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Financial Structure and Firm Innovation

Evidence from around the World

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Abstract

This paper analyzes the relationship between financial structure and innovation. Analysis of cross-country micro data over 2009–18 shows that a firm's financial sources matter for the choice to innovate and the extent to which a firm innovates. The relationship is stronger for firms relying on non-bank financial intermediaries and for firms in low-technology sectors. Moreover, the use of external sources of finance is associated with improved prospects of innovation, especially in more financially developed countries. These findings suggest that developing the financial sector can bring benefits in terms of innovation.

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Financial Structure and Firm Innovation: Evidence from around the World

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1 Introduction

Innovation is paramount for firm growth and productivity. Well-functioning deep financial markets promote innovation by efficiently allocating capital to enterprises with promising projects (Levine 2005). Firms with new and better ideas are provided with the means to finance their projects, gaining competitive advantages through productivity increases (Beck, Levine, and Loayza 2000). Enterprises that fail to innovate are at increased risk of losing their competitive edge and may exit the market, allowing for an efficient allocation of (often scarce) financial resources in the economy. In turn, this efficient allocation leads to higher productivity and, ultimately, growth.

Although the existing literature highlights the importance of financing innovation, less is known about the importance of the firm financial structure in supporting innovation. In this paper, we fill this void by investigating the role of a firm financial structure for innovation. In principle, firms can use either internal funds, cash flows from retained profits or new capital injections, or external funding, credit or risk capital. Each source of finance has different characteristics that in turn help in lessening market frictions that may result in the underinvestment in innovation projects. Thus, an important contribution of the paper is to show how the heterogeneity in funding sources is associated with greater firm innovation.

We also provide evidence on the relationship between a firm's financial structure and innovation, defined both as invention and adoption of new technologies, products, and processes (henceforth adoption for ease of exposition). Invention and adoption have different project timelines and cashflow patterns. Moreover, firms face multiple competing investment decisions -e.g., capital investment, debt payments, dividends- to be financed through internal sources or external sources, such as bank loans or other debt or equity contracts. A firm production process may therefore be influenced by both the availability and type of finance. Besides, external funding can assume different forms and it may bring ancillary benefits (e.g., managerial skills) that may propel a firm's innovation process.

Using survey data on more than 17,000 firms in 104 countries, we investigate the cross-country variation in the relationship between financial structure and innovation distinguishing between the development of invention and adoption and diffusion of new technologies, products, and services. We find that bank funding of fixed assets is strongly and positively associated with both the decision to innovate and the intensity of firm-level innovation. The relationship is stronger for invention. Moreover, funding by non-bank financial institutions (NBFI) is strongly associated with the overall extent of innovation and adoption, especially in countries with more developed financial markets and institutions.

Overall, our findings suggest that enterprises may increase investment in innovation while having access to diversified sources of external finance.

Our study contributes to the literature that analyzes the financing of firm innovation. Invention is difficult to finance because of the uncertainty related to cashflows and the timeline from development to commercialization. Some frictions that characterize the financing of invention include also the non-rival nature of knowledge (i.e., development by one firm does not prevent the use by another) and asymmetric information between the firm and prospective financiers (Hall and Lerner 2010).

Non-rival knowledge and spillovers to other enterprises may lower the private rate of return to innovation below the socially optimal level. Lack of full appropriability can reduce investments in innovation. Innovative enterprises may also be reluctant to share the outcomes of the invention in the early stages of development with investors, for fear of losing the intellectual property right of their innovation to competitors. This increases information asymmetries in the market which, together with the high-risk nature of invention outcomes, may make investors reluctant to invest. Stronger intellectual property rights (IPR), accounting standards, and disclosure requirements may help to alleviate this problem. Nevertheless, these frictions may lead to underinvestment in invention.

Asymmetric information between the entrepreneur and the financier is exacerbated in innovative projects. Ex-ante, evaluating invention is problematic because returns are highly uncertain and skewed. The time between the development of the business concept and commercialization is also often long, making for an illiquid investment. Although the innovator and financier face the same uncertainty, the innovator has better technical and business expertise, and could also be over-optimistic about the chances of success. Thus, a contingent contract is hard to achieve, and this may lead to moral hazard on the part of the inventor, which in turn may lead to underinvestment.

Few studies distinguish between invention and the diffusion and adoption of new technologies (henceforth, abbreviated to adoption). Compared to invention, adoption is safer (in terms of probability of success), its timeline is shorter, and firms' loss exposure is more contained. Agency problems are also more limited due to the lower extent of the novelty of the project, which makes it easier to collect information to appraise investment. Technology adoption may nonetheless be costly, depending on the tacit know-how involved, as well as country- and firm-level characteristics. If firms cannot absorb this cost internally and are unable to find external resources, then they may decide to delay or altogether abandon the adoption of the new technology.

In light of the challenges associated with financing innovation, both theory (see, for example, Cole et al., 2016) and empirical evidence (among the others, Ayyagari et al., 2011; and Gorodnichenko and Schnitzer, 2013) support the view that the type of funding affects firms' decision to innovate as well as the extent to which they innovate. Internal financing, specifically retained earnings and new equity from existing shareholders, is the main source of funding for most innovation projects (Czarnitzki and Hottenrott 2011). These sources of funding are especially relevant for small and medium-sized enterprises (SMEs) and start-ups, which cannot rely on banks or the financial market, because of the lack of reputation, stable free cash flows, or lack of the collateral needed to benefit from external sources of finance. Relying on operating profits for innovation projects is far from ideal, however. Cash flows are volatile sources of finance (Brown, Fazzari, and Petersen 2009). Raising new equity can be costly and, at times, unwarranted (Hottenrott and Peters 2012). As a result, innovative projects with high initial costs may be delayed, postponed, or abandoned due to a lack of external finance. Once again, this issue is likely to be most prominent among smaller, younger firms with greater constraints to accessing external finance.

Early empirical studies have focused on the role of bank finance for innovation, finding that banks are not often a feasible source of finance for innovative firms, because they require collateral, and the risk profile and uncertainty that characterize innovative projects make these projects too risky for bank financing. More recent empirical work advocates the role of bank lending for spurring certain firm innovation. For example, Benfratello et al. (2008) suggest that bank lending fosters process innovation likely because firms invest in fixed assets that can serve as collateral for bank lending. Banks also have an important role in softening information asymmetries, collecting information on counterparts that eventually may lead to the financing of firm innovation especially downstream in the innovation process when firms need to produce and commercialize new products and services (Herrera and Minetti 2007). Availability of bank financing also enables firms to lessen financial constraints and catch up with the technological frontier (Bircan and De Haas 2020).

