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Wiener Institut für Internationale Wirtschaftsvergleiche

The Vienna Institute for International Economic Studies

Working Papers | 95 | February 2013

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R&D and Non-R&D Innovators in the Financial Crisis: the Role of Binding Credit Constraints

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Sandra M. Leitner
and Robert Stehrer

R&D and Non-R&D Innovators in the Financial Crisis: the Role of Binding Credit Constraints

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Abstract

In the course of tapping into external funding sources, innovators frequently encounter binding and insurmountable financing constraints, prompting them to discontinue, postpone or altogether abandon some of their innovative efforts, a key source of their growth and survival. This is even more so during economic crises, when profits collapse, internal resources dwindle and external sources risk drying up altogether. Against that backdrop, the analysis identifies the effects of prevailing credit constraints on innovative efforts of both formal R&D innovators as well as non-R&D innovators, which have mostly been neglected so far. It uses Latin America as its empirical platform and demonstrates that irrespective of the global financial crisis, which manoeuvred global financial markets on the verge of collapse, R&D innovators faced binding credit constraints while non-R&D innovators were unconstrained and remained unaffected by the crisis. In addition, there is no evidence that monetary policies aimed at stabilizing capital markets during the crisis had any noticeable alleviating effect on a firm's probability to pursue R&D-based innovative activities. It also shows that innovative efforts of R&D and non-R&D innovators were driven by entirely different firm characteristics, while, on the contrary, almost identical characteristics determined whether both types of innovators faced any credit constraints at all.

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

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

Sandra M. Leitner and Robert Stehrer

R&D and non-R&D innovators in the financial crisis: the role of binding credit constraints

1. Introduction

It goes beyond mere speculation that R&D activities are one of the key engines of sustained economic growth and development which puts them high on the political agenda of all industrialized countries, and increasingly also, of developing countries. Thus, concerted efforts are taken and specific Science, Technology and Innovation (STI) policies are devised and implemented to strengthen nations' innovative potentials and technological capabilities and to foster the development and introduction of new or significantly improved products and/or processes at the level of the individual firm.

As inherently uncertain and risky activities, innovative activities absorb substantial resources without providing the slightest guarantee that any marketable invention will eventually materialize. In the face of insufficient own resources to fund innovative activities, entrepreneurs often see no alternative but to turn to the capital market to raise the much-needed funds. Here, however, innovators often face insurmountable financing constraints: given innovators' reluctance to disclose sensitive information due to strong appropriability concerns compounded by the absence of efficient institutions which could provide crucial firm and project-specific information, the relationship between the debtor and potential outside investors is plagued by strong asymmetric information (Stiglitz and Weiss 1981) which leads to binding financing constraints. Moreover, the need to provide collateral in any credit transaction but the inability of R&D to act as viable collateral – due to its intangible nature - may also give rise to non-negligible financing constraints (Brown et al. 2010). Hence, faced with insurmountable financing constraints, innovators may feel forced to postpone or altogether abandon their innovative projects, undermining any impetus towards growth and development.

However, the scale and effects of financing constraints tend to differ across groups of innovators. While recognized in innovation theory, academic research and STI policy alike have for the most part neglected the group of innovative firms that do not perform formal R&D. Specifically, a non-negligible share of firms is found to develop technological and non-technological innovations without carrying out any R&D: between 2004 and 2006, in Australia and Norway, the propensity to introduce a product innovation that is new to the market was similar whether or not formal R&D was performed (OECD 2010). Similarly, Arundel et al. (2008) analyse the Innobarometer of 2007 for all EU-27 member countries and demonstrate that slightly more than 50 percent of all innovative firms did not conduct any formal R&D. And even though innovative firms that do not perform R&D spend less on innovation, possess poorer innovative capabilities and are less likely to apply for or receive

support from pubic innovation support programmes, they are not outperformed by innovative firms with formal R&D activities (in terms of a reported change in revenues). And based on micro-aggregated data from the third Community Innovation Survey, Huang et al. (2008) highlight that innovators without formal R&D are more likely to be smaller in size, less likely to be exporters and are short of highly-educated employees (with university education). Moreover, they are less likely to be product innovators or to resort to patenting to protect their innovations. Finally, innovators without formal R&D more strongly rely on suppliers and competitors as vital sources of information. Put together, the specific characteristics of non-R&D innovators together with the particular nature of R&D activities they pursue in terms of riskiness, scale or objective and the significantly lower appropriability issues that arise, non-R&D innovators are expected to face lower and less binding financing constraints than their R&D-based counterparts.

Moreover, in addition to binding financing constraints, both R&D as well as non-R&D based innovative activities of firms also sensitively respond to changes in economic conditions and environments they operate in. Specifically, the recent global financial crisis, which had a strong but short-lived effect on most economies, robbed many entrepreneurs of the financial means to further pursue any innovative activities, as global and local demand faltered, sales collapsed and internal resources quickly melted away. Bereft of internal funds to dispose of, innovators may feel forced to discontinue their innovative activities until recovery sets it. However, R&D and non-R&D innovators may respond differently to the crisis. Given the significantly higher financial requirements of formal R&D, R&D innovators may feel forced to discontinue some of their innovative activities. On the contrary, significantly lower cost of R&D allows non-R&D innovators to more flexibly adjust their innovative activities to changing outside conditions.

Against that backdrop, the ensuing analysis seeks to shed light on i) the presence and effects of binding credit constraints as well as on ii) the effects of the global financial crisis on innovative activities of firms. It uses data for a large group of Latin American countries 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. As such, the study's contributions to the ongoing discussion are manifold: firstly, it provides first evidence on the differential role of credit constraints for both R&D as well as non-R&D innovators, a distinction that has so far been neglected in the literature. Secondly, it explicitly accounts for the effect of the global financial crisis on 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.

Methodologically, a recursive bivariate probit approach with endogenous credit constraints is applied. Empirical findings point at fundamental differences between R&D and non-R&D

innovators: Firstly, irrespective of the crisis, R&D innovators faced binding credit constraints while non-R&D innovators, whose R&D activities are less resource-intensive and risky and more likely the result of learning-by-doing dynamics, remained unrestricted by credit constraints and unaffected by tighter credit markets during the crisis. Secondly, innovative efforts of R&D and non-R&D innovators were driven by entirely different firm characteristics: for *R&D innovators*, there is strong evidence in favour of Schumpeter's 'size-innovation' hypothesis while his 'competition-curbs-innovation' hypothesis finds little empirical support. And while group-membership and international trading status proved conducive to formal R&D efforts, probably due to insufficient indigenous technological capabilities and the still mainly home country based nature of R&D, formal R&D efforts were less likely among majority foreign-owned firms which therefore mainly serve as production entities. In contrast, the probabilities of performing *non-R&D-based* innovative activities was higher among majority foreign-owned or (resource-deficient) smaller firms but lower among firms that both export and import, firms that faced minor product market competition, firms that were part of a group or firms whose business activities were affected by informal sector practices.

Moreover, empirical findings also reveal that very similar firm characteristics determine whether either R&D or non-R&D innovators face binding credit constraints. Specifically, irrespective of the type of innovator, the probability of being credit constrained was lower among larger firms, exporters, firms with higher internal funds or firms with a longer-standing creditor-debtor relationship with banks but higher among firms which experienced rampant corruption.

The remainder of the paper is structured as follows: section 2 discusses related empirical evidence on the role of financing constraints on firm-level innovative activities, while section 3 provides an overview and description of the data used in the ensuing analysis. A general picture of prevailing firm-level funding patterns of working capital and fixed asset investment is drawn in section 4, both before as well as during the crisis of 2009. As such, it throws light on the relative importance of internal versus external financing sources and the role of the banking sector in providing external funds. Both, empirical methodology and results are presented and discussed in depth in section 5. Finally, section 6 concludes.

