Financial Innovation: The Bright and the Dark Sides

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Abstract:

"*Everybody talks about financial innovation, but (almost) nobody empirically tests hypotheses about it.*"

Frame and White (2004)

The financial turmoil from 2007 onwards has spurred renewed debates on the "bright" and "dark" sides of financial innovation. Using bank-, industry- and country-level data for 32, mostly high-income, countries between 1996 and 2006, this paper is the first to explicitly assess the relationship between financial innovation in the banking sector and (i) real sector growth, (ii) real sector volatility, and (iii) bank fragility. We find evidence for both bright and dark sides of financial innovation. On the one hand, we find that a higher level of financial innovation is associated with a stronger relationship between a country's growth opportunities and capital and GDP per capita growth and with higher growth rates in industries that rely more on external financing and depend more on innovation. On the other hand, we find that financial innovation is associated with higher growth volatility among industries more dependent on external financing and on innovation and with higher idiosyncratic bank fragility, higher bank profit volatility and higher bank losses during the recent crisis.

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1. Introduction

"I wish somebody would give me some shred of evidence linking financial innovation with a benefit to the economy."

– Paul Volcker, former Chairman of the Federal Reserve[1]

The Global Financial Crisis of 2007 to 2009 has spurred renewed wide-spread debates on the "bright" and "dark" sides of financial innovation.[2] The traditional *innovation-growth view* posits that financial innovations help reduce agency costs, facilitate risk sharing, complete the market, and ultimately improve allocative efficiency and economic growth, thus focusing on the bright side of financial innovation. The *innovation-fragility view*, on the other hand, focuses on the "dark" side and has identified financial innovations as the root cause of the recent Global Financial Crisis, by leading to an unprecedented credit expansion that helped feed the boom and subsequent bust in housing prices (Brunnermeier, 2009), by engineering securities perceived to be safe but exposed to neglected risks (Gennaioli, Shleifer and Vishny, 2012), and by helping banks and investment banks design structured products to exploit investors' misunderstandings of financial markets (Henderson and Pearson, 2011). Paul Volcker, former chairman of the Federal Reserve, claims that he can find very little evidence that the financial innovations in recent years have done anything to boost the economy.

This paper gauges the relationship between financial innovation and economic growth and volatility, as well as between financial innovation and banks' risk taking and fragility. Specifically, using OECD innovation survey data on banks' R&D expenditures across 32 mostly developed countries over the period 1996 to 2006, we relate financial innovative activities to capital and GDP per capita growth, industry growth and volatility, and bank fragility and bank performance changes during the recent financial crisis. To our best

[1] Quoted in "Paul Volcker: Think More Boldly," *The Wall Street Journal*, December 14, 2009, p. R7.

[2] In early 2010, the Economist organized a 10-day online debate between Ross Levine and Joseph E. Stiglitz on the role and benefits of financial innovation: http://www.economist.com/debate/overview/166.

knowledge, this is the first paper to systematically explore the consequences of financial innovation in a consistent cross-country setting. This allows us to thus test the different views on financial innovation. While not necessarily exclusive, the two views put the emphasis on different outcomes. While the *innovation-growth view* predicts a positive relationship between financial innovation, resource allocation and economic growth, the *innovation-fragility* view predicts higher financial and real sector fragility and volatility.

There is a striking paucity of empirical studies of determinants and consequences of financial innovation, mainly due the lack of data.[3] For example, after their thorough survey using fairly broad criteria and a long time horizon, Frame and White (2004) conclude that (p.116), "a striking feature of this literature, however, is the relative dearth of empirical studies that specifically test hypotheses or otherwise provide a quantitative analysis of financial innovation." Unlike in manufacturing, patents are scarcely used in the financial service industry or even unavailable, as in the European Union. As a consequence, most existing studies take a "case study" approach and focus on very specific innovations such as new forms of financial securities (e.g. Grinblatt and Longstaff, 2000; Schroth, 2003; Henderson and Pearson, 2011), the introduction of credit scoring techniques (Frame and White, 2004, 2009; Akhavein et al., 2005), new forms of mortgage lending (Rosen, 2007) or new organizational forms, such as Internet-only banks (e.g. DeYoung, 2001, 2005). More recently, Laeven, Levine and Michalopoulos (2011) explore the relationship between the introduction of private credit bureaus and economic growth and show that this specific financial innovation results in faster convergence of countries to the growth path of the most advanced country. None of these papers, however, has taken a holistic approach to the process of financial innovation and its implications for bank fragility and economic development. This paper attempts to fill this gap by providing cross-country evidence on the real and financial sector consequences of financial innovation.

[3] Frame and White (2004 and 2009) conduct a thorough survey of the empirical literature on financial innovation. For theoretical literature related to financial innovation, Duffie and Rahi (1995) introduce a special issue of Journal of Economic Theory.

The theoretical literature has provided different hypotheses on the effects of financial innovation. The traditional *innovation-growth view* posits that financial innovation improves the quality and variety of banking services (Merton, 1992; Berger, 2003), facilitates risk sharing (Allen and Gale, 1988, 1991 and 1994), completes the market (Duffie and Rahi, 1995; Elul, 1995; Grinblatt and Longstaff, 2000), and improves allocative efficiency (Ross, 1976, Houston et al., 2010). Dynan, Elmendorf, and Sichel (2006) suggest that financial innovation has played a key role in reducing the volatility of economic activity in the early parts of the 21st century.[4] Examples of financial innovation abound, ranging from new products, such as securities, over new processes, such as credit scoring, to new financial markets or institutions, such as Internet banks. As pointed out by Laeven, Levine and Michalopoulos (2011), financial innovation has been a driving force behind financial deepening and economic development over the past centuries, as the emergence of specialized lenders and investment banks to finance railroad expansion in the 19th century, the emergence of venture capital firms to finance high-technology firms in the 20th century and the financing of biotech firms through pharmaceutical companies in the 21st century show.

The *innovation-fragility view* has focused more on the dark side of financial innovation. Financial innovations such as securitization change the ex ante incentives of financial intermediaries to carefully screen and monitor the borrowers (Allen and Carletti, 2006). Wagner (2007 a, b) shows that financial innovation that reduces asymmetric information can actually increase risk-taking due to agency problems between bank owners and managers, or because of lower costs of fragility. In the context of the recent lending boom and subsequent Global Financial Crisis, several authors have pointed to distortions introduced by financial innovations, such as securitization and new derivative securities, and how they have contributed to aggressive risk taking, reduction in lending standards and thus fragility (e.g., Keys et al., 2010; Dell'Ariccia, Igan, and Laeven, 2008; Rajan, 2006; and Gennaioli, Shleifer and Vishny, 2012). Recent research by Nadauld and Weisbach (2012) also concludes that securitization lowers the cost of corporate debt.

[4] However, see Den Haan and Sterk (2011) for evidence to the contrary.

Rather than reducing market frictions, however, financial innovation can also arise as reaction to regulation (such as Euro market arose as response to regulation Q) or religious restrictions (such as Sharia-compliant financial products). Specifically, it has been argued that the main purpose of recent financial innovations has been to facilitate regulatory arbitrage by shifting off balance sheet investments that would be more costly were they held on balance sheet. In contrast to the traditional view that financial innovation is to provide more efficient diversification of risk, advocates of the regulatory arbitrage view argue that financial innovation serves to shift that risk to naïve investors who do not know what they are holding and to investors who are confident of being bailed out if things go wrong. For example, Henderson and Pearson (2011) provide evidence that financial innovations help banks and investment banks design structured products to exploit investors' misunderstandings of financial markets. Also related to this argument, Houston et al. (2011) find that regulatory arbitrage incentives play a very important role in determining cross border bank activities and international bank flows. Financial innovation driven by regulatory arbitrage should not improve economic growth or resource allocation, but rather increase financial fragility and economic volatility.