External finance can also be provided in the form of debt and equity. Debt contracts might be too binding given the uncertainty and riskiness of cash flows and the relatively long timeline of the investment. Public equity (stock market) is an important source of finance for innovation as it may have positive effects on the rate and quality of innovation, especially in sectors that are more dependent on external finance (Acharya and Xu 2017). Hsu et al. (2014) suggest that equity market development fosters technological innovation whereas credit market development discourages it. Whether the financial instruments provide only liquidity or also absorb some of the entrepreneurial risk may affect the propensity

to innovate. Private equity is not necessarily a silver bullet for innovation, as it may entail agency costs such as managerial myopia. Managers may underinvest in long-term projects, because of a lack of proper monitoring from market shareholders and increased pressure to meet short-term goals. Going public has been associated with less novel innovation since it is perceived as being riskier by managers (Bernstein 2015). Managers also try to protect their companies from losing market value (being undervalued) due to costly and risky innovation projects that are not understood properly by the market, in the fear of becoming targets to hostile takeovers.

A stream of the literature focuses on the beneficial effects of private markets in the funding of firm innovation. Investors in private markets comprise a wide range of finance types and providers, from crowdfunding and wealthy private investors (i.e., angel investors), to large investment funds such as venture capital, private equity, and private debt. For example, private equity involves the pooling of funds from private investors to be invested in private companies and it entails a medium to long-term investment horizon that is well-suited to finance innovative projects. Moreover, the closer monitoring of a firm operation involves the lowering of agency costs. For instance, patents from leveraged buyout (LBO) firms are more cited, and do not lead to shifts in the nature of research and focus on previously established areas of innovation portfolios. Institutional ownership has been associated with greater innovation and higher R&D expenditures which is less likely to decrease following poor performance, as it may be the case in the initial stages of innovation (see for example Aghion, Van Reenen, and Zingales 2013).

The rest of the paper is organized as follows. Section 2 describes the empirical approach. Section 3 presents the results and robustness tests. Section 4 discusses policy implications and concludes.

2 Empirical approach

In this section, we first describe the data, sample, and variables used in the analysis. We then illustrate the empirical model.

2.1 Data and sample

We gather information from multiple rounds of the World Bank Enterprise Surveys (WB ES) for 104 countries over the period 2009-2018.[2] The WB ES collects information from formal enterprises in the manufacturing and services sectors on a variety of aspects, including access to finance, corruption, infrastructure, crime, competition, and performance measures. We focus on the manufacturing sector

[2] The Enterprise Survey data is available at the following link: https://www.enterprisesurveys.org/en/enterprisesurveys.

because data on the innovation module is available only for this category. Besides, measuring firm innovation in the services sector is intrinsically different from the innovation process in manufacturing (Ettlie and Rosenthal 2011). The sample does not include small jurisdictions that may specialize in a limited number of industries. Our final sample includes 104 countries, of which 12 are high-income countries, 33 are upper-middle countries, 36 are middle-income countries, and the remaining 23 are low-income countries. For 52 economies we have data for 1 survey round; two survey rounds are available for 40 additional countries; and 3 survey rounds for the remaining 12 countries (see Appendix A1 for the list of countries and number of survey waves).

2.2 Measuring firm innovation

Given the available data, we adopt a broad definition of innovation as the accumulation of knowledge and implementation of new ideas. Specifically, innovation is defined as the implementation of a new or significantly improved product (good or service) or process, a new marketing method, or a new organizational method in business practices, workplace organization, or external relations (OECD 2015). We consider innovation defined both as "invention" or "discovery", i.e., those developments to push the technological frontier, and as "diffusion" or "adoption" of existing technologies and practices that lead firms to novel ways of producing or acting (in short adoption). Invention is proxied through expenditures in research and development.

We compute 5 variables to measure the extent of firm innovation and different typologies. as being innovative. Two variables capture the overall degree of a firm's innovativeness (i.e., the intensive margin). This first variable (*innovation score*) measures the intensity of innovation without considering what type of innovation is pursued. It is constructed by summing up 4 questions from the World Bank Enterprise Surveys (WB ES), weighted by the number of questions answered by each firm.[3] It ranges between 0 and 1, with the highest values indicating higher innovation. The second variable (*innovation dummy*) measures whether a firm innovates or not. This innovation dummy takes a value of 1 if a firm innovates in any of the 4 elements composing the innovation score, 0 otherwise. We employ the innovation score in OLS regressions to estimate the association between a firm financial structure and the intensity of firm innovation (see equation 2 below). The innovation dummy is instead used to obtain estimates of a firm

[3] In detail, if a question is left unanswered, the answer is not considered for the computation of the innovation score. In robustness tests we drop firms for which answers are not available for all the questions composing the innovation score. The results reported in section 3 remain qualitatively the same.

propensity to innovate (see equation 1 below). In ancillary regressions not reported in the paper, we compute the innovation score by considering just enterprises that provided answers for all the questions (i.e., unweighted average). Results are insensitive to this change.

We distinguish between adoption (product and process) and invention (proxied by undertaking R&D expenditures) to capture the extensive margin. For adoption, we can construct measures related to the extent of firm innovation and the decision to innovate. The *adoption score* is quantified similarly to the innovation score, but it excludes expenditures in R&D. The focus is on existing processes, technologies, products, and services that are new to the domestic market where a firm operates. We also construct an *adoption dummy* that takes a value of 1 if the adoption score is greater than 0. This variable is used in logistic regressions that estimate the relationship between a firm financial structure and the decision of adoption. Finally, we construct a variable (*Invention*) to measure a firm decision to innovate, proxied by the undertaking of R&D expenditures. The variable takes a value of 1 if a firm has recorded expenses in research and development, 0 otherwise. Table 1 below reports the variable names and description of the firms' innovation variables employed in the empirical approach.

2.3 Financial structure and sources of funding

Our main variable of interest is the financial structure of firms, measured using three separate variables that quantify the proportion of fixed assets financed through different sources. The first ratio quantifies the proportion of fixed assets financed by banks. As shown in Table 2, on average bank funding is the most important source of external funding. The second variable is the percentage of fixed assets financed through non-bank financial institutions. The third variable is the percentage of fixed assets financed through other sources, including credit/advances from suppliers/customers.