2. Related literature – the role of access to financing for innovative activities

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 priory* measures of financing constraints and analyse and compare emerging investment-cash flow sensitivities across sub-samples. Greater investment-cash flow sensitivities were 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 cost of 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 (1997, 2000) 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 stress 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 which allows to more directly measure the presence of financing constraints gave fresh impetus to and revived the discussion as to the presence and effects of financing constraints on firm investment behaviour. 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) use the 2004 Capitalia survey on Italian manufacturing firms to analyse the effects of financing constraints both, on the decision to conduct R&D as well as on the level of R&D investment. They apply a recursive bivariate probit approach and find that the presence of financing constraints reduces the probability of doing R&D by around 23 percent. Similar negative effects are found by Männasoo and Meriküll (2011) for a diverse set of developed and transition economies covered in the Business Environment and Enterprise Performance survey (BEEPs). They find an around 70 percentage points lower probability that credit-constrained firms conduct R&D. Similarly, Hajivassilou and Savignac (2008) identify and shed light on prevailing direct as well as reverse effects between financing constraints and innovation. They apply a simultaneous bivariate probit framework with mutual endogeneity of financial constraints and innovation decisions of firms and demonstrate that binding financing constraints curtail innovation and that, simultaneously, probably due to the higher uncertainty and riskiness innovators face, innovative firms more likely encounter binding financing constraints. Mohnen et al. (2008) use the Dutch CIS 3.5 and study the effects of financing constraints on the probability to abandon, prematurely stop, seriously slow down, or not start an innovative project. They point at the high prevalence of diverse obstacles to innovative activities and report that almost every third innovative or potentially innovative firm in their sample felt hampered by one or another factor. They find 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, they stress that prevailing financial constraints tend to reinforce (or, conversely, are reinforced) by other hampering constraints which further increases the likelihood to abandoning, seriously slowing down or not starting innovative projects. Finally, comparable empirical evidence in a developing-country setting is provided by Álvarez and Crespi (2011) who study around 10.000 Chilean firms in 2007 and find conclusive evidence that innovative activities are less likely among financially constrained firms.

In addition, specific firm characteristics are found to be pivotal to a firm's decision to perform R&D and exert innovative efforts. As such, firm size emerges as key determinant such that smaller firms (that are also more financially constrained) show a significantly lower probability to perform R&D (Mancusi and Vezzulli 2011; Hajivassilou and Savignac 2008 or Männasoo and Meriküll 2011). However, the study by Álvarez and Crespi (2011) also highlights that the size-effect is not a universal phenomenon. In addition, the likelihood to conduct R&D is also critically associated with firm-ownership: as an indication of prevailing centralization strategies of R&D activities, heads of firm-groups have a higher probability to perform R&D (Mancusi and Vezzulli 2011) while foreign-ownership matters little only (Mancusi and Vezzulli 2011; Männasoo and Meriküll 2011). Empirical evidence also points at a prevailing complementarity between R&D efforts and tangible investment activities (Mancusi and Vezzulli 2011), rejects Schumpter's (1934) negative competition-innovation nexus which highlights that since competition lowers the expected return from R&D, it tends to curb R&D efforts (Hajivassilou and Savignac 2008) or corroborates that exporters, firms with a more educated and skilled workforce or firms that receive public subsidies show a higher probability to conduct R&D (Männasoo and Meriküll 2011). Furthermore, the probability to perform R&D is also found to be inversely related to (the expected increase in) sales of firms (Álvarez and Crespi 2011; Männasoo and Meriküll 2011).

In addition, consistent evidence is quickly mounting that binding and restrictive financing constraints are unique to firms with very specific characteristics. In particular, there has been a long-standing debate on whether larger firms which 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 (e.g. Mancusi and Vezzulli 2011; Hajivassilou and Savignac 2008). In contrast, Álvarez and Crespi (2011) in their study on Chilean firms support the negative size-constraint nexus and stress that larger firms are less likely to be financially constrained. Moreover, there is some indication that business-group affiliation is associated with lower financing constraints since firms that are part of a business group are less dependent on external financing but alternatively may 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 - turns out to negatively affect the probability of being financially constrained (see e.g. Álvarez and Crespi 2011 or 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 but more attractive debtors. There is also evidence that firms which 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) also point at the potentially critical role of regionally differing credit or capital markets. They highlight that

probably due to inferior credit markets in the south or centre of Italy, firms located in these regions face a higher probability of being credit constrained than their counterparts located in the more developed and industrialized north.

3. Data

The ensuing analysis applies data for a 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.[1] The surveys were conducted during the calendar years 2006 and 2007 as well as 2010 and 2011, respectively, but refer to the last complete fiscal years, that is 2005 for WBES-2006 and 2009 for WBES-2010. Generally, Enterprise Surveys have been conducted regularly since 2002 by means of face-to-face interviews with the manager, owner or director of establishments on a 3 to 4-year rotation with the objective of collecting information about individual firms' business environment, how it is perceived by them, how it changes over time, about various constraints or obstacles to firm performance and growth or the effects a country's business environment on its international competitiveness. Its focus is on private business activities so that establishments with 100 percent state ownership are excluded from the survey.

To obtain unbiased estimates and to guarantee that the final sample covers establishments from all different sectors, each country-sample was selected using random sampling, stratified by size (into small with 5-19 employees, medium-sized with 20-99 employees and large with more than 99 employees), region (of major economic activity) 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 the establishment with five or more full-time employees, located in major urban centres, which engaged in non-agricultural activities. Moreover, given the harmonization of sampling strategies and the comparability of survey instruments used in collecting the data, survey data from different countries are comparable.

Data are collected based on three different questionnaires. As the basic version, the Core Questionnaire includes all common questions asked to all establishments from all sectors. Moreover, the Manufacturing Questionnaire as well as the Service Questionnaire are built

[1] 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

upon the Core Questionnaire but add some specific questions relevant to the respective sectors. The subsequent analysis uses data stemming from the Manufacturing Questionnaire only which covers, in more detail, information on innovative efforts and performance of firms, the strategies they pursue to protect their innovations as well as on the competitive business environment they operate in.

All 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 of the ensuing analysis. Around 37 percent of all manufacturing firms analysed are either micro or small firms with up to 19 employees, 40 percent are medium-sized with between 20 and 99 employees while the remaining 23 percent are large firms with more than 99 employees. Around 13 percent of all manufacturing firms are part of a larger firm while only around 8 percent are majority foreign-owned or young. Finally, in terms of trading status, around 8 percent are exporters only, around 25 percent are importers only while another 10 percent are both exporters and importers. The remaining 57 percent 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 innovative activities of firms. To account for the often neglected but non-negligible role of innovators that do not perform R&D, two different groups of innovators are identified and analysed: so called *R&D innovators* which assigned resources to R&D development activities performed in-house as well as *non-R&D innovators* which did not perform any R&D but still introduced any new or significantly improved products (goods or services) and/or processes (for producing or supplying products) over the last three years.

The analysis uses a self-reported credit-constraint indicator ($fconstr_{ik}$) to identify whether and to what extent financing constraints affected the probability of being either an R&D innovator or a non-R&D innovator, both before and during the global financial crisis of 2009. Specifically, firms are considered to be credit constrained ($fconstr_{ik} = 1$) if they did not apply for loans or lines of credit since either i) application procedures were considered too complex, ii) interest rates were considered too unfavourable, iii) collateral requirements were unattainable, iv) the size of the loan and maturity were insufficient, v) they did not think the credit line would have been approved, or vi) due to other reasons not specified in the survey. In contrast, $fconstr_i = 0$ if the establishment successfully applied for a line of credit or loan (as reference group). This approach is in contrast to Beck et al. (2008) which use a broader Likert-scale based constraint indicator, reflecting whether financing obstacles affected the operation and growth of firms. On the contrary, against the backdrop of globally collapsing capital markets and an alarming drying up of credits markets during the financial crisis, the following analysis explicitly focuses on the role of banks for firm-level innovative activities, before as well as during the global financial crisis. Following the bank-

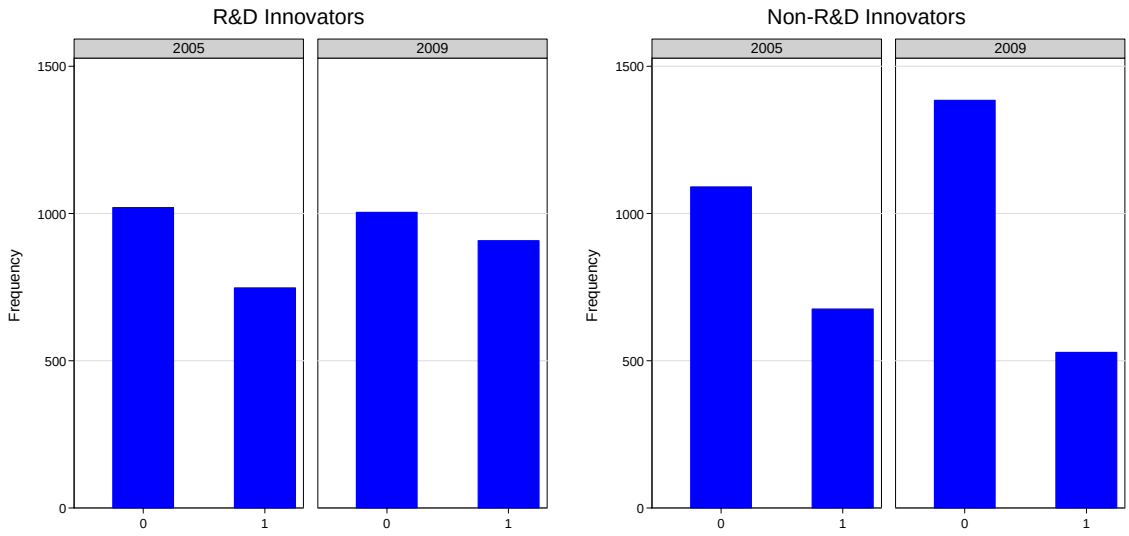
ruptcy of Lehman Brothers in September 2008, Latin America got quickly drawn into the vortex of the crisis which spread swiftly like wildfire. And while the real economy stumbled, no Latin American economy experienced a financial crisis since, thanks to profound central bank and financial market reforms 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 on foreign exchange markets and to make external financing available (Winograd and Brei 2009) while others (in 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 was effective since, relative to emerging market economies in Europe, the decline in bank credits in Central and South American emerging market economies was moderate (Guo and Stepanyan 2011).