Our paper contributes to the literature by focusing on the process of financial innovation rather than the outcome and gauging its relationship with real and financial sector outcomes across a sample of 32 mostly high-income countries.[5] We follow Tufano's (2003) concept of financial innovation, which includes the process of invention (the ongoing research and development function) and diffusion (or adoption) of new products, services or ideas, and focus on R&D spending in the financial sector. While the level of R&D in the financial system is relatively low compared to other sectors in the economy across our sample of 32 mostly developed countries, we find significant and robust relationships with real and financial sector outcomes. Specifically, we find that a higher level of financial innovation is associated with a stronger relationship between a country's growth opportunities and capital and GDP per capita growth and with higher growth of industries that rely more on external

[5] This is different from Laeven, Levine and Michalopoulos (2011), one of the few other cross-country papers in this area, who focus on one specific financial innovation – private credit bureaus.

financing and industries more dependent on R&D activities. On the other hand, higher levels of financial innovation are also associated with higher growth volatility among industries that rely more on external financing and more on innovative activities. Using a sample of more than 1,500 banks across the same sample countries, we find that a higher level of financial innovation is associated with higher bank risk taking and fragility, especially among banks with smaller market shares, lower loan-asset ratios and higher growth rates. This suggests that smaller banks, banks that diversify away from traditional intermediation and faster growing banks are relatively more fragile in countries with higher levels of financial innovation. We also find that financial innovation is more likely to cause bank fragility in countries with tighter capital regulation, indicating that banks operating in countries with more stringent capital regulation have stronger incentives to engage in regulatory arbitrage activities (Acharya, Wachtel and Walter, 2009). The relationship between financial innovation and bank fragility is driven by higher profit volatility of banks in countries with higher levels of financial innovation. Consistent with these findings, we show that banks' profitability dropped at a higher rate during the recent crisis in countries with higher pre-crisis levels of financial innovation and this relationship is stronger among banks with smaller market shares, lower loan-asset ratios, and operating in countries with tighter capital regulation. Overall, these findings are consistent with both the bright and the dark sides of financial innovation.

Our paper is related to and contributes to several strands of the literature. First, we complement the literature on the importance of financial innovation. Banks are intensive users of both financial and IT technologies, and the rapid rate of financial innovation over the past few decades is widely recognized as a stylized fact (Miller, 1986 and 1992; Merton, 1992; Tufano, 2003; Frame and White, 2004 and 2009). There is an extended descriptive literature that discusses financial innovation, but a relative dearth of empirical studies that are based on quantitative analysis. Our paper attempts to fill this gap by providing a consistent cross-country measure of financial innovation and relating it to an array of real and financial sector outcome variables. Second, we contribute to the literature on finance and economic

growth started by King and Levine (1993).[6] Recent contributions have focused on the non-linearity of the finance-growth link, highlighting declining, insignificant or even negative associations of finance with economic growth at high levels of GDP per capita (Aghion et al., 2005, Rioja and Valev, 2004). We find strong evidence that financial innovation is associated with higher levels of economic growth, even when controlling for aggregate indicators of financial development, in our sample of high-income countries, suggesting that it is not so much the level of financial development, but rather innovative activity of financial intermediaries, which helps countries grow faster at high levels of income. However, we also show that this comes at the cost of higher growth volatility in industries that depend more on external finance and on innovative activity.[7]

Third, we add to the literature that explores the determinants of bank risk taking (e.g. Saunders, Strock, and Travlos, 1990; Houston and James, 1995; Laeven and Levine, 2008; Houston et al., 2010; Demirgüç-Kunt and Huizinga, 2010). While our study is not able to directly answer the larger questions regarding optimal risk taking, we do provide interesting insights into the channels through which financial innovative activity influences banks' business decisions, which in turn affect the level of growth and output volatility. Fourth, our paper is also related to the literature on financial crisis, particularly the recent one (e.g. Brunnermeier, 2009; Johnson and Kwak, 2010; Keys et al., 2010). We find evidence that financial innovation increases bank fragility and profit volatility. Furthermore, we use the most recent global financial crisis as a relatively exogenous shock to examine the impacts of financial innovation on bank performance. Finally, we also contribute to the literature of banking regulation (Barth, Caprio and Levine, 2001, 2006 and 2008; Laeven and Levine, 2009). We find that in countries with more stringent capital regulation, financial innovation is more likely to cause bank instability and performance drops during financial crisis.

Before proceeding, we would like to address some potential concerns readers might have with our approach and findings. First, there is a concern that our measure of financial

[6] See Levine (2004) for literature surveys.

[7] There is a small literature on the link between financial development and volatility. See, among others, Raddatz (2006); Beck, Lundberg and Majnoni (2006); Aghion et al. (2009) and Aghion et al. (2010).

innovation is subject to potential measurement bias as the definition of innovative activity might be less clear in the financial sector than it is in the manufacturing sector. While our measure focuses on the process of financial innovation, we show that it is significantly correlated with specific forms of financial innovation, such as off-balance sheet items, and loan securitization and syndication. A second potential problem for interpreting our results is the endogeneity challenge, which is often a concern in the finance and growth literature. We mitigate this concern by offering several tests of channels and mechanisms through which financial innovation is associated with real and financial sector outcome. Among other techniques, we focus on the differential effects of financial innovation on industries with different needs for external finance and real innovative activity, thus a "smoking gun" approach (Rajan and Zingales, 1998). Moreover, we test the robustness of the results using instrumental variable analyses, which will be discussed in details below, as well as with a placebo test. Furthermore, we use the most recent financial crisis as a relatively exogenous shock and examine the effect of financial innovation on performance changes of banks in the financial crisis. Our results remain significant and consistent in all these tests. Though it is impossible to completely eliminate endogeneity, this seems unlikely to account for our main empirical findings.

The rest of the paper proceeds as follows. Section 2 discusses our cross-country indicator of financial innovation. Section 3 relates financial innovation to real-sector outcome variables, while Section 4 gauges its relationship between bank fragility. Section 5 concludes.

2. Measuring Financial Innovation

The literature on innovation in the manufacturing industry has focused mostly on patents (either outstanding or new ones), R&D expenditures, or share of research staff as indicators of innovative activity (e.g. Helpman, 1993; Cohen and Klepper, 1996; Branstetter et al., 2006). Gauging innovative activity in the financial sector is more challenging, as patents in the financial sector rarely exist and not at all in the European Union. R&D expenditures are typically not collected for financial institutions nor are data on research staff. This lack of

data, as already pointed out by Frame and White (2004) has impeded the rigorous study of financial innovation across countries.

We fill this gap by collecting data on R&D expenditure in the financial intermediation industry from the Analytical Business Enterprise Research and Development database (ANBERD). ANBERD was developed to provide a consistent, internationally comparable data set of enterprise R&D expenditures across industries and over time, and builds on data provided to the OECD by its member countries through the joint OECD/Eurostat R&D survey. ANBERD contains OECD estimates that adjust for deficiencies and anomalies that exist in the official data.[8] Most R&D data are derived from retrospective surveys of the units actually carrying out or "performing" R&D projects, and collected from enterprise surveys via the OECD/Eurostat International Survey of Resources Devoted to R&D from 32 nations in the world from 1987 to 2006. R&D expenditure consists of total intramural and extramural expenditure on R&D following the definition in the Frascati Manual. Intramural expenditure includes all R&D expenses conducted within the firms and reported in R&D surveys. Extramural expenditure comprises acquisition of R&D and grants given to others for conducting R&D activities.

We start our analysis from 1996 when data for nearly all sample countries are available, and we complement the data by OECD Science, Technology and R&D Statistics for some missing data in ANBERD. In particular, we obtain banking sector data of 32 countries from SourceOECD Statistics, including 26 OECD (as of 2009) and six non-member countries.[9]

Based on R&D expenditures, we use two different indicators of R&D activities across countries and years. Specifically, SourceOECD database reports financial R&D intensity relative to the value added in the financial intermediation sector (*Financial R&D Intensity*

[8] As pointed out by the explanatory notes of the database, research and development expenditures in some countries may be underestimated, for example due to different treatment of R&D institutes. Depending on the country, R&D institutes serving enterprises are either classified with the industry concerned, or grouped under "Research and Development" (ISIC rev.3.1, Division 73). When these R&D institutes are classified with the industry served, the evaluation of R&D in these industries is more complete and more comparable between countries for the industries concerned.

[9] The countries include Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States, Israel, Romania, Russian Federation, Singapore, and South Africa.