2.4 Other variables

We account also for additional firm characteristics that may affect the decision of and the extent to which a firm innovates. *Size* is measured through the natural logarithm of the number of employees. In principle, larger firms are better equipped to innovate more because of larger cash flows, lower fixed costs, and a wider range of human capital skills and knowledge. Yet small size allows for more flexibility in the undertaking of innovative projects (Rogers 2004). We also include a labor productivity variable as firms with a skilled workforce are more likely to pursue innovative projects. The literature documents that innovation of all types tend to have a positive impact on firm-level productivity, as per the surveys of

evidence by Hall (2011) and Mohnen and Hall (2013). In addition, we include a variable for age to control for the different propensity of firms to innovate over their life cycle (Huergo and Jaumandreu 2004). Finally, we control for ownership as, especially in developing countries, being foreign owned may facilitate acquisition and adoption of foreign technologies. Size, age, and ownership have been also recognized as determinants of financing constraints (Beck et al. 2006). The more expensive it is to finance innovation externally, the more detrimental to innovation are the effects of financial constraints. Descriptions of the main variables employed in the estimations are reported in Table 1.

Table 1: Variables definition

Variable	Description
	Dependent variables
Innovation score	It is computed using the following 4 questions from the WB ES: (1) "Does this establishment at present use technology licensed from a foreign-owned company, excluding office software?" (2) "During the last three years, has this establishment introduced new or significantly improved products or services?" (3) "During the last three years, has this establishment introduced any new or significantly improved process?" (4) "During the last fiscal year, did this establishment spend on formal research and development activities, either in-house or contracted with other companies, excluding market research surveys?". The score is then rescaled using the total number of questions for which an answer is available.
Innovation dummy	It takes a value of 1 if the innovation score is greater than 0, 0 otherwise.
Adoption score	The adoption score uses the questions (1) to (3) used for computing the innovation score. For each question, a value of 1 is assigned to Yes answers, 0 otherwise. The score is then rescaled using the total number of questions for which an answer is available.
Adoption dummy	It takes a value of 1 if the adoption score is greater than 0, 0 otherwise.
Invention	The invention dummy considers the question (4) only. It takes the value of 1 if a firm has recorded expenses in research and development, 0 otherwise.
	Main independent variables
% Fixed assets funded by banks	Proportion of fixed assets financed by banks.
% Fixed assets funded by NBFI	Proportion of fixed assets financed by microfinance institutions, credit cooperatives, credit unions, and finance companies.
% Fixed assets funded by other	Proportion of fixed assets financed by family and friends, money lenders, trade credit, and advances from customers.
	Other controls
Log (employees)	Natural logarithm of the firm's permanent full-time employees.
log (labor productivity)	Natural logarithm of annual real sales divided by full-time employees
Age	Difference between the year the firm was formally registered and the year the firm was surveyed.
Percentage of domestic ownership	Percentage of ownership associated to domestic entities/individuals.

Note: The source of data is World Bank Enterprise Surveys.

The descriptive statistics appear in Table 2. The median firm in our sample reports that has undertaken two of the four elements we consider in the innovation score (Table 2, Panel A). Moreover, 78 percent of the enterprises undertake at least one of the four elements used to categorize a firm as being

innovative. Turning to adoption and invention, the median firm undertakes one of foreign technology, product, or process innovation, while almost 43 percent of enterprises in the sample spend on formal research and development activities. Fixed assets are financed mostly by internal funding, followed by banks and other sources of funding. Financing from non-bank financial institutions (NBFI) is very limited, perhaps reflecting the fact that capital and private markets are little developed in most emerging markets and developing economies (EMDEs) in our sample. Finally, there is a moderate pairwise correlation among all the explanatory variables (Table 2, Panel B).

Table 2: Descriptive statistics

Panel A: Summary statistics

Variables	N	Mean	Median	St dev	Min	Max
Innovation score	17,276	0.440	0.500	0.319	0.000	1.000
Innovation dummy	17,276	0.782	1.000	0.413	0.000	1.000
Adoption score	17,276	0.445	0.333	0.332	0.000	1.000
Adoption dummy	17,276	0.744	1.000	0.436	0.000	1.000
Invention	17,276	0.428	0.000	0.495	0.000	1.000
% Fixed assets funded by banks	17,276	0.128	0.000	0.278	0.000	1.000
% Fixed assets funded by NBFI	17,276	0.014	0.000	0.101	0.000	1.000
% Fixed assets funded by other	17,276	0.087	0.000	0.222	0.000	1.000
Log (employees)	17,276	3.718	3.638	1.281	0.000	9.997
log (labor productivity)	17,276	10.178	10.393	1.752	-14.919	20.188
Age	17,276	16.108	13.000	12.176	0.000	193.000
Percentage of domestic ownership	17,276	0.934	1.000	0.231	0.000	1.000

Note: This table reports the descriptive statistics of the main variables included in the estimations. The sample covers 104 countries over the period 2008-2019 (see Table A1).

Panel B: Correlation matrix

Variables		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Innovation score	(1)	1.00										
Innovation dummy	(2)	0.85	1.00									
Adoption score	(3)	0.97	0.85	1.00								
Adoption dummy	(4)	0.85	0.97	0.87	1.00							
Invention	(5)	0.70	0.51	0.43	0.39	1.00						
% Fixed assets funded by banks	(6)	-0.02	-0.02	-0.02	-0.01	0.03	1.00					
% Fixed assets funded by NBFI	(7)	0.02	0.03	0.03	0.03	-0.05	-0.05	1.00				
% Fixed assets funded by other	(8)	0.04	0.04	0.05	0.04	-0.02	-0.14	-0.03	1.00			
Log (employees)	(9)	0.26	0.22	0.24	0.21	0.23	0.04	-0.01	-0.01	1.00		
Log (labor productivity)	(10)	0.12	0.09	0.11	0.09	0.11	0.06	-0.01	-0.03	0.07	1.00	

Age	(11)	-0.03	-0.01	-0.03	0.00	0.01	0.05	0.04	0.00	0.13	-0.03	1.00
Percentage of domestic ownership	(12)	-0.11	-0.10	-0.11	-0.10	-0.05	0.03	0.00	0.00	-0.15	0.05	0.03

Note: This table reports the pairwise correlations of the main variables included in the estimations. The sample covers 104 countries over the period 2008-2019 (see Table A1).