As a starting point, Figure 1 depicts frequencies of R&D and non-R&D innovators in the sample before as well as during the crisis. It highlights that between 2005 and 2009, the frequency of R&D innovators increased slightly: of all 2,242 manufacturing firms, 747 firms (or 33 percent) spent on in-house R&D in 2005 relative to 908 firms (or 40 percent) in 2009. In contrast, the number of non-R&D innovators declined between 2005 and 2009: in 2005, 676 firms (or 30 percent) introduced a new product and/or process without performing any R&D compared to only 528 firms (or 24 percent) in 2009. 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 R&D, entrepreneurs are less likely to discontinue their R&D activities.

Furthermore, the frequency of credit constraints by firm-level activity is depicted in Figure 2 both for the pre-crisis year of 2005 as well as the crisis-year of 2009. It points at the presence of non-negligible credit constraints among manufacturing firms and shows that both in 2005 and 2009, around one fifth of all firms in the manufacturing sector faced credit constraints. Additionally, it stresses that the number of R&D innovators and non-R&D innovators is lower among firms that face credit constraints: the frequency of either R&D innovators or non-R&D innovators is around 30 to 40 percent lower among firms that face credit constraints. Finally, Figure 2 highlights that between 2005 and 2009, the frequency of R&D innovators with credit constraints remained unchanged while the frequency of non-R&D innovators with credit constraints slightly decreased.

Figure 1

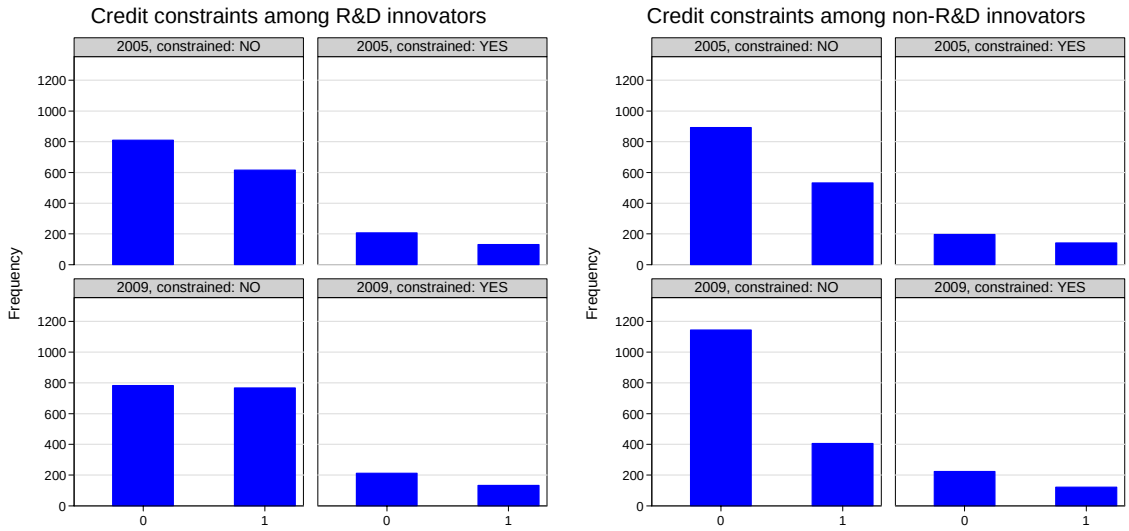
Frequency of R&D innovators and non-R&D innovators in manufacturing: 2005 and 2009



Note: R&D innovators is a dummy variable with is equal to 1 if the firm reported non-negative R&D expenditure and 0 otherwise. *Non-R&D innovators* is a dummy variable which is 1 if the firm did not perform any R&D but still introduced any new or significantly improved product and/or process and 0 otherwise. Data stem from the WBES component of the Latin American and Caribbean (LAC) Enterprise Surveys 2006 and 2010.

Figure 2

Frequency of reported credit constraints among manufacturing firms, by activity: 2005 and 2009



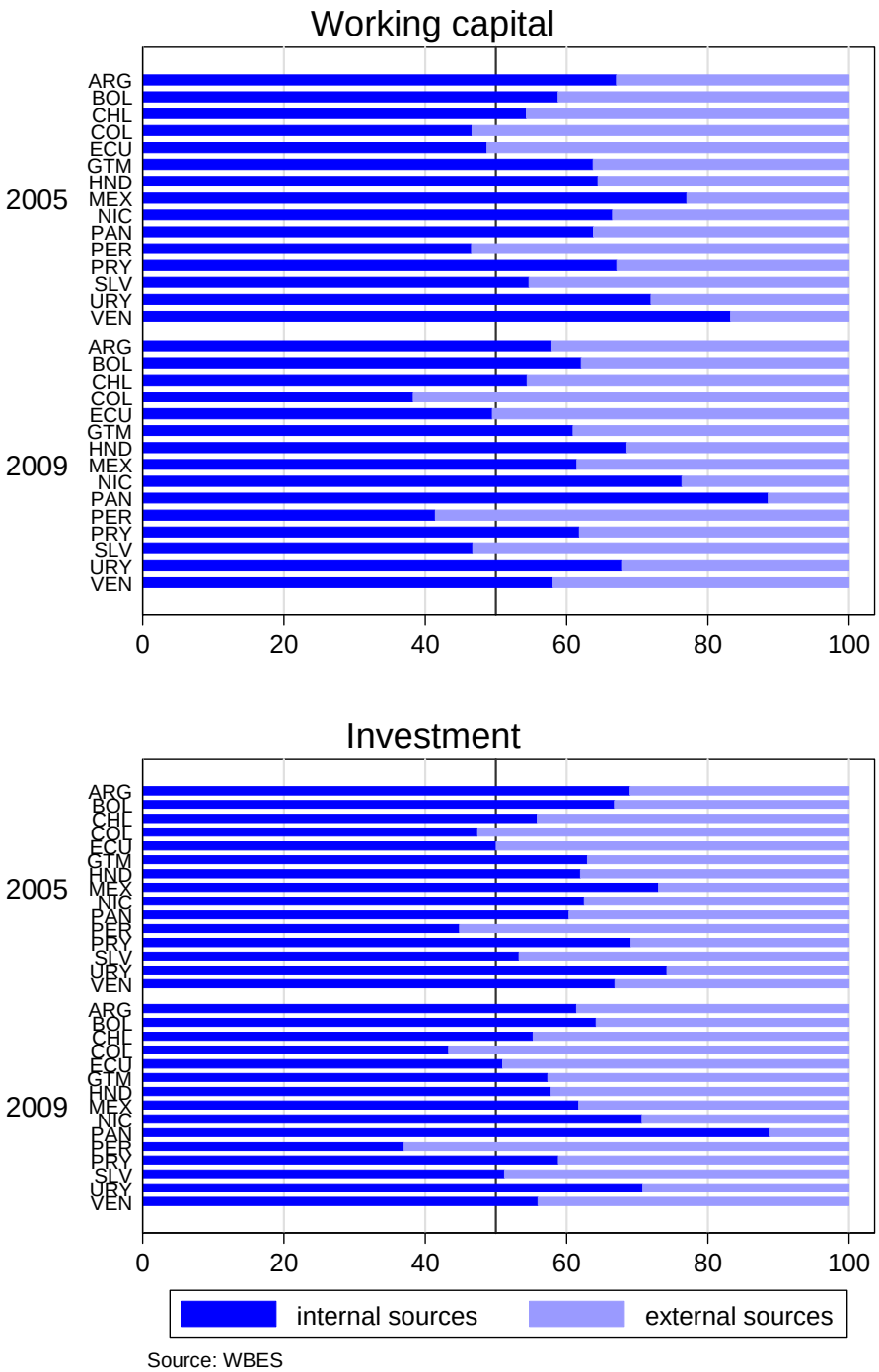
Note: The left-hand panel depicts *R&D innovators* (=1 if the firm reported non-negative R&D expenditure) and non-innovators (=0, otherwise) while the right-hand panel depicts *non-R&D innovators* (=1 if the firm did not perform any R&D but still introduced any new or significantly improved product and/or process) and non-innovators (=0 otherwise). 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 6 reasons: i) the application procedure was too complex, ii) interest rates were unfavourable, 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 capital, the firm did not apply for a loan. Data stem from the WBES component of the Latin American and Caribbean (LAC) Enterprise Surveys 2006 and 2010.