(Value Added)), and we rely on this as our main gauge of financial innovation. Value added is the value of output less the value of intermediate consumption, and it is a measure of the contribution to GDP made by an individual producer, industry or sector. We use an alternative indicator by standardizing financial R&D by total operating cost of banks to obtain *Financial R&D Intensity (Cost*), where total operating cost refers to total non-interest expenses.[10] The information is drawn from OECD Banking Statistics. For the missing values in some countries, we complement with data from BankScope, using aggregate information for the respective country and year. We note, however, that this alternative indicator may overestimate financial innovation, as we divide by costs related to the banking rather than the overall financial system.[11]

The descriptive statistics in Table 2 (Panel A) shows that the mean value of Financial R&D Intensity (Value Added) is 0.33%, with a standard deviation of 0.39%. The high standard deviation is dominated by cross-country variation (0.34%), with a much lower within-country standard deviation (0.20%). We note that these values are relatively low, though in line with an average R&D intensity of 0.428% in the service industry, excluding the financial sector. They compare to an average of 2.113% in manufacturing across the same sample of countries and years. This relatively limited R&D activity in the financial as opposed to the manufacturing sector shows the relatively limited importance of such activities in banking compared to other sectors of the economy and will also bias our estimations against finding significant relationships between financial innovation and real and financial sector outcomes. *Financial R&D Intensity (Cost)* shows a higher average value (given the smaller denominator) with 1.18%.

While our sample is a relatively homogenous sample of mostly high-income countries, we find high cross-country variation in financial innovation. Appendix Table A1 reports the summary statistics of financial R&D expenditures in absolute numbers (millions USD) across countries, averaged over the sample period 1996 to 2006. While Hungarian banks report

[10] In regression analysis, we further multiply our measures of Financial R&D Intensity by 100 to scale the estimated coefficients for simplicity.

[11] In unreported robustness tests, we also used a gauge of financial innovation based on revenue, with qualitatively similar results.

R&D expenditures of 1.01 million USD, the numbers are 1,358 and 2,042 million USD for the UK and US, respectively. Also banks in Australia, Canada, Denmark, and South Africa report R&D expenditures of more than 100 million USD.[12] Appendix Figure A1 shows an increasing trend in financial innovation over time across our sample countries, almost doubling between 1996 and 2006, consistent with anecdotal evidence on increasing innovative activity within the banking system during this period. Behind this overall trend, however, are important cross-country differences, with Australia, South Africa and the UK experiencing increasing levels of financial innovation and Switzerland experiencing decreasing levels.

[Tables 1 and 2 here]

While most countries in our sample have developed financial systems, we still find a positive correlation between Private Credit and our two indicators of financial R&D intensity, significant at least at the 5% level. The pairwise correlation coefficients are 0.321 (*Financial R&D Intensity (Value Added)*, p-value=0.000), and 0.122 (*Financial R&D Intensity (Cost*), p-value=0.021), respectively. We also find significantly positive correlations between R&D intensity in the financial sector and in other sectors of the economy, including the service industry (without financial sector) and manufacturing. Finally, we find that financial intermediaries in countries with a higher level of GDP per capita report a higher level of financial R&D, though the correlation is not as strong as that between financial depth and financial innovation. The correlations are reported in Appendix Table A2.

We recognize that our indicators of financial innovation are subject to potential measurement error, even though they have been adjusted for irregularities. Most importantly, the data on innovative activity are survey-based and might thus be driven by country-specific concepts of what constitutes financial innovation, even though our sample is a relatively

[12] The high expenditure in Denmark might be related to the high share of mortgage credit in this economy, while South African banks have undertaken significant attempts at expanding outreach after the end of apartheid.

homogeneous one of industrialized economies. We offer four pieces of evidence to show the validity of our measure. The first three link specific forms of financial innovation to our measure of innovative activity.

First, we consider the correlation of financial innovation with the value of off-balance-sheet items (aggregated on the country level and averaged over 1996-2006). Some forms of financial innovation, such as credit card receivables, or subprime residential mortgages are often portrayed as having arisen in part as a means of "arbitraging" regulatory capital requirements by booking assets off the balance sheets of regulated banks (Calomiris, 2009). Therefore, if our variables correctly measure financial innovation, we should find a positive and significant correlation between them. Appendix Figure A2 shows indeed a positive and significant correlation between *Log (Off-Balance-Sheet Items)* and *Log (Financial R&D Expenditure)*. The pairwise correlation coefficient is 0.6546 with p-value of 0.0001.

Second, we plot out the correlations between the natural logarithm of international syndicated credit facilities, domestic and international debt securities issued by financial institutions, and the natural logarithm of financial R&D expenditure. International syndicated credit facilities, like securities, can be traded on the secondary market. The recent innovative products and practices in international syndicated credit facilities include transferable loan certificates (TLCs), transferable participation certificates (TPCs), transferable loan instruments (TLIs), and the use of special purpose vehicle (SPV). Collateralized securities (such as CDOs, CMOs, GNMAs) are included in debt securities. In contrast to domestic debt securities, international debt securities comprise domestic and foreign currency issues by residents of a given country outside their respective domestic market, foreign currency issues by residents in their domestic market and foreign and domestic currency debt securities issued in the domestic market by non-residents. The figures are shown in Appendix Figure A3. The vertical axis is the natural logarithm of the total value of signed international syndicated credit facilities in Panel A, of total amounts outstanding of domestic debt securities in Panel B, and of international debt securities in Panel C, averaged

over 1996-2006 per country, and the horizontal axis is the natural logarithm of financial R&D expenditures of all banks averaged over 1996-2006 per country. The data of international syndicated credit facilities, domestic and international debt securities come from Bank for International Settlement Statistics. We find that all of the correlations are positive and highly significant at 0.1% level, with coefficients above 0.6 or 0.7.

Third, Appendix Figure A4 shows the correlation between the use of CDS, one well-known real example of financial innovation, and the natural logarithm of financial R&D expenditure. We have three panels. The vertical axis in Panel A is the natural logarithm of the number of reference entities holding CDS for each country, with data coming from Markit. The pairwise correlation with financial innovation has a coefficient of 0.5711, which is significant (P-value: 0.0133). The vertical axis is the natural logarithm of the gross notional value of CDS in Panel B and the natural logarithm of the net notional value of CDS in Panel C in aggregate for each country, with data provided by the Depository Trust & Clearing Corporation (DTCC).[13] As shown in Panel B and C, both gross and net notional values of CDS are positively and significantly correlated with financial innovation, with both of the correlation coefficients larger than 0.72 and p-values below 0.001.

Finally, we compare manufacturing R&D intensity from the same OECD survey with patent data in manufacturing from the World Intellectual Property Organization (WIPO) Statistics Database. We find a close and statistically significant relationship between the two (Appendix Figure A5). This reduces concerns that our survey data are driven by country-specific concepts of innovative activity. Overall, this gives us confidence that our indicator is a good proxy for innovative activity in the financial sector.

In summary, our indicators of financial innovation correlate in a meaningful way with real examples of financial innovation and also indicators of innovation in other sectors.

[13] Gross notional values are the sum of CDS contracts bought (or equivalently sold) for all warehouse contracts in aggregate. Aggregate gross notional value and contract data provided are calculated on a per-trade basis. Net notional value with respect to any single reference entity is the sum of the net protection bought by net buyers (or equivalently net protection sold by net sellers). The aggregate net notional data provided is calculated based on counterparty family.

Unlike in other sectors, however, financial innovation cannot be easily captured by a summary output-based gauge, so that our indicator focuses on the process of financial innovation. So, rather than trying to distill new retail products, lending tools and securities into a summary measure, we focus on the process of financial sector R&D. This also implies that our indicator proxies for a more general attitude of a country's financial system towards innovation rather than pick up specific forms of innovation.

3. Financial Innovation and the Real Economy

This section assesses empirically the relationship between financial innovation, on the one hand, and real sector growth and volatility, on the other hand. In doing so, we will employ different panel data sets (i) across countries and over time and (ii) across countries and across industries. In each case, we will first explain the methodology, then describe data and finally discuss the results.