2.5 Estimation method

We employ two different approaches to relate a firm's financial structure to firm innovation. We first run a logistic regression where we relate funding sources to the decision to innovate. The specification is as follows:

$$logit(p_{it}) = ln\left(\frac{p_{it}}{1-p_{it}}\right) = \sum_{p=1}^{3} \beta^p O_{it,c}^p + \sum_{k=1}^{4} \gamma^k F_{it,c}^k + \varepsilon_{it} \quad (1)$$

where the subscripts *i* and *t* denote a firm and year. *p* is either the probability of undertaking an innovation, adoption, or invention. *O* are 3 variables that capture the percentage of fixed assets financed through banks, non-bank financial intermediaries, and other sources. The omitted base category is the percentage of fixed assets financed through internal funds. *F* are 4 controls for size (*Log (employees)*), labor productivity (*log (labor productivity)*), *age* (*Age*), and domestic ownership (*Percentage of domestic ownership*). Standard errors are clustered at the strata level.[4] In some specifications, we add country-fixed effects to capture any systematic difference in countries' level of economic development and institutional environment. We also add time fixed effects to account for the different timing when the WB ES are performed and control for specific occurrences that might affect the decision of a firm to innovate. We also use different samples. In detail, we employ just data on the last WB ES available at the country level or we pool together information on all the WB ES performed over the period 2009-2018 for a country. In addition, in some estimations, we exclude high-income countries to test whether there are systematic differences in the estimated relationship between developing and advanced economies.

$$Score_{it,c} = \sum_{p=1}^{3} \beta^p O_{it,c}^p + \sum_{k=1}^{4} \gamma^k F_{it,c}^k + \varepsilon_{it} \quad (2)$$

where *Score* is either the innovation score or the adoption score. The independent variables are as per Equation (1).

[4] The ES uses the following characteristics to determine the stratified random samples: firm size, business sector and geographic region within a country.

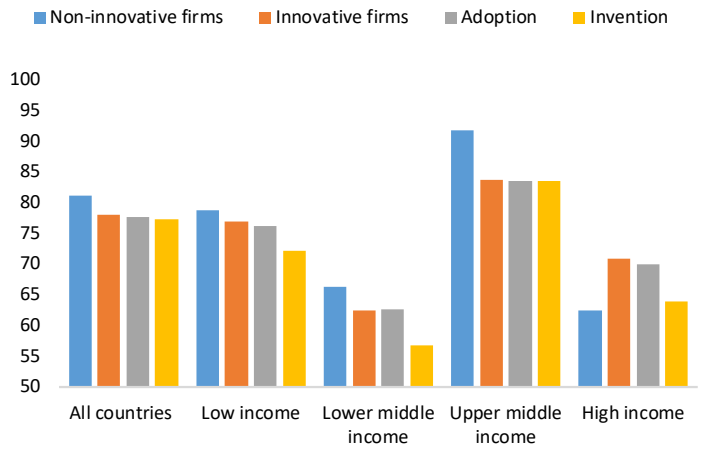
3 Results

We first provide descriptive evidence on the unconditional average association between firm innovation and external finance. Figure 1, Panel A shows the mean percentage of fixed assets financed through internal funds for non-innovative firms, innovative firms, firms adopting innovations, and firms undertaking invention. Countries are grouped according to their income level using the 2019 World Bank classification. Overall, a large percentage of enterprises in EMDEs (i.e., countries other than high-income countries) finance working capital through internal funds, though there is a noticeable difference across income levels. The difference between innovative and non-innovative firms is wider in upper-middle-income countries, and it flips for high-income countries. In general, firms pursuing invention finance working capital with sources other than internal funds, especially in low income and lower-middle-income countries.

Firm innovation is higher for firms that collect funds through external sources (Figure 1, Panel B). Firms at the 25th percentile of the distribution of the percentage of fixed assets financed through internal funds have an innovation score of around 0.41, while firms at the 75th percentile of the distribution have an innovation score of around 0.30. Likewise, there is a strong association between firms pursuing adoption and firm financing of fixed assets, as the interquartile difference is negative and statistical significant at the 1 percent level. The magnitude of the interquartile difference is greater for firms undertaking invention, with a 0.15 interquartile difference between firms that finance working capital through internal funds.

Figure 1: Relationship between firm innovation and funding

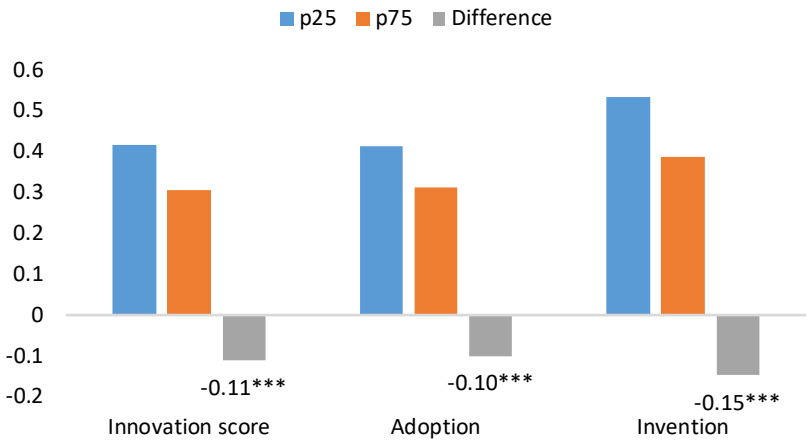
Panel A: Mean percent of fixed assets financed through internal funds, manufacturing



Source: Own elaboration using data from the World Bank – Enterprise Surveys.

Note: This figure reports the mean percent of fixed assets for manufacturing firms financed through internal funds for non-innovative firms; innovative firms (i.e., innovation dummy equals 1); firms that adopt a new product, service or process (i.e., adoption dummy equals 1); firms that undertake invention proxied by whether a firm spend on research and development.

Panel B: Interquartile difference in the financing of fixed assets through internal funds, manufacturing



Source: Own elaboration using data from the World Bank – Enterprise Surveys.
Note: This figure reports the mean percent of fixed assets financed through internal funds for innovative firms. The blue bar denotes the mean percent of fixed assets financed through internal funds for firms in the bottom 25 percent of the distribution of the innovation score and adoption score. The red bars represent the percentage of fixed assets financed through internal funds for firms in the 75 percent of the distribution of the innovation score and adoption score. The gray bars characterize the interquartile differences for the three groups of firms. *** indicates statistical significance at the 1 percent level of the test of the interquartile difference in means.

Table 3 reports the estimates of the association of firm financial structure and firm innovation. The dependent variable is a firm innovation dummy. Across estimations, the percentage of fixed assets funded by banks is strongly associated with the probability of firm innovation. Comparing estimations including the largest set of controls (Table 3, columns 4, 6), the magnitude of the effect is stronger when we include high-income countries in the sample (Table 3, column 4). Estimates are also economically significant as increasing by one percentage point the percentage of fixed assets funded by banks is associated with an increase in the probability of innovation of 6.5 percent. Estimates for the percentage of fixed assets funded by NBFI and other sources of funding are, in most regression, statistically insignificant. Looking at the other control variables, size, and labor productivity are strongly and positively associated with higher firm innovation. Conversely, domestic ownership is negatively associated with firm innovation, perhaps suggesting that foreign ownership implies a greater access to financial resources, technology, knowledge and spurs improvements in corporate governance that lead to higher innovation activities (Choi, Lee, and Williams 2011).

