is strong evidence in favor of the Schumpeterian "size-innovation" hypothesis while his "competition-curbs-innovation" hypothesis found no empirical support. Moreover, group membership, which should guarantee easier access to group-internal funds or know-how, and international trading status, which induces firms to innovate in order to stay competitive in the face of fierce international competition, are conducive to formal R&D efforts. In contrast, *non-R&D-based* innovative activities were more likely among smaller and therefore resource-poorer firms, which traditionally more strongly pursue informal innovative activities (Brouwer and Kleinknecht, 1997) as well as younger firms with still insufficient technological and business know-how. Furthermore, non-R&D-based innovative activities were also more likely among firms with higher foreign-ownership shares, which—together with the insignificant effect for formal R&D innovators—suggests that probably due to insufficient indigenous technological capabilities, formal R&D of foreign mother companies is still predominantly home-country based (see, e.g., Belderbos *et al.*, 2013; Blomkvist *et al.*, 2011; Patel and Pavitt, 1991). Hence, there is strong need for capability upgrading to improve the formal innovation potential of Latin American firms in general and their ability to profit from foreign-ownership in terms of easier access to technology and know-how in particular. Similarly, trading internationally proved conducive and rendered exporters only and importers only more likely to pursue non-R&D-based innovative efforts. Hence, just as for formal R&D innovation activities, trading internationally also proves important for non-R&D-based innovation activities, which emphasizes the importance of international competition for domestic innovative efforts, on the one hand, and of easier access to internationally available technology that facilitates technology transfer, on the other. From a policy perspective, it is therefore imperative to have export and import policies and particular measures in place, like duty exemption schemes, export promotion schemes, and import

promotion capital goods schemes, to name but a few, that encourage trade and consequently help to improve the research and innovation performance of Latin American firms.

Finally, the analysis points to particular firm characteristics that proved advantageous and translated into lower obstacles to external funds. For instance, larger, more resource-intensive, and more collateral-rich firms and internationally trading firms—particularly importers only as well as exporters and importers—which are typically more productive and competitive and, therefore, more creditworthy than purely domestically oriented firms and firms that had an overdraft facility and, therefore, longer-standing and more reputable debtor-creditor relationships with banks, were less likely to face credit constraints. These findings emphasize the difficulties smaller firms face in raising funds in capital markets and stress the need for SME-specific initiatives and measures to improve their access to external funds.

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# APPENDIX

## Table A1. List of variables and definitions

| Variable | Definition |
|---|---|
| R&D innovator | D=1 if firm that assigned resources to R&D development activities performed in-house |
| Non-R&D innovator | D=1 if firm that did not perform any R&D but still introduced new or significantly improved products over the last three years |
| Non-innovators | D=1 if firm neither invested in formal R&D nor introduced a new product (base category) |
| Credit constrained | D=1 if firm did not apply for a credit or loan since either i) application procedures were considered too complex, ii) interest rates were too unfavorable, iii) collateral requirements were unattainable, iv) the size of the loan and maturity were insufficient, v) did not think the credit line would have been approved, or vi) due to other reasons |
| Crisis | D=1 if year=2009 |
| Small | D=1 if firm had up to 19 employees (reference group) |
| Medium-sized | D=1 if firm had more than 19 but less than 99 employees |
| Large | D=1 if firm had more than 99 employees |
| Log age | Log of age |
| Part of a larger firm | D=1 if firm was part of a larger firm |
| Foreign ownership share | Percentage of firms owned by private foreign individuals, companies or organizations |
| Exporter only | D=1 if firm exported only |
| Importer only | D=1 if firm imported only |
| Exporter and importer | D=1 if firm exported and imported |
| Domestic firms | D=1 if firm draws from and caters to domestic markets only (reference group) |
| Informal sector practices | Likert scale variable; whether practices of competitors in the informal sector were: no obstacle=1, minor obstacle=1, moderate obstacle=2, major obstacle=3 and very severe obstacle=4 |
| Competition: none | D=1 if firm faced no competitors in major market (reference group) |
| Competition: minor | D=1 if firm faces only one competitor in major market |
| Competition: moderate | D=1 if firm faces between two and five competitors in major market |
| Competition: strong | D=1 if firm faces more than five competitors in major market |
| Non-production labor share | Ratio of non-production to production workers |
| Working capital financed by internal funds | Share of working capital financed from internal sources |
| Overdraft | D=1 if firm has an overdraft facility |
| Sales per employee | Log of annual sales (in US-$) per employee |