3.1. Does financial innovation help exploit growth opportunities?

Bekaert et al. (2005, 2007) show that exogenous growth opportunities predict subsequent GDP growth and more so in countries with liberalized capital accounts, banking systems and equity markets. We build on this work and gauge the relationship between financial innovation, growth opportunities and GDP per capita and capital per capita growth. We follow Bekaert et al.'s (2007) methodology and measure exogenous growth opportunities for each country by the weighted average of industry price-earnings ratios using data across our sample countries, as we describe in more detail below. We then relate a country's growth opportunities and financial innovation to GDP per capita growth in the following regression model:

$$Growth_{i,t} = \beta_1 GGO\_MA_{i,t} + \beta_2 FI_{i,t} + \beta_3 GGO\_MA_{i,t} * FI_{i,t} + \gamma X_{i,t} + \varepsilon_{i,t}, \quad (1)$$

where $Growth_{i,t}$ is the five-year moving average annual real GDP per capita or real capital growth in country *i* and period *t*; *GGO_MA* is a measure of global growth opportunities and *FI* is one of our indicators of financial innovation. Following Bekaert et al. (2007), we use overlapping five year samples to exploit the time-series information in our sample to a maximum and adjust standard errors accordingly. In addition to presenting OLS regressions, we use a Generalized Methods of Moments (GMM) estimation technique to control for endogeneity and omitted variable bias, with the weighting matrix correcting for cross-sectional heteroskedasticity and for potential endogeneity. Specifically, we use the Arellano and Bond (1991) difference GMM estimator, with lagged levels as the instruments for the first-differenced regressors.[14] Since Bekaert et al. (2007) find that domestic banking development is important for exploiting growth opportunities, we also control for the interaction of GGO_MA and a measure of financial development: Private Credit, which is calculated as the natural logarithm of financial institutions' claims on the private sector divided by GDP. To capture the potential effect of financial liberalization in affecting growth, we also control for the interaction between GGO_MA and a measure of financial liberalization, defined as a dummy that takes on a value of one if there has been a positive change towards financial liberalization index in the respective year (Abiad et al., 2010).[15] We therefore pick up any additional direct effect of financial innovation on growth, beyond the effect through financial development or the effect due to financial liberalization.

The estimate of the regression coefficients β allows us to differentiate between different hypotheses regarding the role of financial innovation. Specifically, a positive β_2 would be evidence in favor of the innovation-growth hypothesis. In addition and consistent with predictions by Laeven et al. (2011), a positive and statistically significant β_3 would provide

[14] In unreported robustness tests, we confirmed our main findings using alternative GMM estimators, including the Arrellano and Bover (1995) system estimator.

[15] The financial liberalization index records financial policy changes along seven different dimensions: credit controls and reserve requirements, interest rate controls, entry barriers, state ownership, policies on securities markets, banking regulations, and restrictions on the financial account. Liberalization scores for each category are then combined in a graded index. The index ranges from 0 to 21, with a larger number indicating a larger extent of financial liberalization. The index was introduced by Abiad and Mody (2005) and extended in Abiad et al. (2010). The extended version covers 91 economies over the period 1973–2005.

evidence for a channel through which financial innovation enhances economic growth, namely through the exploitation of growth opportunities.

We follow Bekaert et al. (2007) in constructing our indicator of growth opportunities. This measure is based on the assumptions that a country's growth potential is reflected in the growth potential of its industry mix and that price-earnings (PE) ratios contain valuable information about an industry's growth opportunities.[16] We compute the global growth opportunities of a country *i* in year *t* as the PE ratios computed on global data on listed companies, averaged across 35 sectors weighed by annual country-specific industry weights based on lagged market capitalization. As this measure might be driven by differences in persistent discount rates, we follow Bekaert et al. (2007) and remove a 60-month moving average from this measure. The descriptive statistics show an average GGO_MA of 0.094 across countries and over time, with a standard deviation of 0.427 (Table 2, Panel B).

We use annual real per capita GDP growth and annual real per capita capital growth rates, using data from the World Development Indicators (WDI). The average real per capita GDP growth rate (5-year moving average) is 1.7%, ranging from -2.1 % in Israel in 2003-2007 to 8.4% in Russia in 2002-2006, with a standard deviation of 2.1%. Real capital per capita growth rates show a higher average (4.0%), but also higher standard deviation (4.0%).

The results in Table 3 show a positive and significant relationship between the interaction of global growth opportunities of a country and financial innovation and both GDP per capita growth and real capital per capita growth. The interaction between *Financial R&D Intensity* (*Value Added)* and growth opportunities enters positively and statistically significant in the regressions of both GDP per capita and real capital per capita growth and both in the OLS and GMM regressions (columns 1, 2, 4 and 5). The level of financial innovation, on the other hand, does not enter significantly, which suggests that it is not financial innovation per se that is associated with faster economic growth and more rapid capital growth, but rather higher levels of financial innovation in countries and periods with

[16] For a more detailed discussion on the advantages of PE ratios over other measures of growth opportunities and details on their construction, see Bekaert et al. (2007).

high growth opportunities. Critically, the positive interaction of global growth opportunities and financial innovation is significant controlling for the interaction of growth opportunities with financial depth, as proxied by Private Credit to GDP, and the interaction of growth opportunities with financial liberalization, neither of which enter significantly.[17]

[Table 3 here]

The effect is not only statistically, but also economically significant. At the mean of financial innovation (0.33%), a move from a country and period with growth opportunities at the mean of 0.09 to a country and period with growth opportunities of one standard deviation above the mean (0.52) predicts an increase in annual real per capita GDP growth from 1.0% to 2.2%. The same increase in growth opportunities in a country with financial innovation one standard deviation above the mean, on the other hand, will lead to an increase of real per capita GDP growth to 3.9%.[18] The economic effect on capital growth rates is even stronger, with 4.3% higher growth at the mean of financial innovation and 6.3% higher growth at mean plus one standard deviation of financial innovation. The results are confirmed by using our alternative indicator of financial innovation, *Financial R&D Intensity* (*Cost)* (columns 3 and 6). The finding that it is financial innovation rather than financial depth that is associated with higher rates of economic and capital growth in our sample of high-income countries is consistent with other evidence that shows a declining effect of financial development on economic growth at higher levels of income per capita or even an insignificant effect (Aghion et al., 2005, Rioja and Valev, 2004). In summary, the evidence presented in Table 3 is consistent with the innovation-growth hypothesis. The relationship between growth opportunities and actual capital and GDP growth is stronger in countries where banks invest more in financial innovation.

[17] Note that the insignificance of the interactions of growth opportunities with Private Credit and financial liberalization might be driven by the limitation of the sample to high-income countries.

[18] To compute these economic effects, we add up the level and the interaction effects of financial innovation.

3.2. Does financial innovation help or hurt industries that rely more on external finance and innovation?

In addition to cross-country estimations, we follow the seminal work by Rajan and Zingales (1998) to test the effect of financial innovation on the growth of industries with different needs for external financing and industries that depend to a different degree on R&D activities. Rajan and Zingales (1998) show that industries that are naturally heavy users of external finance benefit disproportionately more from financial development than industries that are not naturally heavy users of external finance. The methodology has been widely used in the recent literature to explore the differential impact of financial development or specific financial sector characteristics on the differential growth of industries of different characteristics.[19] Larrain (2006) and Raddatz (2006) also look at the effects of bank and financial development on industrial volatility, and we follow their work and investigate the effects of financial innovation on growth volatility. Specifically, we estimate the following two models:

$$Growth_{i,k} = \sum_j \alpha_j Country_j + \sum_l \beta_l Industry_l + \gamma Share_{i,k} + \delta_1 (EFD_k * FI_i) + \delta_2 (EFD_k * FD_i) + \varepsilon_{i,k}, \quad (2)$$

$$Volatility_{i,k} = \sum_j \alpha_j Country_j + \sum_l \beta_l Industry_l + \gamma Share_{i,k} + \delta_1 (EFD_k * FI_i) + \delta_2 (EFD_k * FD_i) + \varepsilon_{i,k}, \quad (3)$$

where $Growth_{i,k}$ is the average annual growth rate of value added in industry k and country i, over the period 1996 to 2006, and $Volatility_{i,k}$ is the standard deviation of the annual growth rate of value added over the same period. *Country* and *Industry* are country and industry dummies, respectively, and $Share_{i,k}$ is the share of industry k in manufacturing in country i in 1996. We interact the external financial dependence (EFD) of an industry with both (a) a measure of overall financial development (*FD*) and (b) an indicator of financial innovation (FI). We do not include financial development or financial innovation on their own, since we focus on within-country, within-industry variation. The dummy variables for industries

[19] See, e,g., Cetorelli and Gambera (2001); Beck and Levine (2002); Raddatz (2006); Kroszner, Laeven and Klingebiel (2007).

and countries control for country and industry specific characteristics that might determine industry growth patterns. We thus isolate the effect that the interaction of EFD and financial development/innovation has on industry growth rates and their volatility relative to country and industry means. By including the initial share of an industry we control for a convergence effect: industries with a large share might grow more slowly, suggesting a negative sign on γ. $\varepsilon_{i,k}$, finally, is the error term. We include several additional interaction terms of external dependence with country characteristics. Specifically, we control for the interaction of external dependence with the Herfindahl index of concentration, government ownership share and entry into banking requirements to thus control for market structure and competition in banking. We also interact external dependence with creditor rights and credit information sharing to thus control for the contractual and informational infrastructures banks operate in. Finally, we include the interaction of external dependence with the foreign bank share to thus control for spill-over effects of financial innovation from parent banks to subsidiaries. The sample excludes the industrial sectors in US, which serves as the benchmark (Rajan and Zingales, 1998). We compute heteroskedasticity-robust standard errors clustered on the country-level.