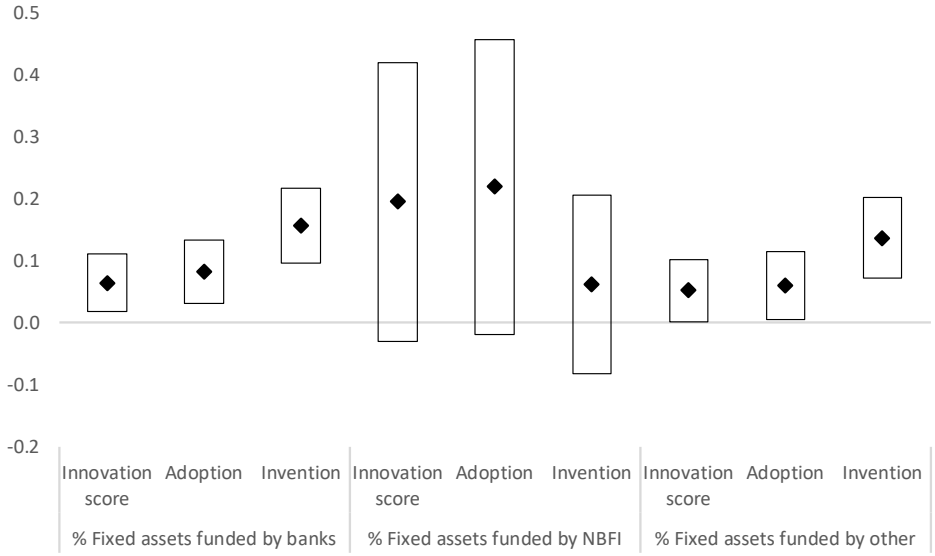
Table 3: Relationship between firm innovation and the sources of funding of fixed assets

Variables	(1)	(2)	(3)	(4)	(5)	(6)
% Fixed assets funded by banks	0.1234***	0.1210***	0.0986***	0.0651**	0.0866**	0.0560*
	(0.0443)	(0.0419)	(0.0380)	(0.0283)	(0.0377)	(0.0302)
% Fixed assets funded by NBFI	0.0903	0.1516	0.3100**	0.1957	0.3221**	0.1955
	(0.0943)	(0.1030)	(0.1326)	(0.1367)	(0.1388)	(0.1467)
% Fixed assets funded by other	0.0224	0.0514	0.0349	0.0526*	0.0290	0.0460
	(0.0433)	(0.0408)	(0.0360)	(0.0305)	(0.0375)	(0.0325)
Log (employees)		0.0317***	0.0337***	0.0333***	0.0331***	0.0338***
		(0.0106)	(0.0114)	(0.0096)	(0.0120)	(0.0104)
log (labor productivity)		0.0218***	0.0342***	0.0239***	0.0308**	0.0248***
		(0.0063)	(0.0125)	(0.0088)	(0.0125)	(0.0091)
Age		0.0004	-0.0006	0.0001	-0.0006	0.0000
		(0.0009)	(0.0009)	(0.0007)	(0.0010)	(0.0008)
Percentage of domestic ownership		-0.1227***	-0.1057***	-0.1193***	-0.1052***	-0.1159***
		(0.0346)	(0.0332)	(0.0353)	(0.0350)	(0.0399)
Country FE			Yes	Yes	Yes	Yes
Year FE				Yes		Yes
Sample	MRES	MRES	MRES	Full	MRES	Full
					No HInc	No HInc
Observations	11,335	11,335	11,271	17,267	10,199	15,563
Number of countries	103	103	103	104	91	92

Note: This table reports the results of the estimation of Equation (1). The dependent variable is a dummy variable measuring whether a firm innovates (value of 1) or not (value of 0), as described in Table 1. In columns (1), (2), (3) and (5) we include data on the last survey available for each country. In columns (4) and (6) we employ the full sample. In columns (5) and (6) we exclude high-income countries. *, **, and *** represent statistical significance at 10%, 5%, and 1% two-tailed level, respectively. Robust standard errors in parentheses, clustered at strata level.

Using the set of controls employed in Table 3, column 4, we run regressions where the dependent variable is either the adoption dummy or invention. Coefficients and their confidence interval at a 90 percent level are reported in Figure 2. Access to bank funding is strongly and positively associated with both adoption and firm invention. The magnitude of the coefficients denotes a stronger increase in the probability of undertaken invention compared to adoption and overall innovation. This pattern of increase in the strength of association from the innovation score to invention is also observed in the case of financing via other sources of funding. Figure 2 shows also the large variability associated with the estimates of the relationship between the percentage of fixed assets financed by NBFIs and innovation measures, resulting in statistically insignificant coefficients.

Figure 2: Relationship between firm innovation, adoption, invention and the sources of funding of fixed assets



Note: This figure reports the coefficients (denoted as diamonds) and the confidence intervals at the 90 percent level (denoted by the rectangular area) resulting from the estimation of Equation (1). The dichotomous dependent variables are the innovation score, adoption, and invention, as described in Table 1. We report the coefficients and the relative confidence intervals for the percentage of fixed assets funded by banks, or non-bank financial institutions (NBFI), or funded by other. All additional controls are as per Equation (1). We also include country and year fixed effects, as done in column (4) Table 3.

Turning to the intensive margin, we find stronger support for the relationship between the intensity of innovation (i.e., how many different types of innovation an enterprise undertakes) and a firm financial structure (Table 4). Estimates for funding sourced through banks are strongly and statistically significant at least at the 5 percent level. The size of the coefficients does not vary significantly across specifications and it implies an increase in the innovation score between 14.6 percent and 18.6 percent of the sample mean for a one percentage point increase in the percentage of fixed assets funded by banks. The estimated coefficients for funding by NBFI and funded by others are also significant at least at the 10 percent level in all regressions except in Table 4, column 1, suggesting that the diversity of sources of funding could be a key driver of a firm intensity in pursuing innovation. In this regard, our results on alternative sources of finance are in line with Allen et al. (2019) that argue that informal finance can improve firm performance.