## Table A2. Descriptive statistics

| Variable | R&D innovator (N=1392) | Non-R&D innovator (N=1058) | Non-innovator (N=713) |
|---|---|---|---|
| | Mean (*Std.Dev*) [Min; Max] | Mean (*Std.Dev*) [Min; Max] | Mean (*Std.Dev*) [Min; Max] |
| Credit constrained | 0.16 (*0.37*) [0; 1] | 0.22 (*0.42*) [0; 1] | 0.20 (*0.40*) [0; 1] |
| Crisis | 0.55 (*0.50*) [0; 1] | 0.44 (*0.50*) [0; 1] | 0.58 (*0.49*) [0; 1] |
| Credit constrained*crisis | 0.08 (*0.27*) [0; 1] | 0.10 (*0.30*) [0; 1] | 0.12 (*0.32*) [0; 1] |
| Medium-sized | 0.44 (*0.50*) [0; 1] | 0.38 (*0.49*) [0; 1] | 0.34 (*0.47*) [0; 1] |
| Large | 0.32 (*0.47*) [0; 1] | 0.14 (*0.34*) [0; 1] | 0.11 (*0.31*) [0; 1] |
| Log age | 3.14 (*0.81*) [0; 5.05] | 2.91 (*0.85*) [0; 5.02] | 3.02 (*0.78*) [0; 4.73] |
| Part of a larger firm | 0.18 (*0.39*) [0; 1] | 0.10 (*0.31*) [0; 1] | 0.07 (*0.26*) [0; 1] |
| Foreign ownership share | 0.08 (*0.27*) [0; 1] | 0.05 (*0.23*) [0; 1] | 0.02 (*0.15*) [0; 1] |
| Exporter only | 0.06 (*0.24*) [0; 1] | 0.04 (*0.19*) [0; 1] | 0.02 (*0.14*) [0; 1] |
| Importer only | 0.36 (*0.48*) [0; 1] | 0.23 (*0.42*) [0; 1] | 0.15 (*0.36*) [0; 1] |
| Exporter & importer | 0.11 (*0.31*) [0; 1] | 0.04 (*0.20*) [0; 1] | 0.03 (*0.17*) [0; 1] |
| Informal sector practices | 2.24 (*1.32*) [0; 4] | 2.24 (*1.36*) [0; 4] | 1.92 (*1.39*) [0; 4] |
| Competition: minor | 0.03 (*0.17*) [0; 1] | 0.02 (*0.15*) [0; 1] | 0.07 (*0.25*) [0; 1] |
| Competition: moderate | 0.03 (*0.18*) [0; 1] | 0.03 (*0.17*) [0; 1] | 0.05 (*0.22*) [0; 1] |
| Competition: strong | 0.37 (*0.48*) [0; 1] | 0.32 (*0.47*) [0; 1] | 0.28 (*0.45*) [0; 1] |
| Non-production labor share | 0.84 (*1.15*) [0; 14.33] | 0.79 (*2.11*) [0; 54.00] | 0.70 (*1.42*) [0; 29.00] |

**Table A3. Correlation matrix**

| | R&D innov | Non-R&D innov | Non-innov | CCons | Crisis | CCons*crisis | Medium | Large | Log age | Part | Foreign | Exponly | Imponly | Expimp | Inform | COMPmin | COMPmed | COMPstr | NPLS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R&D innov | 1 | | | | | | | | | | | | | | | | | | |
| Non-R&D innov | -0.63 | 1 | | | | | | | | | | | | | | | | | |
| Non-innov | -0.48 | -0.37 | 1 | | | | | | | | | | | | | | | | |
| CCons | -0.06 | 0.06 | 0.01 | 1 | | | | | | | | | | | | | | | |
| Crisis | 0.05 | -0.11 | 0.07 | -0.01 | 1 | | | | | | | | | | | | | | |
| CCons*crisis | -0.04 | 0.02 | 0.03 | 0.67 | 0.31 | 1 | | | | | | | | | | | | | |
| Medium | 0.07 | -0.02 | -0.05 | -0.04 | -0.01 | -0.04 | 1 | | | | | | | | | | | | |
| Large | 0.22 | -0.12 | -0.12 | -0.13 | 0.03 | -0.09 | -0.41 | 1 | | | | | | | | | | | |
| Log age | 0.11 | -0.11 | -0.01 | -0.03 | 0.16 | 0.02 | 0.04 | 0.21 | 1 | | | | | | | | | | |
| Part | 0.11 | -0.05 | -0.07 | -0.05 | 0.02 | -0.04 | -0.02 | 0.23 | 0.05 | 1 | | | | | | | | | |
| Foreign | 0.09 | -0.02 | -0.08 | -0.05 | 0.00 | -0.04 | -0.03 | 0.22 | -0.02 | 0.20 | 1 | | | | | | | | |
| Exponly | 0.08 | -0.03 | -0.06 | -0.01 | 0.01 | -0.01 | 0.01 | 0.08 | 0.04 | 0.02 | 0.04 | 1 | | | | | | | |
| Imponly | 0.15 | -0.05 | -0.13 | -0.10 | 0.04 | -0.07 | 0.08 | 0.13 | 0.11 | 0.07 | 0.09 | -0.17 | 1 | | | | | | |
| Expimp | 0.16 | -0.08 | -0.10 | -0.06 | 0.00 | -0.04 | -0.04 | 0.29 | 0.10 | 0.07 | 0.19 | -0.10 | -0.20 | 1 | | | | | |
| Inform | 0.04 | 0.03 | -0.09 | 0.07 | -0.01 | 0.05 | 0.02 | -0.07 | 0.03 | -0.06 | -0.08 | -0.01 | -0.01 | -0.11 | 1 | | | | |
| COMPmin | -0.02 | -0.06 | 0.09 | 0.02 | -0.02 | -0.01 | -0.01 | -0.02 | 0.00 | -0.02 | -0.01 | 0.01 | -0.05 | 0.00 | -0.17 | 1 | | | |
| COMPmed | 0.00 | -0.02 | 0.03 | 0.00 | 0.00 | 0.00 | 0.03 | -0.01 | -0.02 | -0.03 | 0.03 | 0.01 | -0.02 | 0.04 | -0.11 | -0.04 | 1 | | |
| COMPstr | 0.07 | -0.02 | -0.07 | -0.03 | 0.00 | -0.02 | 0.03 | 0.06 | -0.01 | 0.09 | 0.08 | 0.05 | 0.09 | 0.06 | -0.13 | -0.14 | -0.14 | 1 | |
| NPLS | 0.03 | 0.00 | -0.03 | -0.03 | 0.00 | -0.02 | 0.00 | 0.03 | 0.04 | 0.08 | 0.02 | -0.02 | 0.09 | -0.02 | 0.00 | -0.03 | -0.03 | -0.02 | 1 |