In a second step, we will run both regressions with R&D intensity (RDI), as measured for a sample of U.S. firms, as industry characteristics to gauge the hypothesis that financial innovation helps disproportionately manufacturing industries that rely more on innovative activity. This hypothesis is based on Laeven, Levine and Michalopoulos (2011) that financial and real sector innovations are positively correlated with each other. On the other hand, higher financial innovation might also expose industries more reliant on external finance or R&D activities to higher growth volatility.

A positive and statistically significant δ_1 in regression (2) would be evidence for the innovation-growth hypothesis, as it would not only suggest a positive impact of financial innovation on industries that are most in need of external finance or more reliant on R&D activities, but such effect would be in addition to the positive effect of financial depth, gauged by δ_2, an effect shown by Rajan and Zingales and confirmed by other authors. A

positive and statistically significant δ_1 in regression (3), on the other hand, would be evidence for the innovation-fragility hypothesis, as it would imply higher growth volatility for industries more reliant on external finance or more dependent on R&D activities in countries with higher levels of financial innovation.

Following Rajan and Zingales (1998), we measure industrial growth as the annual real growth in industry value added. The data on value added for each industry in each country are obtained from the Industrial Statistics Database (INDSTAT4) which is published by United Nations Industrial Development Organization (UNIDO) in 2010. We calculate the average growth rate in real value added for 1996 to 2006 for each industry in each country (*Average Growth Rate in Real Value Added*). The industry level data on *External Financial Dependence (EFD)* are calculated by Rajan and Zingales (1998), who construct their index at the industry level for a sample of US firms. EFD is the fraction of capital expenditures not financed with internal funds for U.S. firms in each three-digit ISIC industry between 1980 and 1990. A higher value of this ratio means that a smaller fraction of capital expenditures is financed by ongoing revenue and therefore represents a higher level of external financial dependence. Rajan and Zingales (1998) argue that for technological reasons such as scale economies, gestation period, the cash harvest period, and intermediate product intensity, some industries might rely more heavily on external finance than others. They further argue that the financial dependence of U.S. industries can serve as an appropriate benchmark because the relatively frictionless, sophisticated, and developed U.S. financial markets should allow U.S. firms to encounter fewer obstacles to achieving their desired financial structure than firms in other countries. This approach thus provides a valid and exogenous way to gauge the extent of an industry's external dependence anywhere in the world. Similarly, we use Computstat data to calculate the average R&D intensity (RDI) across the sample period for each four-digit ISIC industry, defined as weighted-average (based on firm size) R&D intensity (calculated as R&D expenditures divided by total asset) of all the firms with non-missing R&D expenditures in each four-digit ISIC industry.

The final sample used in our average growth regression analysis includes 735 industry observations in 28 countries (Table 2, Panel C).[20] The mean EFD is 0.343, ranging from -0.450 in tobacco industry to 1.490 in drugs industry. The mean R&D intensity (RDI) is 0.031, ranging from 0.002 in manufacture of cement, lime and plaster industry to 0.109 in manufacture of electronic valves and tubes and other electronic components industry. The mean of average growth rate in value added is 0.05%, and this is not surprising since most countries included in the sample are developed countries. The average growth volatility is 23.7% and ranges from 5.4% to 196.6%. The industry with the – on average – highest growth rate over this period was the petroleum refineries industry, while the industry with the – on average – lowest growth rate was the spinning industry. The industry with the – on average – highest growth volatility over this period was the petroleum refineries industry, while the industry with the – on average – lowest growth volatility was the paper and products industry.

The results in columns 1 and 2 of Table 4 show that industries with higher external financial dependence grow faster in countries with higher levels of financial innovation, even controlling for the interaction of external dependence with an indicator of financial development as well as other country characteristics, including the Herfindahl index of concentration, government bank ownership, foreign bank ownership, entry into banking requirements, creditor rights and credit information sharing.[21] The interaction of both measures of financial innovation and external dependence enters positively and statistically significant in the regressions of average growth in real value added. Again, the effect is not only statistically, but also economically significant. Following Rajan and Zingales (1998), we compute the growth difference between industries at the 25th and 75th percentiles of External Dependence and countries at the 25th and 75th percentiles of financial innovation. This growth difference is 1.5%, compared to the average growth of 0.05% in our sample. While the interactions of external dependence with Private Credit and with most other country-level

[20] There are more observations in the industry regressions with RDI, since the matching of industries from SIC to ISIC is a different one than the one used by Rajan and Zingales.

[21] Houston et al. (2010) address the role of creditor rights and credit information sharing in industrial growth, and we therefore also control for these variables. Our results are robust to estimations where we exclude these additional interaction terms.

variables do not enter significantly, we find that industries more dependent on external finance grow more slowly in countries with higher entry requirements for new banks and faster in countries with a higher share of foreign banks, providing evidence for the negative effect of lacking contestability in banking. In unreported robustness tests, we also control for reverse causation by focusing on a sample of industries below the respective country's median industry share in total manufacturing. By focusing on industries with a smaller share we control for the possibility that larger industries' demand will drive supply of credit by financial institutions. Our results are confirmed for the sample of "small" industries.

[Table 4 here]

The results in Table 4 also show that industries more dependent on R&D activities grow faster in countries with higher levels of financial innovation. The interaction terms between R&D intensity (RDI) and financial innovation enter positively and significantly in the regressions of columns (3) and (4) in Table 4. As before, the effect is also economically significant and even stronger than in the case of external dependence, as the growth difference between the industry at the 25th and the 75th percentile of R&D intensity and countries at the 25th and 75th percentiles of Financial Innovation is 4.3%. The results are confirmed when using our alternative indicator of financial innovation. None of the other interaction terms enters significantly in either regression. As in the case of external dependence, we confirm our results focusing on sample of industries below the respective country's median industry share in total manufacturing, thus reducing concerns of reverse causation.

The results in columns 1 and 2 of Table 5 show that industries that rely more on external finance experience higher growth volatility in countries with higher levels of financial innovation. Here, we report regressions of the standard deviation of industry growth over the period 1996 to 2006 on the interaction of financial innovation and external dependence, controlling for the same interactions of external dependence with other country

characteristics as in Table 4. To the same extent that financial innovation helps industries more dependent on external finance grow faster, it could introduce a higher degree of growth volatility in these industries, similar to the effect of financial deepening on growth fluctuations in externally dependent industries (Braun and Larrain, 2005; Kroszner et al., 2007). The coefficient on the interaction of *Financial R&D Intensity (Value Added)* and *External Financial Dependence* enters positively and significantly at the 10% level in column 1, while Financial *R&D Intensity (Cost)* enters positively and significantly at the 1% level in column 2. The economic effect is similarly significant. We undertake the same exercise as in Table 4, computing the growth volatility difference between industries at the 25th and 75th percentiles of External Dependence and countries at the 25th and 75th percentiles of Financial Innovation. This difference in growth volatility is 7.2%, compared to the average growth volatility of 23.7% in our sample. In relative terms, thus, financial innovation explains a smaller share of cross-country cross-industry variation in growth volatility than in industry growth.

The results in columns 3 and 4 of Table 5 show that manufacturing industries that rely more on innovative activity experience higher growth volatility in countries with higher levels of financial innovation. The coefficient on the interaction of *Financial R&D Intensity (Value Added)* and *R&D Intensity* enters positively and significantly at the 5% level in column 3, while Financial *R&D Intensity (Cost)* enters positively and significantly at the 1% level in column 4. The effect is also economically significant. The growth volatility difference between industries at the 25th and 75th percentiles of R&D Intensity and countries at the 25th and 75th percentiles of Financial Innovation is 14.1%, thus larger than the effect of industry differences in external dependence.