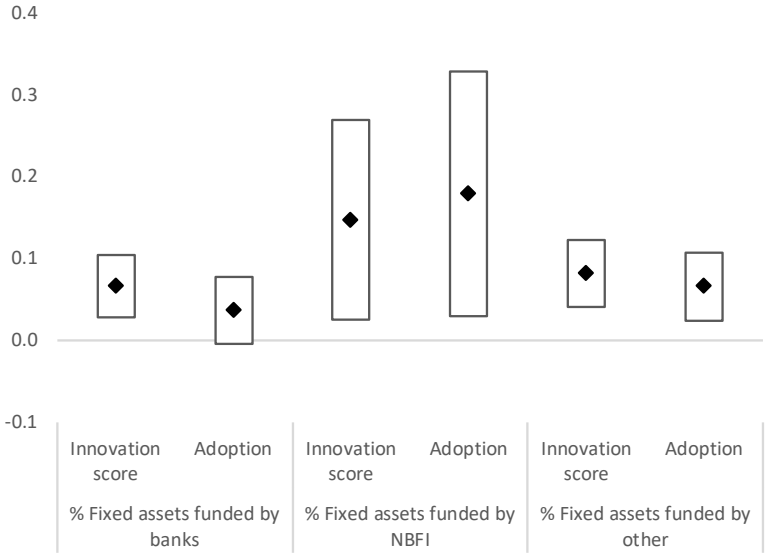
Table 4: Relationship between the extent of firm innovation and the sources of funding of fixed assets

Variables	(1)	(2)	(3)	(4)	(5)	(6)
% Fixed assets funded by banks	0.0645**	0.0643**	0.0707**	0.0660***	0.0820***	0.0717***
	(0.0274)	(0.0259)	(0.0298)	(0.0229)	(0.0268)	(0.0235)
% Fixed assets funded by NBFI	0.0156	0.1004*	0.2196***	0.1470**	0.2325***	0.1518*
	(0.0494)	(0.0569)	(0.0711)	(0.0740)	(0.0739)	(0.0826)
% Fixed assets funded by other	0.0258	0.0539*	0.0749**	0.0812***	0.0693**	0.0764***
	(0.0343)	(0.0310)	(0.0309)	(0.0247)	(0.0321)	(0.0266)
Log (employees)		0.0513***	0.0493***	0.0463***	0.0522***	0.0487***
		(0.0085)	(0.0088)	(0.0075)	(0.0088)	(0.0078)
log (labor productivity)		0.0229***	0.0327***	0.0226***	0.0304***	0.0235***
		(0.0052)	(0.0082)	(0.0064)	(0.0081)	(0.0066)
Age		0.0001	0.0000	0.0002	-0.0002	0.0002
		(0.0007)	(0.0007)	(0.0005)	(0.0007)	(0.0005)
Percentage of domestic ownership		-0.1111***	-0.1136***	-0.1059***	-0.1270***	-0.1100***
		(0.0389)	(0.0389)	(0.0317)	(0.0425)	(0.0374)
Country FE			Yes	Yes	Yes	Yes
Year FE				Yes		Yes
Sample	MRES	MRES	MRES	Full	MRES	Full
					No HInc	No HInc
Observations	11,335	11,335	11,335	17,276	10,263	15,572
Number of countries	103	103	103	104	91	92
R-squared	0.003	0.0753	0.1249	0.1447	0.1260	0.1471

Note: This table reports the results of the estimation of Equation (2). The dependent variable is the innovation score, as described in Table 1. In columns (1), (2), (3) and (5) we include data on the last survey available for each country. In columns (4) and (6) we employ the full sample. In columns (5) and (6) we exclude high-income countries. In the full sample (column 4) we can include in the analysis Ethiopia for which we do not have all the relevant information for MRES. *, **, and *** represent statistical significance at 10%, 5%, and 1% two-tailed level, respectively. Robust standard errors in parentheses, clustered at strata level.

We run regressions in Table 4 including as a dependent variable a firm adoption score. Results are in line with Table 4 and denote a strong association between a firm financial structure and innovation (see Figure 3). Once more the magnitude of the coefficients on the NBFI funding suggests that the development of financing from non-bank financial intermediaries could bring larger benefits than other sources of funding.

Figure 3: Relationship between the extent of firm innovation and adoption, and the sources of funding of fixed assets



Note: This figure reports the coefficients (denoted as diamonds) and the confidence intervals at the 90 percent level (denoted by the rectangular area) resulting from the estimation of Equation (2). The dichotomous dependent variables are the innovation score and adoption, as described in Table 1. We report the coefficients and the relative confidence intervals for the percentage of fixed assets funded by banks, or non-bank financial institutions (NBFI), or funded by others. All additional controls are as per Equation (2). We also include country and year fixed effects, as done in column (4) Table 4.

The literature stresses the importance of technological opportunity to understand the relationship between a firm characteristics and firm-level innovation. Enterprises in information technology or in other high-tech industries are more likely to innovate, according to the World Bank Enterprise Survey data for East Asia (Cirera and Mason, 2021).[5] We, therefore, take a closer look at the innovation performance of the manufacturing firms based on their technology intensiveness. We use the classification from the United Nations Industrial Development Organization (UNIDO),[6] which is based on the R&D expenditure incurred in the production of manufactured goods. Firms are categorized in two buckets: low-technology and medium-high-technology. In line with Bircan and De Haas (2020), we find that firms in less technologically oriented industrial sectors innovate more while using external finance (Table 5). This is particularly true for firms financed through non-bank financial intermediaries, as denoted by the magnitude of the coefficients.

[5] Evidence from few countries suggests that innovation is equally likely in knowledge-intensive business services (Pires et al. 2008).

[6] https://stat.unido.org/content/focus/classification-of-manufacturing-sectors-by-technological-intensity-%2528isic-revision-4%2529;jsessionid=4DB1A3A5812144CACC956F4B8137C1CF.