4. Firm-level financing patterns

To shed light on the relative importance of internal and external financing sources before as well as during the crisis, Figure 3 depicts average firm-level financing patterns for each

Figure 3

External versus internal financing sources of working capital and investment in fixed assets: 2005 and 2009



Source: WBES

country included in the overall country sample. It captures firm financing of either working capital as an indicator of operating liquidity or of fixed assets like machinery, vehicles, equipment, land or buildings as the proportion of working capital or fixed assets that was financed from different sources like: internal funds or retained earnings as internal sources or private or state-owned banks, non-bank financial institutions, purchased on credit from suppliers and advances from customers as well as rest (comprising family and friends, informal sources, issued new debt/equity to finance fixed-asset investment) as external sources.

Figure 3 highlights that prior to the crisis, with very few exceptions only (Colombia, Ecuador and Peru), working capital was predominantly financed through internal sources, with Venezuela, Mexico, Uruguay, Guatemala and Argentina most reliant on internal sources. The overall dominance of and reliance on internal financing hardly changed once the crisis hit in 2009. In the course of the crisis, external financing became more widespread in the majority of countries (however, in Panama, external firm-level financing collapsed and more than halved from around 36 percent in 2005 to only 11 percent in 2009, while comparatively minor reductions occurred in Honduras, Nicaragua, Bolivia, Ecuador and Chile). However, internal funds remained the major financing source except for firms located in Peru, Colombia, Ecuador as well as El Salvador. From initially 17 percent in 2005 to around 42 percent in 2009, the shift towards external financing was most pronounced in Venezuela.

These working capital financing patterns are replicated for fixed assets, for which internal financing sources dominated prior to the crisis as well as during the crisis (except for Colombia and Peru), but whose investment activities were to a higher degree financed by external sources during the crisis. The only exceptions were Panama, where, once the crisis struck, the purchase of fixed assets became almost exclusively financed by internal sources (from around 60 percent in 2005 to 89 percent in 2009), Nicaragua and Ecuador.

In addition, to identify the most important external financing sources and to throw light on the role of the banking sector in providing external funds, the pooled external financing sources of either working capital or fixed asset investment are disaggregated by particular external financing source and presented in Table 1 for 2005 and 2009. It shows that before the crisis, banks dominated external financing sources of working capital in the majority of countries considered while purchases on credit from suppliers and advances from customers represented the second most important external financing source, particularly for firms located in Argentina, Ecuador, Guatemala, Mexico, Paraguay and Uruguay. However, with the onset of the crisis, bank financing lost its dominant role to purchases on credit from suppliers and advances from customers in the majority of economies: firms located in Honduras, Nicaragua, Panama and Peru still drew about half of all external sources from

Table 1

External financing sources of working capital and fixed assets, disaggregated by particular source: 2005 and 2009

		Working capital					Fixed capital investments					
Country	Year	external	Banks	non-banks	supplier /customer	other	external	Banks	non-banks	supplier/ customer	new equity	other
Argentina	2005	32.9	8.8	1.2	19.5	3.4	31.0	5.3	2.8	4.7	1.0	17.2
Argentina	2009	42.1	12.0	1.1	26.8	2.1	38.6	19.7	1.6	12.3	3.7	1.3
Bolivia	2005	41.2	19.5	1.6	12.7	7.3	33.2	20.6	1.0	4.5	1.4	5.7
Bolivia	2009	37.9	16.7	2.1	16.0	3.1	35.8	17.0	2.6	6.7	7.6	1.9
Chile	2005	45.7	25.3	1.1	15.8	3.4	44.1	30.2	1.5	7.4	1.8	3.3
Chile	2009	45.6	19.5	1.6	22.6	1.8	44.7	29.2	1.9	9.3	2.7	1.6
Colombia	2005	53.4	23.2	1.2	21.3	7.7	52.6	33.6	4.4	7.8	0.5	6.3
Colombia	2009	61.7	20.8	1.4	35.3	4.1	56.7	33.1	4.5	11.9	4.2	2.9
Ecuador	2005	51.3	18.5	0.6	24.3	7.7	50.0	26.8	1.7	14.2	0.7	6.7
Ecuador	2009	50.5	18.7	1.5	26.7	3.7	49.0	20.0	3.9	12.0	7.9	5.2
El Salvador	2005	45.3	23.3	1.3	12.7	8.1	46.7	30.6	1.6	9.1	1.1	4.3
El Salvador	2009	53.3	22.0	2.1	25.2	4.0	48.7	23.9	2.7	15.1	4.4	2.7
Guatemala	2005	36.2	12.6	1.0	16.8	5.8	37.0	20.8	2.4	8.9	0.8	4.1
Guatemala	2009	39.1	10.7	1.8	23.7	2.9	42.7	20.0	4.6	12.6	3.1	2.4
Honduras	2005	35.5	19.9	1.6	9.5	4.5	38.0	14.9	2.5	4.0	0.5	16.1
Honduras	2009	31.4	16.6	1.4	10.7	2.7	42.2	24.1	1.1	5.6	7.4	4.0
Mexico	2005	23.0	2.7	0.5	14.0	5.7	27.0	7.5	0.6	12.1	0.3	6.4
Mexico	2009	38.5	9.3	1.4	24.9	3.0	38.3	12.5	3.2	16.3	4.0	2.2
Nicaragua	2005	33.5	14.0	3.6	11.1	4.9	37.5	22.5	2.4	3.3	0.5	8.7
Nicaragua	2009	23.6	12.1	0.8	9.9	0.8	29.3	22.7	1.0	1.8	2.5	1.3
Panama	2005	36.2	22.7	0.5	9.2	3.7	39.6	28.6	0.4	5.8	0.3	4.5
Panama	2009	11.5	4.0	2.0	3.8	1.7	11.2	3.6	0.0	2.6	4.8	0.2
Peru	2005	53.5	27.7	0.9	19.3	5.6	55.1	41.1	0.6	9.2	0.6	3.5
Peru	2009	58.6	29.6	2.3	23.8	2.9	63.0	46.7	2.0	8.2	4.1	2.0
Paraguay	2005	32.9	9.2	4.2	13.7	5.5	30.9	8.9	4.2	10.7	1.4	5.7
Paraguay	2009	38.2	16.5	3.9	16.0	1.8	41.1	21.3	4.9	10.8	2.3	1.8
Uruguay	2005	28.0	7.8	0.4	15.3	4.4	25.8	14.1	1.4	5.5	0.2	4.5
Uruguay	2009	32.2	8.6	1.0	20.7	1.9	29.2	17.5	1.3	5.9	3.2	1.4
Venezuela	2005	16.8	13.1	0.7	.	2.9	33.1	24.4	1.5	.	3.8	3.4
Venezuela	2009	41.9	14.6	1.7	23.5	2.0	44.0	20.3	1.8	16.5	4.8	0.6

Note: average source per country; external is the sum of the following sources: banks, non-banks, suppliers/customers and other (like moneylenders, friends, relatives etc.). For Venezuela, suppliers/customers and other are grouped together for 2005.

Source: own calculations (WBES)

private or state-owned banks. A somewhat different picture emerges for fixed asset investment: except for Argentina, where external sources predominantly stemmed from other sources, or Mexico and Paraguay, where supplier and customers represented the most important external funding source, banks were the single most important external financing source in 2005. Moreover, once the crisis struck, even though purchases on credit from suppliers and advances from customers gained importance, banks remained the dominant external financing source, except for Panama, where fixed asset investments were mainly financed through the issuance of new equity. Additionally, across all countries considered, the reliance on banks as external financing sources was strongest in Peru, where around 80 percent of external funds were drawn from banks, both, before as well as during the crisis.