[Table 5 here]

Summarizing, the results in Table 5 are consistent with the innovation-fragility view, as industries more reliant on external finance and on innovative activity experience higher

growth volatility in countries where financial intermediaries invest more in financial innovation. Together, the results from our industry regressions in Tables 4 and 5 show a clear trade-off in the effects of financial innovation on the real economy – higher growth, but also higher volatility. In the following, we explore one possible explanation for the positive relationship between financial innovation and volatility, the relationship between financial innovation and banks' fragility and performance during the recent crisis.

4. Financial Innovation and Bank Fragility

This section explores the relationship between financial innovation and bank fragility. Specifically, we relate country-level variation in financial innovation to (i) bank-level variation over time in bank fragility as gauged by the Z-score, including exploring bank-level differences in this relationship, and (ii) bank-level variation in changes in profitability between 2006 and 2008. In doing so, we do not only test the innovation-fragility hypothesis, but also explore mechanisms of why we found a positive relationship between financial innovation and growth volatility in industries that rely more on external finance and on innovative activity.

4.1. Does financial innovation make banks more fragile?

First, following Laeven and Levine (2008) and Houston et al. (2010), we relate a bank-level stability indicator to financial innovation and an array of bank- and country-level control variables:

$$Z_{i,k,t} = \alpha X_{k,\,t-1} + \beta Y_{i,\,t-1} + \gamma FI_{i,t-1} + \nu_i + \sigma_t + \varepsilon_{i,k,t}, \qquad (4)$$

In this setup, the indices *i, k*, and *t* stand respectively for country, bank and time. Z is the log of the z-score of bank *k* in country *i* in period *t*, *X* is a vector of bank characteristics, *Y* is a vector of country characteristics and *FI* is our country-level indicator of financial innovation. The *Z-score* represents the number of standard deviations by which profits would have to fall below the mean so as to deplete equity capital (Boyd et al., 2006) and is defined as (ROA+CAR)/σ(ROA), where ROA is the rate of return on assets, CAR is the ratio of equity

to assets, and σ(ROA) is the standard deviation of ROA. The Z-score is a measure of a bank's distance from insolvency (Roy, 1952) and has been widely used in the recent literature (e.g. Laeven and Levine, 2009; Houston et al., 2009; Demirguc-Kunt and Huizinga, 2010). Since the Z-score is highly skewed, we follow Laeven and Levine (2009) and use the natural logarithm of the Z-score as the risk measure.[22] For brevity, we use the label "Z-score" in referring to the logged Z-score in the remainder of the paper. In our analysis, we use data for more than 1,500 banks across 32 countries over the period from 1996 to 2007 using the BankScope database. We further divide the total of 12 years into four three-year non-overlapping sub-periods, which results in around 4,000 bank-time observations.

Looking at the summary statistics in Panel D of Table 2, we find that the mean log Z-score is 3.93, and that the standard deviation is 1.29.[23] The fairly high standard deviation and the wide range in Z-scores suggest that there is considerable cross-sectional variation in the level of bank risk.

In regression (4), we also include country and time fixed effects ν_i and σ_t, to control for omitted or unobservable country-specific and time-specific variables by capturing the maximum extent of unobservable heterogeneity, following Beck et al. (2013). We also control for several bank-level factors that the literature has shown to predict financial fragility, including bank size (measured as log of total assets in millions of USD), growth in revenue, the liquidity ratio (the ratio of liquid assets to short-term debt), a too-big-to-fail proxy (a dummy variable that takes a value of one if the bank's share in the country's total deposits exceeds 10%) and the Herfindahl index (HHI) to control for market structure. We include the share of foreign-owned banks to control for the spillover effects of financial innovation from one country to another. We also control for several other country factors, including the log of GDP to control for market size, the log of GDP per capita to control for income level as well

[22] Some papers have used the transformation ln(1+Z-score) to avoid truncating the dependent variable at zero. Following Beck et al. (2013), we take the natural logarithm after winsorizing the data at the 1% level. As none of the Z-scores is lower than zero after winsorizing, this approach is similar, save for a rescaling, to the former approach and winsorizing after the transformation.

[23] These summary statistics are similar to those reported by Beck et al. (2011) – looking at a larger sample of more than 80,000 bank-year observations in 79 countries from 1994 to 2009 they report a mean of 4.0057 and a standard deviation of 1.3178, and also to the one by Houston et al. (2010) – a sample of 2,386 banks in 69 countries they report a mean of 3.24.

as several regulatory variables that might be related with banks' risk-taking decisions and thus fragility, including restrictions on banks' activities, requirements on entry into banking, official supervisory power, a tight capital regulation dummy and an index of financial statement transparency, all from the first three waves of the Barth, Caprio and Levine (2008) Bank Regulation and Supervision Database. Specifically, the values of regulation and foreign bank ownership variables for the period of 1996 to 1999 are taken from the first survey recorded in 1998/1999. The values for the period of 2000 to 2003 are taken from the second survey that assesses the state of regulation as of the end of 2002, and the measures for the period of 2004 to 2006 are taken from the third survey that was recorded in 2005/2006.[24] The information of GDP and GDP per capita comes from World Development Indicators (WDI). Although we control for an array of country characteristics, the stability of individual banks within a country might be driven by an omitted factor or might be otherwise correlated with each other. We therefore allow for clustering, i.e. we relax the restrictions that the error terms of banks within a country and period are independent of each other, following Petersen (2009). A negative and statistically significant coefficient estimate γ would be evidence in favor of the innovation-fragility view, suggesting that an increase in financial innovation within a country is related to increased bank fragility, controlling for other time-varying bank and country-level factors. A positive and statistically significant γ, on the other hand, would suggest that a higher level of financial innovation is associated with more stable banking

While we use OLS for our baseline regressions, we also use instrumental variable (IV) analysis to control for omitted variable and endogeneity biases. Specifically, we employ the following two variables to extract the exogenous component of financial R&D intensity: (i) R&D intensity in the service industry excluding financial intermediation firms, and (ii) an intellectual property rights protection index. Intellectual property rights protection index is measured by a score that describes a country's overall protection degree of intellectual

[24] Note that we further divide the sample of 12 years into four three-year non-overlapping period, in order to fully utilize the information. Therefore, the values of regulation for the period of 1996 to 1998 are taken from the first survey, while the values for the period of 1999 to 2001 are the average of the three years 1999 (first survey), 2000 (second survey) and 2001 (second survey). Similarly, the measures for the period of 2002 to 2004 come from the average of three years 2002 (second survey), 2003 (second survey) and 2004 (third survey), while the values for the last period are taken from the third survey.

property rights in year *t*, available from the World Competitiveness Yearbook of the IMD, which is compiled from a comprehensive questionnaire among executives worldwide every year. Each executive is asked to assign a score from 0 (lowest) to 10 (highest) to measure the extent to which "intellectual property rights are adequately enforced." The intuition of using the first instrument is that R&D intensity in the service sector is highly correlated with R&D intensity in banks for each country, reflecting the general attitude towards innovation, but should not have direct effects on risk taking of individual bank except through the channel of R&D intensity in banks. Similarly, the intellectual property rights protection is expected to exert a positive impact on financial innovation activities but is unlikely to directly influence the bank risk taking except through financial innovation.

The results in Table 6 show that banks in countries with higher levels of financial innovation are closer to insolvency, thus providing evidence for the innovation-fragility relationship. The estimation results show a significant and negative coefficient on both measures of financial innovation, while controlling for a large array of bank and country-level indicators. The effect is not only statistically significant but also economically meaningful. For instance, as shown in column 1, a one standard deviation increase in *Financial R&D Intensity (Value Added)* is associated with a reduction in Z-scores of about 23% (=-0.610*0.39). Similarly, a one standard deviation increase in *Financial R&D Intensity (Cost)* is associated with a reduction in Z-score of about 62% (column 2). These effects are thus not only statistically, but also economically significant.

Turning to bank- and country-level control variables, we find banks with higher loan-asset ratios and higher revenue growth have higher z-scores. On the other hand, none of the country-level control variables is consistently associated with banks' Z-score.