Table 5: The role of technology and financial structure in financing firm innovation

	OLS		Logit - marginal effects	
Variables	**low tech**	**med-high tech**	**low tech**	**med-high tech**
% Fixed assets funded by banks	0.0924***	0.0346	0.0949**	0.0286
	(0.0352)	(0.0399)	(0.0408)	(0.0413)
% Fixed assets funded by NBFI	0.3384**	0.0129	0.3589*	0.0176
	(0.1672)	(0.1416)	(0.1872)	(0.1106)
% Fixed assets funded by other	0.1264***	-0.0333	0.1340***	-0.0333
	(0.0391)	(0.0432)	(0.0477)	(0.0385)
Adoption				
% Fixed assets funded by banks	0.1428***	0.0290	0.1591***	0.0265
	(0.0369)	(0.0435)	(0.0454)	(0.0446)
% Fixed assets funded by NBFI	0.3818**	0.0301	0.4070**	0.0372
	(0.1594)	(0.1381)	(0.1804)	(0.1191)
% Fixed assets funded by other	0.1379***	-0.0235	0.1455***	-0.0231
	(0.0441)	(0.0450)	(0.0542)	(0.0413)
Invention				
% Fixed assets funded by banks			0.0909*	0.2347***
			(0.0479)	(0.0526)
% Fixed assets funded by NBFI			0.1707**	-0.0011
			(0.0758)	(0.1608)
% Fixed assets funded by other			0.1557***	0.1187**
			(0.0473)	(0.0549)
Additional controls	As per Eq (1)	As per Eq (1)	As per Eq (2)	As per Eq (2)
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	8,972	8,119	8,972	8,119
Number of countries	104	104	104	104

Note: This table reports the results of the estimation of Equation (1) and (2). The dependent variable is the innovation score, as described in Table 1. *, **, and *** represent statistical significance at 10%, 5%, and 1% two-tailed level, respectively. Robust standard errors in parentheses, clustered at strata level.

We run several robustness checks to test the general validity of the results. To mitigate reverse causality issues,[7] we follow Caggese (2019) and restrict the analysis to firms that are not likely to be financially distressed. Because data in the Enterprise Survey is limited, we can consider just firms that are above the median value of real annual sales scaled by the total number of employees. Results in Table 6 shows that funding by NBFI remains weakly related to both the extent of firm innovation and a firm decision to innovate, allaying concerns that the overall strength of the relationship is related to the success of firms to get funding in the first place. Results for firm innovation adoption are also in line with the estimates in Tables 3 and 4.

[7] Debt usage may correlate with future investment in innovation because firms may borrow in anticipation of investment in innovation, rather than borrowing to invest in current innovative projects.

Table 6: Relationship between firm innovation and the sources of funding of fixed assets for the most performing firms

Variables	OLS	Logit
% Fixed assets funded by banks	0.0133	0.0114
	(0.0359)	(0.0373)
% Fixed assets funded by NBFI	0.2036*	0.1962*
	(0.1194)	(0.1172)
% Fixed assets funded by other	0.0291	0.0202
	(0.0423)	(0.0409)
Adoption		
% Fixed assets funded by banks	0.0560	0.0629
	(0.0385)	(0.0441)
% Fixed assets funded by NBFI	0.2255*	0.2331*
	(0.1196)	(0.1318)
% Fixed assets funded by other	0.0571	0.0521
	(0.0455)	(0.0471)
Invention		
% Fixed assets funded by banks		0.0952*
		(0.0553)
% Fixed assets funded by NBFI		0.0845
		(0.1116)
% Fixed assets funded by other		0.0299
		(0.0635)
Additional controls	As per Eq (1)	As per Eq (2)
Country FE	Yes	Yes
Year FE	Yes	Yes
Observations	9,126	9,112
Number of countries	104	104

Note: This table reports the results of the estimation of Equation (1) and (2). The sample comprehends firms above the median value of value of real annual sales scaled by total number of employees. Under the column (OLS), the dependent variables are the innovation score and adoption score, as described in Table 1. Under the column (Logit), the dependent variables are the innovation dummy, the adoption dummy and invention, as described in Table 1. For logit regressions, we report the marginal effects at the means for the explanatory variables. *, **, and *** represent statistical significance at 10%, 5%, and 1% two-tailed level, respectively. Robust standard errors in parentheses, clustered at strata level.

The degree of a country's financial development may also play a role in explaining the relationship between firm innovation and the sourcing of funding of fixed assets. In detail, the association between financing obtained through the formal financial system may be stronger in countries with more developed financial markets and institutions because of the variety of instruments, investors and ancillary services that may spur investment in innovation. Using the financial development index computed by the International Monetary Fund (IMF),[8] we split the sample into countries with low financial development (i.e., in the first quartile of the distribution of the IMF financial development index), and high financial

[8] The explanation and data for the index are available at the following link: https://data.imf.org/?sk=F8032E80-B36C-43B1-AC26-493C5B1CD33B.

development (in the fourth quartile of the IMF financial development index). The estimates show a stronger and significant association between financing from banks and NBFI and the extent of innovation in countries with a high level of financial development (Table 7, OLS, column High FD). Interestingly, the coefficients on financing by other is positive and significant in the sample with low financial development countries for both the innovation score and adoption score (Table 7, OLS, column Low FD), perhaps suggesting that low financial development entails a lower access to external sources of formal financing for innovative firms.

Table 7: Financial development, firm innovation and the sources of funding of fixed assets

	OLS		Logit	
Variables	**Low FD**	**High FD**	**Low FD**	**High FD**
% Fixed assets funded by banks	0.0493	0.0810**	0.0526	0.0841*
	(0.0323)	(0.0397)	(0.0365)	(0.0447)
% Fixed assets funded by NBFI	0.1785	0.2642***	0.1814	0.4113*
	(0.1735)	(0.0715)	(0.1826)	(0.2316)
% Fixed assets funded by other	0.0703**	0.0182	0.0714*	0.0179
	(0.0354)	(0.0512)	(0.0375)	(0.0504)
Adoption				
% Fixed assets funded by banks	0.0312	0.1152***	0.0308	0.1215**
	(0.0329)	(0.0436)	(0.0357)	(0.0513)
% Fixed assets funded by NBFI	0.1776	0.3367***	0.1793	0.5643**
	(0.1666)	(0.0783)	(0.1682)	(0.2804)
% Fixed assets funded by other	0.0641*	0.0394	0.0609	0.0372
	(0.0370)	(0.0583)	(0.0389)	(0.0605)
Invention				
% Fixed assets funded by banks			0.0629*	0.2322***
			(0.0340)	(0.0637)
% Fixed assets funded by NBFI			0.0583	-0.1315
			(0.0881)	(0.1751)
% Fixed assets funded by other			0.0294	0.2696***
			(0.0367)	(0.0828)
Additional controls	As per Eq (1)	As per Eq (1)	As per Eq (2)	As per Eq (2)
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	12,095	4,744	12,095	4,744
Number of countries	87	13	87	13

Note: This table reports the results of the estimation of Equation (1) and (2). The sample comprehends firms in countries in the lowest quartile (Low FD) and highest quartile (High FD) of the distribution of the IMF financial development index. Under the columns (OLS), the dependent variables are the innovation score and adoption score, as described in Table 1. Under the column (Logit), the dependent variables are the innovation dummy, the adoption dummy, and invention, as described in Table 1. For logit regressions, we report the marginal effects at the means for the explanatory variables. *, **, and *** represent statistical significance at 10%, 5%, and 1% two-tailed level, respectively. Robust standard errors in parentheses, clustered at strata level.