Unfortunately, no information is available on financing patterns and strategies of more resource intensive and riskier R&D activities. However, above analysis of financing patterns may imply that somewhat similar financing strategies were also applied for innovative activities, namely i) mainly internal funds, with ii) a non-negligible but crisis-related declining role of the banking sector as an external financing source.

5. Credit constraints and the propensity to innovate

To identify whether and to what extent credit constraints affected the probability of being either an R&D innovator or a non-R&D innovator, a recursive bivariate probit model with endogenous credit constraints is applied. The potential endogeneity of the credit constraint indicator stems from two different sources: firstly, latent heterogeneous factors (like entrepreneurial behaviour) may affect both the probability of being credit constrained and the probability of being an innovator, and secondly, the decision to pursue innovative activities and how to finance them (that is by means of internal or external sources) may be simultaneous.

The recursive system is specified as follows where equation (1) is the outcome equation that explains the probability that a firm is an innovator while equation (2) is the structural equation that specifies the probability that a firm is credit constrained:

$$I_{tk}^{*} = \alpha_1 fconstr_{tk} + \mathbf{x}_{tk}\boldsymbol{\beta}' + e_{tk} \quad (1)$$

$$fconstr_{tk}^{*} = \mathbf{y}_{tk}\boldsymbol{\theta}' + u_{tk}, \quad (2)$$

where I_{tk}^{*} and $fconstr_{tk}^{*}$ are latent variables, while I_{tk} and $fconstr_{tk}$ are dichotomous variables defined as follows:

$I_{tk} = 1$ *if* $I_{tk}^{*} > 0$ *and* $I_{tk} = 0$, *otherwise*

and

$fconstr_{tk} = 1$ *if* $fconstr_{tk}^{*} > 0$ *and* $fconstr_{tk} = 0$, *otherwise*.

I_{tk} is a binary variable that is 1 if at time $t = 2005\, or\ 2009$ establishment k reported innovative activities and 0 otherwise. Two different types of innovative activities are differentiated: *formal R&D activities* performed in-house ($I_{tk} = FINNOV_{tk}$) on the one hand or *non-formal, non-R&D-based activities* that do not involve any R&D expenditure but still result in new or modified products and/or processes ($I_{tk} = NFINNOV_{tk}$) on the other. Moreover, $fconstr_{tk}$ is the self-reported credit-constraint indicator specified and discussed above.

For the purpose of identification, the error terms are assumed to be independently and identically distributed as bivariate normal as follows:

$$\begin{pmatrix} e_{tk} \\ u_{tk} \end{pmatrix} \sim IID\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \right)$$

,

where $\rho = Cov(e_{tk}, u_{tk})$.

$\mathbf{x}_{tk}$ is a vector of the following characteristics: 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 favour 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) develop 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 findings are diverse, a positive relationship between firm size and R&D effort is found by Pavitt et al. (1987) while Crépon et al. (1998) highlight that the probability of engaging in research increases with firm size. Firm size is included as dummy variables for either medium-sized firms (with between 20 to 99 employees) or large firms with more than 99 employees. The group of micro and small firms with up to 19 employees represents the reference group.

As emphasized by Arrow (1962), firm performance tends to improve with **age** since firms become more efficient over time as learning-by-doing effects materialize and new products emerge or processes become more routinized, standardized and cost-efficient. In contrast, performance may deteriorate with age: as argued by Agarwal and Gort (1996 and 2002), age may render knowledge and skills obsolete as successful routines permanently permeate the firm's organization, rendering it inflexible and rigid and unresponsive to frequently

changing market conditions in terms of competition or demand. Supportive evidence of the latter organizational-rigidity hypothesis is provided by Loderer and Waelchli (2010) who demonstrate that R&D activities experience a relative decline as firms mature and grow older. Moreover, the probability of being an innovator may be higher among younger firms: specifically, as emphasized by Schumpeter (1934), new entrants are vital sources of novel and technologically superior products and processes so that younger firms are more likely to be innovators also. To account for the role of age, a dummy variable is included with is equal to one if, prior to the crisis, the firm was younger than 4 years old and zero otherwise.

Moreover, thanks to easier access to knowledge, human resources and internal funds[2] together with more effective and widespread risk-diversification strategies, R&D efforts may be higher among both, firms that are **part of a group** as well as **foreign-owned firms**. Empirical evidence seems to consistently point at the opposite, however: compared to their domestic counterparts, foreign-owned firms tend to be characterized by lower R&D intensities since the lion's share of innovative activities is still undertaken in their home countries (see e.g. Griffith et al. 2004 or Falk and Falk 2006). Moreover, empirical evidence on the propensity to innovate is mixed and inconclusive. Balcet and Evangelista (2005) find 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) emphasizes that the higher propensity to innovate observable among foreign-owned firms is mainly due to differences in firm characteristics (particularly size). Frenz and Ietto-Gillies (2007) demonstrate 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 are found by Johansson et al. (2008) in a study on four Nordic countries or Dachs and Ebersberger (2009) in a study on Austria. A dummy variable is included which is one for firms that are part of a larger firm and zero otherwise. Additionally, a dummy variable is included which is one for majority foreign-owned firms (with more than 50 percent owned by private foreign individuals, companies or organizations) and zero otherwise.

In addition, firms which 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 invest in R&D to maintain or gain a leading edge over their competitors and to survive and thrive. Moreover, **internationally trading firms** also benefit from their exposure to international technology and the ensuing technology transfer that

[2] 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.

may take place. Aw et al. (2007) provide evidence for the Taiwanese electronics industry that exporters that also invest in R&D expand their knowledge bases and accumulate technological capabilities that help them assimilate and utilize new foreign technologies. Related to that, foreign capital goods markets are vital sources for productivity-enhancing leading-edge machinery and equipment, particularly for technologically lagging economies with underdeveloped or altogether lacking capital goods markets. Hence, all in all, internationally trading firms may have a higher propensity to innovate and, due to better information about the availability as well as access to foreign embodied and disembodied technology, may also exert higher R&D efforts. 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 importers only and, firms that both export and import. Each trading status is captured by means of an individual dummy variable.

In his seminal work, Schumpeter (1934) advocated a negative relationship between **product market competition** on the one hand and R&D on the other since competition lowers the expected return from R&D and therefore decreases R&D efforts. On the contrary, Aghion and Howitt (1999) demonstrate 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 is found by Horowitz (1962) or Gustavsson and Poldahl (2003) while, for a broad sample of developing countries, Ayyagari et al. (2007) finds that the propensity to innovate is higher, the higher the number of competitors. 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 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 none as the reference group:

In a similar vein, competitive pressures also emanate from the **informal sector**, which is often a substantial part of the economy, particularly in developing or emerging economies. And while informal sector establishments tend to spend less on R&D and be less 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 R&D efforts if they result in higher competitiveness but may also curb such efforts if they prove detrimental to formal establishment performance. The role of informal sector practices is accounted for by a Likert-scale variable that captures whether the 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.

Moreover, it goes beyond mere speculation that the endowment of firm-specific **human capital** is privotal to any R&D efforts. On the one hand, human capital is a key input into

any knowledge-intensive innovation process. For example, Janz et al. (2003) demonstrates that firms with higher human capital endowment (as proxied by the share of employees with a college or university degree) have a higher propensity to innovate. Hence, to account for the skill-bias in innovation activities, the non-production labour share as the ratio of non-production workers to production workers is included.

Finally, in the absence of any sector characteristics, a series of manufacturing sector dummies is included to account for sector-specific characteristics[3] while country characteristics are captured by means of country dummies.

The credit constrained equation (2) controls for the following characteristics (included in the vector $\mathbf{y}_{tk}$): size, age, business-group affiliation and ownership (all as defined above), exporter status (dummy=1 if a firm earns more than 10 percent of its sales from exporting goods and services) to capture that given their riskier operations, exporters may face stronger constraints, the share of working capital financed by internal funds (as a proxy for the availability of internal funds), whether a firm already had a credit or loan (dummy) to capture that firms that already use external financing may face stronger constraints, whether corruption was an obstacle to current business operations (Likert-scale variable from 0 to 4 for 'no obstacle', 'minor obstacle', 'moderate obstacle', 'major obstacle' and 'very severe obstacle') to highlight that corruption may also spill over to the credit market. Again, country and industry dummies are included.

Table 2 presents results of the analysis for different samples. Columns (1) and (2) refer to the group of R&D innovators for 2005 and 2009 while columns (3) and (4) refer to the group of non-R&D innovators, again for 2005 and 2009, respectively.