[Table 6 here]

Our results are robust to controlling for endogeneity and omitted variable biases. One might argue that a bank engages in more financial innovation because its managers are more

risk loving ex-ante, thus an omitted variable drives both innovation and bank stability. Alternatively, more fragile banks might be willing to engage in more innovative activity in an attempt to save the bank. In the above analysis, we have lagged the independent variables by one period, and therefore the reverse causality problem is less a concern. Nevertheless, we conduct some robustness tests using instrumental variable (IV) analysis. The empirical results are presented in columns 3 and 4 of Table 6. As reported at the bottom of Table 6, F-tests of the significance of the instrument in the first-stage model are always highly significant (p-values lower than 0.001) and exceed 10, which puts us at ease in regard to the weak IV problem.[25]

The results in columns 3 and 4 of Table 6 show that our results are robust to the use of instrumental variables. The coefficients on both measures of *Financial R&D Intensity* remain negative and significant in all model specifications. The results confirm our finding that more financial innovation is associated with higher bank fragility. The IV coefficients are somewhat larger than the ordinary least squares (OLS) coefficients, indicating the existence of potential measurement error, which would tend to ‘‘attenuate’’ the coefficient estimate toward zero in the OLS regression.

Table 7 provides additional evidence on mechanisms and thus causality by exploring a differential relationship between innovation and bank fragility across banks and countries with different characteristics. In other words, we explore whether the relationship between financial innovation and bank fragility is particularly strong for some specific types of banks or for banks in particular regulatory regimes. First, we gauge the effect of financial innovations on bank fragility across heterogeneous bank sizes and market power and interact *Bank Market Share* with financial R&D intensity. On the one hand, banks with dominant market positions might be more tempted to translate higher financial innovation into more risk-taking, exploiting their market power. On the other hand, smaller banks might be more affected by risk-taking following from financial innovation, given the lack of risk

[25] Studies have pointed out that serious problems would arise if instruments are only weakly correlated with the endogenous explanatory variables (Stock et al., 2002; Murray, 2006; Angrist and Pischke, 2009). The standard approach is to rely on the rule of thumb, suggested by Staiger and Stock (1997) and Stock et al. (2002) that values for the first-stage F-Statistic below 10 indicate a weak instrumental variable problem.

diversification possibilities. Second, we interact *Bank Growth* with financial R&D intensity (*Value Added*), as the effect of financial innovations on risk taking and fragility should be more pronounced for high growth banks. Thirdly, we interact *Loan-Asset Ratio* with financial R&D intensity (*Value Added*) to explore whether the effect of financial innovation on bank fragility is more or less pronounced for banks with higher loan to asset ratios. Banks with higher loan to asset ratios are banks with a smaller portfolio of securities. As widely discussed in the recent literature, many of the securities (e.g. CDOs) are products of financial innovation. In the presence of more credit-risky securities, we therefore expect a stronger effect of financial innovation on bank fragility for banks with lower loan-asset-ratios. Finally, we interact *Tight Capital Regulation* with financial R&D intensity (*Value Added*) to investigate whether the effect of innovation on bank instability is larger or smaller for banks in a country with more stringent capital regulation. *Tight Capital Regulation* is a dummy variable which equals to one if the country's capital regulatory index is greater than the median value of the sample. We expect that banks in countries with more stringent capital regulation are more likely to use financial innovation for purposes of regulatory arbitrage to get around strict capital regulation standards, and therefore expect a more pronounced relationship between financial innovation and bank fragility in countries with tighter capital regulation. The empirical results are presented in Table 7. For variables of bank characteristics, we first report regressions with each of the interaction term separately, before including all of them simultaneously. Finally, we report a regression with all three interaction terms with bank-level variables where we replace the country-level time-varying control variables with country-time dummies, which eliminate the impact of omitted or unobservable country-specific variables by capturing the maximum extent of unobserved time-varying country heterogeneity. Exploring the differential relationship between financial innovation and bank fragility across different banks within a country is an additional mechanism to control for biases due to endogeneity and simultaneity.

[Table 7 here]

The results in Table 7 show that the relationship between financial innovation and banks' Z-score is stronger for banks with smaller market shares, higher growth rates and higher loan-asset ratios. As shown in column 1, the interaction term between market share and financial innovation enters the regression significantly at 1% level and shows a positive effect, indicating that the relationship between financial innovation and risk taking is more pronounced for smaller banks. Given the relative size of the two coefficients, however, financial innovation is negative and significant for most of the banks in our sample. Moreover, we find some evidence that the relationship between financial innovation and bank fragility is more pronounced for high growth banks, as indicated by the negative and statistically significant interaction term in columns 4 and 6, though the coefficient is insignificant in column 2. Consistent with our expectation, we find that the relationship between financial innovation and fragility is less pronounced for banks with high loan-asset ratios, though the relationship is negative across the range of loan-asset ratios in our sample.[26] In column 5, we find that the interaction term with *Tight Capital Regulation* is negative and statistically significant at 5% level, indicating that the effect of financial innovation on bank instability is stronger in countries with more stringent capital regulation. This is consistent with our expectation that in countries with tight capital regulation, financial innovation is more likely to cause instability. The regression in column 6 confirms our finding of a declining relationship between financial innovation and bank fragility as banks' market share increases, their revenue growth rate is lower and with a higher reliance on loans. As this regression includes country-time dummies, we explore variation across banks within a given country and given time period and thus control for any omitted time-varying country-level impact that might drive the innovation-fragility relationship.

To further test the robustness of the results and gain insights into the channels through which financial innovation is associated with bank fragility, we consider the three components of the Z-score as well as two alternative measures of bank risk. Specifically,

[26] We also test the robustness of our findings to the use of our alternative indicator of financial innovation, Financial R&D Intensity (Cost). The empirical results are qualitatively similar but less significant.

Table 8 reports regression results with the *Capital-Asset Ratio, ROA*, *Volatility of ROA, Volatility of ROE*, and the *Sharpe Ratio*. All five measures are calculated based on the four three-year non-overlapping sub-periods from 1996 to 2007. Following Demirguc-Kunt and Huizinga (2010), the *Sharpe Ratio* is defined as the mean return on equity over the standard deviation of the return on equity. As in Graham et al. (2008), we take the natural logarithm of these variables to mitigate the effect of skewness in the data.

[Table 8 here]

The results in Table 8 show that higher financial R&D intensity is significantly related to higher volatility of bank profits, but not capitalization or profit levels. Specifically, we find that higher levels of financial innovation are associated with higher levels of ROA volatility, as shown in column 6 (though it enters insignificantly in the *Financial R&D Intensity (Value Added)* regression), higher ROE volatility, as shown in columns 7 and 8 and a lower Sharpe ratio, as shown in columns 9 and 10. On the other hand, we find an insignificant relationship between financial innovation and both ROA and the capital-asset ratio, i.e. the two components of the numerator of the Z-score. Given the positive relationship between financial innovation and ROA volatility, this suggests that the negative relationship between financial innovation and bank stability is driven by higher volatility in banks' profits, while cross-country variation in financial innovation is not related to bank-level variation in capitalization or profitability.

Summarizing, the results in Tables 6 to 8 are supportive of the innovation-fragility hypothesis. Banks are less stable in countries with higher levels of financial innovation, due to higher profit volatility. This relationship is stronger for banks with smaller market shares, banks with faster growth rates and with lower loan-asset-ratios thus more prominent non-traditional banking business. Financial innovation is thus not only associated with higher real sector volatility, as documented in the previous section, but also with higher financial sector volatility.

4.2. Did financial innovation hurt banks during the global crisis?

In a final test of the innovation-fragility hypothesis, we gauge the relationship between banks' profitability during the recent crisis and the intensity of financial innovation before the crisis. Specifically, we regress the difference in ROA or ROE between 2008 and 2006 on financial innovation in 2006 to assess whether banks in countries with higher average levels of financial innovation in the banking sector were affected more negatively during the first year of the global financial crisis. Specifically, we run the following regression

$$\Delta R_{i,k} = \alpha X_k + \beta Y_{i,} + \gamma FI_i + \varepsilon_{i,k}, \quad (6)$$

where R is either ROA and ROE and the right-hand side variables are taken for 2006. A negative sign on γ would indicate that banks in countries with higher levels of financial innovation suffered more during the global financial crisis, consistent with the innovation-fragility hypothesis. As in the panel regressions, we also interact financial innovation with different bank characteristics to gauge whether financial innovation before the crisis is related to bank performance during the crisis differently across banks with different market shares, loan-asset ratios and growth rates.

We use a bank-level panel to assess the relationship between pre-crisis financial innovation and changes in banks' profitability between 2006 and 2008. Descriptive statistics for this sample of 1,537 banks across 32 countries are reported in Panel E of Table 2. On average, banks' ROA dropped by 1.2% between 2006 and 2008, while their ROE dropped by 12%.