Finally, in ancillary regressions not reported in the paper, we control for heterogeneity in the industry by including dummy variables constructed using the two-digit standard industrial classification system. We also drop from the sample the country with the largest number of observations (India) to test whether the results are driven by this country. Results, available from the authors upon request, remain qualitatively the same.

4 Concluding remarks

Firm innovation plays a key role for economic development. Using the World Bank Enterprise Surveys data for a large sample of countries, we find that bank funding of fixed assets is strongly and positively associated with both the decision to innovate and the intensity of firm-level innovation. The relationship is stronger for invention. Funding by NBFI is strongly associated with the overall extent of innovation and adoption, especially in countries with more developed financial markets and institutions. Funding through other sources (including informal financing though family and friends) is also significantly related to the extent of innovation and adoption, indicating the positive association between heterogeneity in the sources of funding and firm innovation.

The most important source in terms of magnitude is NBFI funding, implying that the development of financing from non-bank financial intermediaries could bring larger benefits than other sources of funding. Nonetheless, the high variability around the point estimates cautions that further analyses are needed to dig deeper in the heterogeneity of financing by non-bank financial institutions to capture what country and firm circumstances bring the higher benefits in terms of firm innovation.

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Appendix

Table A1: Sample of countries

In this table we report the countries included in the analysis, the income group according the 2019 World Bank classification, the number of firms included in the last Enterprise Survey available, the total number of firms in the full sample, and the number of surveys available since 2008.

Country	Income group (WB 2019)	Last survey available	Full sample	Number of surveys
India	Lower middle income	1,789	1,789	1
China	Upper middle income	893	893	1
Mexico	Upper middle income	585	591	2
Nigeria	Lower middle income	548	548	1
Chile	High income	436	438	2
Philippines	Lower middle income	360	360	1
Colombia	Upper middle income	325	758	3
Vietnam	Lower middle income	323	323	1
Bangladesh	Lower middle income	315	315	1
Peru	Upper middle income	284	800	3
Argentina	Upper middle income	247	761	3
Myanmar	Lower middle income	202	331	2
Kenya	Lower middle income	183	359	2
Tunisia	Lower middle income	178	178	1
Ukraine	Lower middle income	169	279	2
Costa Rica	Upper middle income	164	164	1
Ghana	Lower middle income	146	146	1
El Salvador	Lower middle income	141	261	3
Tanzania	Low income	133	133	1
Czech Republic	High income	126	184	2
Indonesia	Lower middle income	123	123	1
Mozambique	Low income	112	112	1
Malaysia	Upper middle income	111	111	1
Slovenia	High income	105	162	2
Uganda	Low income	99	99	1
Turkey	Upper middle income	98	356	2
DRC	Low income	97	97	1
Romania	Upper middle income	91	91	1
Zimbabwe	Lower middle income	90	214	2
Uzbekistan	Lower middle income	88	141	2
Thailand	Upper middle income	88	88	1
Sri Lanka	Upper middle income	81	81	1
Nepal	Low income	80	80	1
Kazakhstan	Upper middle income	79	143	2
Zambia	Lower middle income	77	224	2
Hungary	High income	76	96	2
Israel	High income	76	76	1
Russia	Upper middle income	74	544	2
Bolivia	Lower middle income	65	147	3
Belarus	Upper middle income	64	118	2

Country	Income group (WB 2019)	Last survey available	Full sample	Number of surveys
Ecuador	Upper middle income	64	158	3
Paraguay	Upper middle income	62	145	3
Guatemala	Upper middle income	60	214	3
Pakistan	Lower middle income	58	58	1
Malawi	Low income	57	57	1
Sierra Leone	Low income	53	53	1
Uruguay	High income	53	235	3
Nicaragua	Lower middle income	51	132	3
Estonia	High income	50	99	2
Lao PDR	Lower middle income	49	80	2
Senegal	Lower middle income	49	49	1
Dominican Republic	Upper middle income	47	104	2
Jamaica	Upper middle income	47	47	1
Cambodia	Lower middle income	46	132	2
Venezuela	Upper middle income	44	44	1
Latvia	High income	44	88	2
Namibia	Upper middle income	43	43	1
Liberia	Low income	43	43	1
Bulgaria	Upper middle income	42	86	2
Honduras	Lower middle income	42	115	3
South Sudan	Low income	39	39	1
Poland	High income	38	96	2
Bosnia and Herzegovina	Upper middle income	38	92	2
Georgia	Upper middle income	38	89	2
Cameroon	Lower middle income	37	37	1
Gambia	Low income	35	35	1
Rwanda	Low income	35	71	2
Yemen	Low income	32	32	1
Mongolia	Lower middle income	32	96	2
Bhutan	Lower middle income	31	31	1
Lebanon	Upper middle income	31	130	2
Kyrgyz Republic	Lower middle income	29	71	2
Côte d'Ivoire	Lower middle income	29	29	1
Armenia	Upper middle income	28	28	1
Mali	Low income	28	28	1
Slovak Republic	High income	27	68	2
Burundi	Low income	26	26	1
Moldova	Lower middle income	26	52	2
Mauritania	Lower middle income	25	25	1
Serbia	Upper middle income	25	77	2
Benin	Low income	24	24	1
North Macedonia	Upper middle income	24	83	2
Central African Republic	Low income	23	23	1
Lesotho	Lower middle income	23	23	1
Lithuania	High income	22	68	2
Egypt	Lower middle income	21	531	3
Afghanistan	Low income	21	21	1

Country	Income group (WB 2019)	Last survey available	Full sample	Number of surveys
Togo	Low income	20	20	1
Kosovo	Upper middle income	20	74	2
Djibouti	Lower middle income	20	20	1
Croatia	High income	19	94	2
Albania	Upper middle income	19	46	2
Eswatini	Lower middle income	19	19	1
Papua New Guinea	Lower middle income	18	18	1
Chad	Low income	16	16	1
Morocco	Lower middle income	14	88	2
Niger	Low income	13	13	1
Guinea	Low income	10	10	1
Azerbaijan	Upper middle income	9	9	1
Tajikistan	Low income	9	44	2
Jordan	Upper middle income	6	75	2
Sudan	Lower middle income	6	6	1
Montenegro	Upper middle income	5	15	2
Ethiopia	Low income		88	1
Total		**11,335**	**17,276**	**168**