Results in columns (1) and (3) highlight that, prior to as well as during the crisis, credit constraints posed substantial obstacles to the propensity of being an R&D innovator: firms that faced credit constraints had a 3.6 percent (before the crisis) and 1.8 percent (during the crisis) lower probability of performing any R&D. Generally, this is in line with similar analyses which find a strong and negative relationship between the presence of financing constraints and a firm's likelihood to conduct R&D (Álvarez and Crespi 2011; Hajivassilou and Savignac 2008; Mancusi and Vezzulli 2010; Männasoo and Meriküll 2011). However, the test on the equality of credit-constraint coefficients for 2005 and 2009 is not rejected (chi2(1)=0.26, p=0.6104), hence there is no evidence that the effects of binding credit constraints were significantly lower during the crisis. This suggests that monetary policies

[3] 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 & 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 & apparatus, medical, precision & optical instruments, 34-35: Motor vehicles, trailers and semi-trailers & other transport equipment, 36-37: Furniture, manufacturing n.e.c., recycling.

aimed at mobilizing extra capital for additional bank loans had no discernible *alleviating* effect on a firm's probability to pursue R&D-based innovative activities. In contrast, non-R&D innovators responded differently to prevailing credit constraints: non-R&D innovators remained unaffected by credit constraints, despite the crisis. Put together, there is evidence that during economically difficult and crisis-stricken times like the global financial crisis when local and global demand faltered, sales collapsed and firms had to more intensely resort to external sources to fund their resource-intensive innovative activities, R&D innovators faced binding credit constraints which barred them from accessing much-needed resources and forced them to discontinue their innovative efforts. In contrast, non-R&D innovators, whose innovative activities are less costly and resource intensive but more of a by-product of daily business operations and a result of learning-by-doing dynamics remained unrestricted by any credit constraints and unaffected by the crisis.

Moreover, the analysis identifies several firm characteristics that are pivotal to any R&D-based or non-R&D-based innovative activities. In particular, probably due to richer and more comprehensive internal funds, before and during the crisis, the propensity to perform formal R&D was significantly higher among medium-sized firms (by around 2 percent) and large firms (by around 3 percent). Hence, for R&D innovators, there is evidence in favour of Schumpeter's size-R&D nexus. On the contrary, non-R&D based innovative activities appear to be in the domain of smaller and relatively resource-deficient firms.

Additionally, in times of crisis, younger firms tend to be more likely to pursue non-R&D-based innovative activities.

The analysis also demonstrates that group membership and foreign ownership were of vital importance, with different effects though. Prior to the crisis, firms that were part of a group and had a higher probability of performing R&D-based innovative activities but a lower probability of performing non-R&D-based innovative activities. Hence, comparatively easy access to vital group-internal technical knowledge, human resources or funds is conducive to R&D-based innovative activities. However, for non-R&D innovators only, the crisis exerted an equalizing effect such that the probability of being a non-R&D innovator became independent of group membership. On the contrary, before the crisis, relative to their predominantly domestically-owned counterparts, majority foreign-owned firms were more likely to be innovative without performing any formal R&D (by 3.3 percent). In the face of the crisis, however, majority foreign-owned firms became less likely to perform non-R&D-based innovative activities but remained more likely to perform R&D-based innovative efforts. 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-

based. Hence, as predominantly production-oriented entities with scarce or no resources for formal R&D, majority foreign-owned firms appear to rely on or resort to non-R&D-based innovative activities to develop new or significantly improved products and/or processes.

Table 2

Probability of being an R&D or non-R&D innovator: 2005 and 2009

	(1)	(2)	(3)	(4)
Variables	R&D innovator 2005	R&D innovator 2009	Non-R&D innovator 2005	Non-R&D innovator 2009
Constant	-0.451**	-0.247	-0.348**	-0.375**
	(2.42)	(1.42)	(2.05)	(2.10)
Credit constrained (yes=1)	-0.605**	-0.426*	0.407	0.118
	(2.56)	(1.86)	(1.61)	(0.48)
Medium-sized (yes=1)	0.391***	0.434***	-0.182**	-0.148
	(4.23)	(4.75)	(2.13)	(1.64)
Large (yes=1)	0.784***	0.571***	-0.425***	-0.387***
	(5.85)	(4.75)	(3.31)	(3.07)
Young (yes=1)	-0.078	-0.077	0.091	0.288**
	(0.57)	(0.58)	(0.69)	(2.18)
Part of a group (yes=1)	0.261**	0.220*	-0.214*	-0.046
	(2.17)	(1.91)	(1.73)	(0.38)
Majority foreign-owned (yes=1)	-0.174	-0.274*	0.344**	0.308*
	(1.02)	(1.67)	(1.99)	(1.82)
Exporter only (yes=1)	0.315*	0.459**	-0.076	-0.059
	(1.76)	(2.52)	(0.42)	(0.31)
Importer only (yes=1)	0.312***	0.466***	-0.086	-0.161
	(3.29)	(4.96)	(0.89)	(1.63)
Exporter and importer (yes=1)	0.603***	0.747***	-0.456**	-0.361**
	(3.55)	(4.54)	(2.52)	(2.05)
Informal sector practices (Likert scale)	0.061**	0.091***	0.002	-0.041
	(2.15)	(2.97)	(0.06)	(1.30)
Competition: minor (yes=1)	0.397**	0.061	-0.761***	-0.447*
	(2.03)	(0.26)	(3.51)	(1.78)
Competition: moderate (yes=1)	-0.012	0.272	-0.147	-0.248
	(0.06)	(1.41)	(0.74)	(1.19)
Competition: strong (yes=1)	0.100	0.070	-0.004	0.016
	(1.24)	(0.87)	(0.05)	(0.20)
Non-production labour share	-0.042	-0.043	0.014	0.027
	(1.41)	(1.49)	(0.76)	(1.01)
Industry dummies	YES	YES	YES	YES
Country dummies	YES	YES	YES	YES
No of observations	1,361	1,397	1,360	1,398
Rho	0.475	0.237	-0.268	0.0495
Log likelihood	-1318.82	-1315.45	-1385.64	-1286.50

Note: Robust z-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Columns (1) and (2) refer to the R&D innovators for 2005 and 2009, respectively, while columns (3) and (4) refer to non-R&D innovators for 2005 and 2009, respectively. Country and industry dummies are included in all regressions. Dependent variable: probability of being an R&D innovator or a non-R&D innovator.

Furthermore, there is supportive evidence that a firm's probability to innovate is affected by its trading status. Particularly, relative to their purely domestic counterparts, internationally

trading firms show a significantly higher probability of performing R&D-based innovative activities, irrespective of the crisis. A somewhat different picture emerges for non-R&D based innovative activities: firms that both exported and imported only were less likely to perform non-R&D based innovative activities, both before the crisis (by 1.7 percent) as well as during the crisis (by 1.2 percent). Overall, emerging patterns seem to suggest that internationally trading firms may have to perform costly adaptive R&D activities to adjust imported or to be exported consumer or producer goods to prevailing conditions (like specific consumer preferences or legal regulations) on the markets they cater to, costs which non-R&D innovators have severe difficulties shouldering.

The degree of competitive pressures firms face on their main product markets also affected their probability to innovate. In particular, contrary to Schumpeter's 'competition-curbs-R&D'-hypothesis but in line with findings by Ayyagari et al. (2007), firms are found to be more likely to pursue R&D-based innovative activities, at least until the crisis set in: prior to the crisis, competition encouraged formal R&D efforts such that firms which operated on product markets with *minor* competition only had a 2 percent higher probability of performing R&D-based innovative activities. With the crisis, however, formal R&D efforts became independent of the degree of product market competition, disrupting any previous competition-R&D nexus. On the contrary, product market competition turns out to be detrimental to non-R&D based innovative activities: irrespective of the crisis, firms showed a lower probability to innovate without performing any formal R&D on product markets with *minor* competition only.

Similarly, firms also responded differently to practices of competitors in the informal sector. Particularly, irrespective of the crisis, firms were more likely to perform R&D-based innovate activities if informal sector practices were more of an obstacle to their current business operations. Hence, innovative efforts may be exerted to gain a competitive edge over firms in the informal sector and to guarantee firm survival and growth. On the contrary, informal sector practices had no significant effect non-R&D based innovative activities, both before as well as during the crisis.

Finally, the endowment with human capital played no role for the propensity to innovate.

Moreover, Table 3 presents results on the probabilities of being credit constrained (equation (2) above) for each of the four specifications in Table 2. Results highlight that the probability of both R&D and non-R&D innovators of being credit constrained was determined by very similar characteristics, both before as well as during the crisis. Specifically, prior to and during the crisis, it was lower among larger (and more resource-abundant) firms and firms that already used a line of credit or loan and therefore had a longer-standing and more reputable debtor-creditor relationship with outside creditors, like banks. Hence, firms that had higher own financial resources at their disposal, also faced a lower

probability of being credit constrained. Moreover, firms which financed their working capital requirements predominantly by means of internal funds and therefore had more substantial internal resources at their disposal showed a significantly lower likelihood of being credit constrained, but only before the crisis struck. On the contrary, exporters faced a significantly lower likelihood of being credit constrained, but during the crisis only.

In contrast, during the crisis only, firms which considered corruption an important obstacle to their current business operations were more likely to face credit constraints.

Table 3

Probability of being credit constrained: 2005 and 2009

	(1)	**(2)**	**(3)**	**(4)**
	R&D innovator	R&D innovator	Non-R&D innovator	Non-R&D innovator
Variables	2005	2009	2005	2009
Constant	0.997**	0.386	0.986**	0.168
	(2.18)	(0.75)	(2.08)	(0.33)
Medium-sized (yes=1)	-0.167*	-0.150	-0.160	-0.156
	(1.72)	(1.47)	(1.64)	(1.52)
Large (yes=1)	-0.423***	-0.315**	-0.426***	-0.337**
	(2.88)	(2.09)	(2.85)	(2.23)
Young (yes=1)	0.080	0.147	0.093	0.140
	(0.52)	(0.94)	(0.59)	(0.90)
Part of a group (yes=1)	-0.093	-0.074	-0.090	-0.064
	(0.64)	(0.49)	(0.60)	(0.42)
Majority foreign-owned (yes=1)	0.153	-0.276	0.167	-0.281
	(0.71)	(1.17)	(0.77)	(1.18)
Exporter	-0.067	-0.284*	-0.053	-0.311*
	(0.42)	(1.66)	(0.33)	(1.80)
Working capital financed by internal funds	-0.004***	-0.002	-0.004***	-0.002
	(3.08)	(1.51)	(3.30)	(1.40)
Credit (yes=1)	-1.082***	-1.243***	-1.095***	-1.246***
	(10.63)	(12.48)	(10.72)	(12.52)
Corruption (Likert scale)	-0.022	0.063*	0.003	0.067**
	(0.69)	(1.91)	(0.09)	(2.04)
Log sales per employee (in US-$)	-0.057	-0.020	-0.060	-0.002
	(1.35)	(0.43)	(1.37)	(0.05)
Industry dummies	YES	YES	YES	YES
Country dummies	YES	YES	YES	YES
No of observations	1,361	1,397	1,360	1,398

Note: Robust z-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Columns (1) and (2) refer to the R&D innovators for 2005 and 2009, respectively, while columns (3) and (4) refer to non-R&D innovators for 2005 and 2009, respectively. Country and industry dummies are included in all regressions.

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. Conse-

quently, bereft of crucial resources, many R&D projects share a common fate and are postponed or abandoned altogether, robbing economies of a strong and reliable engine towards sustained growth and development.

Against that backdrop, the analysis sought to shed light on whether and to what extent prevailing financing constraints in the form of binding credit constraints affected firms' probabilities of being innovators, both before as well as during the global financial crisis of 2009. It therefore explicitly identifies the role of the banking sector for firm-level innovative activities during the global financial crisis which was characterized by globally collapsing capital markets and swiftly contracting global and local credits markets that risked drying-up altogether. Moreover, to also account for the mostly neglected but sizeable group of innovators which introduce innovations without performing any formal R&D, the analysis studies separately constraint-responses of the group of formal R&D innovators - which assign resources to R&D development activities performed in-house - as well as of the group of non-R&D innovators – which do not perform any R&D but still develop and introduce new or significantly improved products and/or processes.

For that purpose, the analysis applies data for a set of Latin American countries 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. Methodologically, a recursive bivariate probit approach is used that incorporates the endogenous nature of the credit constraint condition. Results point at the presence and effects of non-negligible credit constraints: irrespective of the crisis, R&D innovators faced binding credit constraints which rendered them less likely to perform formal R&D. Moreover, there is no evidence that monetary policies aimed at stabilizing capital markets during the crisis by mobilizing extra capital for additional bank loans improved the probability of pursuing R&D-based innovative activities. On the contrary, non-R&D innovators, whose R&D activities are less resource-intensive and risky and more likely the result of learning-by-doing dynamics, remained unrestricted by credit constraints and unaffected by tighter credit markets during the crisis.

In addition, the analysis identified specific firm characteristics that were conducive or obstructive to any R&D or non-R&D activities. It demonstrates that innovative efforts of R&D and non-R&D innovators were driven by an entirely different set of firm characteristics. For *R&D innovators*, there is strong evidence in favour of Schumpeter's 'size-innovation' hypothesis but some indication against his 'competition-curbs-innovation' hypothesis. Furthermore, results also reveal that probably due to insufficient indigenous technological capabilities and the still mainly home country based nature of R&D, formal R&D efforts were less likely among majority foreign-owned firms. Moreover, group-membership and international trading status proved conducive to formal R&D efforts since firms which were part of a group profited from easy access to group-internal technical knowledge, human resources

or funds while internationally trading firms had to adapt their products and/or processes to conditions and needs on their major (domestic or foreign) markets. On the contrary, *non-R&D-based* innovative activities were more likely among majority foreign-owned or smaller firms while firms that both export and import, faced minor product market competition, were part of a group or considered informal sector practices detrimental to their own business activities were less likely to perform non-R&D innovative activities.

Finally, evidence is found that almost identical firm characteristics determined whether R&D and non-R&D innovators faced any binding credit constraints: the probability of encountering any credit constraints was higher among firms whose business operations were more severely affected by corruption but lower among larger firms, exporters, firms with higher internal funds to dispose of and firms that had longer-standing and therefore most likely more reputable debtor-creditor relationships with outside creditors.

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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
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 unfavourable, 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.
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
Young	D=1 if in 2005, firm was younger than 4 years old
Part of a larger firm	D=1 if firm was part of a larger firm
Majority foreign-owned	D=1 if more than 50 percent was owned by private foreign individuals, companies or organizations
Exporter	D=1 if firm earned more than 10 percent from export activities
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
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: minor	D=1 if firm faces only 1 competitor in major market
Competition: moderate	D=1 if firm faces between 2 and five competitors in major market
Competition: strong	D=1 if firm faces more than 5 competitors in major market
Non-production labour share	Ratio of non-production to production workers
Working capital financed by internal funds	Share of working capital financed from internal sources
Credit	D=1 if firm already used a line of credit or loan
Corruption	Likert scale variable; whether corruption was obstacle to current business operations of firms: no obstacle=1, minor obstacle=1, moderate obstacle=2, major obstacle=3 and very severe obstacle=4
Sales per employee	Log of annual sales (in US-$) per employee

Table A2

Descriptive statistics for R&D innovators: 2005

Variable	Obs	Mean	Std. Dev.	Min	Max
R&D innovator	1361	0.42	0.49	0	1
Constrained	1361	0.20	0.40	0	1
Medium-sized	1361	0.41	0.49	0	1
Large	1361	0.20	0.40	0	1
Young	1361	0.08	0.27	0	1
Part of a larger firm	1361	0.12	0.33	0	1
Majority foreign-owned	1361	0.05	0.23	0	1
Exporter only	1361	0.04	0.21	0	1
Importer only	1361	0.26	0.44	0	1
Exporter and importer	1361	0.07	0.25	0	1
Informal sector practices	1361	2.20	1.42	0	4
Competition: minor	1361	0.04	0.19	0	1
Competition: moderate	1361	0.04	0.19	0	1
Competition: strong	1361	0.34	0.47	0	1
Non-production labour share	1361	0.79	1.94	0	54

Table A3

Descriptive statistics for R&D innovators: 2009

Variable	Obs	Mean	Std. Dev.	Min	Max
R&D innovator	1397	0.48	0.50	0	1
Constrained	1397	0.18	0.38	0	1
Medium-sized	1397	0.40	0.49	0	1
Large	1397	0.23	0.42	0	1
Young	1397	0.08	0.28	0	1
Part of a larger firm	1397	0.14	0.34	0	1
Majority foreign-owned	1397	0.06	0.24	0	1
Exporter only	1397	0.05	0.21	0	1
Importer only	1397	0.29	0.45	0	1
Exporter and importer	1397	0.07	0.26	0	1
Informal sector practices	1397	2.12	1.28	0	4
Competition: minor	1397	0.03	0.17	0	1
Competition: moderate	1397	0.04	0.19	0	1
Competition: strong	1397	0.34	0.47	0	1
Non-production labour share	1397	0.80	1.35	0	34

Table A4

Descriptive statistics for non-R&D innovators: 2005

Variable	Obs	Mean	Std. Dev.	Min	Max
Non-R&D innovator	1360	0.38	0.49	0	1
Constrained	1360	0.20	0.40	0	1
Medium-sized	1360	0.41	0.49	0	1
Large	1360	0.20	0.40	0	1
Young	1360	0.08	0.27	0	1
Part of a larger firm	1360	0.12	0.33	0	1
Majority foreign-owned	1360	0.05	0.23	0	1
Exporter only	1360	0.04	0.21	0	1
Importer only	1360	0.26	0.44	0	1
Exporter and importer	1360	0.07	0.25	0	1
Informal sector practices	1360	2.20	1.42	0	4
Competition: minor	1360	0.04	0.19	0	1
Competition: moderate	1360	0.04	0.19	0	1
Competition: strong	1360	0.33	0.47	0	1
Non-production labour share	1360	0.78	1.92	0	54

Table A5

Descriptive statistics for non-R&D innovators: 2009

Variable	Obs	Mean	Std. Dev.	Min	Max
Non-R&D innovator	1398	0.28	0.45	0	1
Constrained	1398	0.18	0.38	0	1
Medium-sized	1398	0.40	0.49	0	1
Large	1398	0.23	0.42	0	1
Young	1398	0.08	0.28	0	1
Part of a larger firm	1398	0.14	0.35	0	1
Majority foreign-owned	1398	0.06	0.24	0	1
Exporter only	1398	0.05	0.21	0	1
Importer only	1398	0.29	0.45	0	1
Exporter and importer	1398	0.07	0.26	0	1
Informal sector practices	1398	2.12	1.28	0	4
Competition: minor	1398	0.03	0.17	0	1
Competition: moderate	1398	0.04	0.19	0	1
Competition: strong	1398	0.34	0.47	0	1
Non-production labour share	1398	0.80	1.35	0	34

Table A6

Correlation matrix for R&D innovators: 2005

	CONSTR	MEDIUM	LARGE	YOUNG	PART	FOREIGN	EXPonly	IMPony	EXPIMP	INFORM	COMmin	COMmed	COMstr	NPLS
CONSTR	1													
MEDIUM	-0.044	1												
LARGE	-0.127	-0.416	1											
YOUNG	0.018	-0.034	-0.097	1										
PART	-0.047	-0.042	0.291	-0.060	1									
FOREIGN	-0.030	-0.049	0.231	-0.034	0.186	1								
EXPonly	0.018	0.017	0.073	-0.036	0.061	0.012	1							
IMPony	-0.101	0.074	0.191	-0.050	0.071	0.122	-0.128	1						
EXPIMP	-0.082	-0.027	0.273	-0.045	0.105	0.130	-0.058	-0.160	1					
INFORM	0.060	0.011	-0.022	-0.003	-0.038	-0.034	0.012	-0.052	-0.082	1				
COMmin	0.023	-0.030	-0.005	-0.002	-0.018	-0.032	-0.025	-0.034	-0.024	-0.194	1			
COMmed	-0.019	0.027	-0.009	0.001	-0.038	0.091	-0.004	-0.028	0.057	-0.154	-0.039	1		
COMstr	-0.027	0.076	0.015	0.041	0.103	0.050	0.052	0.108	0.041	-0.135	-0.143	-0.139	1	
NPLS	-0.033	-0.001	0.066	-0.001	0.088	0.032	-0.031	0.081	0.009	-0.014	-0.027	-0.020	-0.016	1

Table A7

Correlation matrix for R&D innovators: 2009

	CONSTR	MEDIUM	LARGE	YOUNG	PART	FOREIGN	EXPonly	IMPony	EXPIMP	INFORM	COMmin	COMmed	COMstr	NPLS
CONSTR	1													
MEDIUM	-0.064	1												
LARGE	-0.136	-0.448	1											
YOUNG	0.040	-0.049	-0.082	1										
PART	-0.058	-0.072	0.315	-0.083	1									
FOREIGN	-0.055	-0.080	0.269	-0.032	0.199	1								
EXPonly	-0.021	-0.035	0.132	-0.016	0.054	0.033	1							
IMPony	-0.117	0.103	0.183	-0.038	0.123	0.155	-0.138	1						
EXPIMP	-0.089	-0.053	0.241	-0.045	0.040	0.151	-0.061	-0.178	1					
INFORM	0.117	0.013	-0.124	0.012	-0.059	-0.048	-0.021	-0.072	-0.085	1				
COMmin	-0.006	0.003	-0.028	0.022	-0.034	-0.027	0.002	-0.066	0.031	-0.145	1			
COMmed	0.003	0.005	-0.006	-0.007	-0.026	-0.003	-0.008	-0.004	0.044	-0.066	-0.035	1		
COMstr	-0.038	0.022	0.081	-0.015	0.078	0.101	0.063	0.071	0.066	-0.118	-0.126	-0.144	1	
NPLS	-0.040	-0.021	0.029	0.007	0.114	0.015	0.010	0.085	-0.015	0.030	-0.024	-0.052	-0.038	1

Table A8

Correlation matrix for non-R&D innovators: 2005

	CONSTR	MEDIUM	LARGE	YOUNG	PART	FOREIGN	EXPonly	IMPony	EXPIMP	INFORM	COMmin	COMmed	COMstr	NPLS
CONSTR	1													
MEDIUM	-0.044	1												
LARGE	-0.128	-0.416	1											
YOUNG	0.018	-0.034	-0.097	1										
PART	-0.047	-0.042	0.290	-0.060	1									
FOREIGN	-0.030	-0.050	0.231	-0.034	0.186	1								
EXPonly	0.018	0.016	0.073	-0.036	0.061	0.012	1							
IMPony	-0.101	0.074	0.190	-0.050	0.071	0.122	-0.128	1						
EXPIMP	-0.082	-0.027	0.273	-0.046	0.105	0.130	-0.058	-0.160	1					
INFORM	0.060	0.010	-0.022	-0.003	-0.038	-0.034	0.012	-0.052	-0.082	1				
COMmin	0.023	-0.030	-0.005	-0.002	-0.018	-0.032	-0.025	-0.034	-0.024	-0.194	1			
COMmed	-0.019	0.027	-0.009	0.001	-0.038	0.091	-0.004	-0.028	0.057	-0.154	-0.039	1		
COMstr	-0.025	0.075	0.016	0.042	0.104	0.050	0.053	0.109	0.041	-0.136	-0.143	-0.138	1	
NPLS	-0.031	-0.006	0.069	0.001	0.090	0.034	-0.031	0.084	0.010	-0.018	-0.027	-0.020	-0.022	1

Table A9

Correlation matrix for non-R&D innovators: 2009

	CONSTR	MEDIUM	LARGE	YOUNG	PART	FOREIGN	EXPonly	IMPony	EXPIMP	INFORM	COMmin	COMmed	COMstr	NPLS
CONSTR	1													
MEDIUM	-0.064	1												
LARGE	-0.137	-0.448	1											
YOUNG	0.040	-0.049	-0.082	1										
PART	-0.058	-0.074	0.317	-0.084	1									
FOREIGN	-0.055	-0.079	0.268	-0.032	0.198	1								
EXPonly	-0.021	-0.035	0.132	-0.016	0.053	0.033	1							
IMPony	-0.117	0.103	0.182	-0.038	0.121	0.155	-0.138	1						
EXPIMP	-0.090	-0.055	0.245	-0.046	0.046	0.149	-0.061	-0.179	1					
INFORM	0.117	0.014	-0.126	0.012	-0.062	-0.047	-0.021	-0.071	-0.089	1				
COMmin	-0.006	0.003	-0.028	0.023	-0.034	-0.027	0.002	-0.066	0.031	-0.144	1			
COMmed	0.003	0.005	-0.006	-0.007	-0.026	-0.003	-0.008	-0.004	0.043	-0.065	-0.035	1		
COMstr	-0.038	0.022	0.080	-0.015	0.076	0.101	0.063	0.071	0.064	-0.117	-0.126	-0.144	1	
NPLS	-0.040	-0.020	0.028	0.007	0.113	0.015	0.010	0.085	-0.016	0.030	-0.024	-0.052	-0.038	1

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P.b.b. Verlagspostamt 1060 Wien