The results in Table 9 suggest that higher pre-crisis financial innovation is associated with higher drops in profitability during 2008. Both indicators of financial innovation enter negatively in the regressions of changes in ROA and significantly at 1%. In the regressions of changes in ROE, we find similar results: both financial innovation measures enter negatively and significantly at the 1% and 10% level respectively. The economic effect of this relationship is also large. Taking the columns 1 and 3 estimates, for example, it suggests that a one standard deviation in *Financial R&D Intensity (Value Added)* is associated with a 0.54

percentage point drop in ROA and a 2.76 percentage point drop in ROE, compared to average drops of 1.2 percentage point in ROA and 12 percentage point drop in ROE across our sample.

[Table 9 here]

To drill further down, we also explore whether the effect of the financial innovation on bank performance is particularly strong for some specific types of banks, in a similar manner as in Table 7. Specifically, we interact *Bank Market Share* with financial R&D intensity (*Value Added*) to explore whether small banks suffered more in crisis in countries with higher levels of financial innovation. Moreover, we interact *Loan to Asset Ratio* with financial R&D intensity to explore whether banks with higher loan to asset ratios experienced greater performance drops in countries with higher levels of financial innovation. Thirdly, we interact *Bank Growth* with financial R&D intensity to explore whether faster growing banks suffered a larger decrease in profitability in countries with higher levels of financial innovation. Finally, we interact *Tight Capital Regulation* with financial R&D intensity (*Value Added*) to investigate whether the effect of innovation on bank losses is larger for banks in a country with more stringent capital regulation. Table 10 reports the empirical results of these tests, which support our expectation that banks with weaker market power and banks with lower loan to asset ratios experienced greater performance drops in countries with higher levels of financial innovation, although not all the interaction terms enter significantly. Interestingly, we do not find any significant interaction with bank growth or consistent interactions with tight capital regulation.

[Table 10 here]

In a final test whether our findings in this section are not driven by omitted variable bias, we replace the financial innovation indicator with R&D intensity in manufacturing as a placebo test. If our indicator of financial innovation reflects a general attitude towards

risk-taking in society and the findings in this section are thus driven by a spurious correlation, the indicator of R&D intensity in manufacturing should also enter negatively and significantly. This test is biased in favor of this hypothesis as R&D intensity in manufacturing is positively and significantly correlated with Financial R&D intensity, as discussed earlier.

The results in Appendix Table A3 show that Financial R&D intensity does not proxy for general innovative attitude in the economy. Here, we replicate the regressions of the Z-score for the panel of Table 6 and the regressions of change in ROA and change in ROE for the panel of Table 9. R&D intensity in manufacturing enters positively and insignificantly in the Z-score regressions. Similarly, it also enters positively and insignificantly in the regressions of the changes in ROA and ROE from 2008 to 2006. Thus all of the results have a sign opposite to those in Tables 6 and 9. Overall, these findings provide additional evidence that the relationship between financial innovation and bank fragility is not driven by a spurious correlation.

5. Conclusions

The recent global financial crisis has spurred renewed debates on the "bright" and "dark" sides of financial innovation. Despite its crucial importance and the continuing debate, however, there is a striking paucity in the empirical study of financial innovation and its effect on financial fragility and economic development. Using bank-, industry- and country-level data in 32 countries over the last decade, this paper is the first to explicitly assess the empirical relationship between financial innovation and banks' risk taking and fragility as well as real sector growth and volatility.

We find supportive evidence for both the *innovation-growth* and the *innovation-fragility view.* In support of the *innovation-growth view*, we find that a higher level of financial innovation is associated with a stronger relationship between a country's growth opportunities and capital and GDP per capita growth and with higher growth of industries that rely more on external financing and depend more on R&D activity. In support of the *innovation-fragility view*, we find that a higher level of financial innovation is associated with

higher growth volatility among industries that rely more on external financing and depend more on R&D activity and with higher bank fragility. In addition, banks in countries with higher pre-crisis levels of financial innovation experienced larger drops in ROA and ROE between 2006 and 2008. Moreover, results indicate that in countries with more stringent capital regulation, financial innovation is more likely to cause bank instability and performance drops during financial crisis.

Overall, our results suggest that there are both "bright" and "dark" sides to financial innovation. Financial innovation appears to encourage banks to take on more risks, which helps provide valuable credit and risk diversification services to firms and households, which in turn enhances capital allocation efficiency and economic growth. On the downside, the "dark" side of greater risk taking is that it significantly increases the bank profit volatility and their losses during a banking crisis, which translates into higher volatility in industries that also benefit more from financial innovation.

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Table 1

Variable definitions and data sources

Variable	Definition	Original Sources
Financial Innovation Measures		
Financial R&D Intensity (Value Added)	Banking industry's business enterprise R&D expenditure scaled by financial intermediation sector's total value added in the previous year in each country each year from 1996 to 2006 (reported in SourceOECD Statistics 2010). We further multiply by 100 to scale the estimated coefficients in our empirical results. The R&D data are presenting research and development expenditure statistics in financial intermediation industry collected from enterprise and bank surveys via the OECD/Eurostat International Survey of Resources Devoted to R&D from 32 nations in the world from 1996 to 2006. We complement the data by OECD Science, Technology and R&D Statistics for some missing data. R&D and related concepts follow internationally agreed standards defined by the Organization for Economic Cooperation and Development (OECD), published in the 'Frascati' Manual.	SourceOECD Statistics 2010
Financial R&D Intensity (Cost)	Banking industry's business enterprise research and development expenditure scaled by banking sector's total revenue in each country each year from 1996 to 2006. Operating cost refers to total non-interest expenses. The information is drawn from OECD Banking Statistics. For the missing values in some countries, we complement by the data from BankScope. Specifically, we aggregate all the banks' operating expenses for each country each year in BankScope. We further multiply Financial R&D Intensity by 100 to scale the estimated coefficients in our empirical results.	SourceOECD Statistics 2010, OECD Banking Statistics, BankScope
Exogenous Growth Opportunities Analysis Variables		
Annual Real GDP Growth (5-year horizon)	Growth of real per capita gross domestic product. Available for all countries from 1980 to 2007.	World Development Indicators (2010)
Annual Real Investment Growth (5-year horizon)	Growth of real per capita gross fixed capital formation, which includes land improvements (fences, ditches, drains, and so on), plant, machinery, and equipment purchases, and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings.	World Development Indicators (2010)
GGO_MA	We measure exogenous growth opportunities as GGO_MA, estimated similarly as in Bekaert et al. (2007). Specifically, GGO_MA is the log of the inner product of the vector of global industry PE ratios and the vector of country-specific industry weights, less a 60-month moving average. Country-specific industry weights are determined by relative equity market capitalization.	Datastream
Private Credit	A log of Private credit divided by GDP.	Beck, Demirgüç-Kunt and Levine (2000), updated in 2007
Financial Liberalization	Financial liberalization is an indicator with one indicating financial reform takes place in the year in the country. Specifically, it takes a value of one when the change of financial liberalization index is larger than zero (Abiad et al., 2008). Financial liberalization index recognizes the multifaceted nature of financial reform and records financial policy changes along seven different dimensions: credit controls and reserve requirements, interest rate controls, entry barriers, state ownership, policies on securities markets, banking regulations, and restrictions on the financial account. Liberalization scores for each category are then combined in a graded index. The index ranges from 0 to 21, with a larger number indicating larger extent of financial liberalization. The index was introduced by Abiad and Mody (2005) and extended in Abiad et al. (2008). The extended version covers 91 economies over the period 1973–2005.	Abiad and Mody (2005), Abiad et al. (2008)
Initial Log (GDP Per Capita)	A log of GDP per capita in 1996.	World Development Indicators (2010)
Industrial Level Analysis Variables		
Average Growth Rate in Real Value Added	The average growth rate in real value added for 1996-2006 for each industry in each country. The sample excludes the industrial sectors in the US, which serves as the benchmark (Rajan and Zingales, 1998).	UNIDO INDSTAT4, 2010
Growth Volatility in Real Value Added	The standard deviation of real value added growth for 1996-2006 for each industry in each country. The sample excludes the industrial sectors in the US, which serves as the benchmark (Rajan and Zingales, 1998).	UNIDO INDSTAT4, 2010
EFD	External Financial Dependence (EFD), firstly developed by Rajan and Zingales (1998), is the fraction of capital expenditures not financed with internal funds for U.S. firms in each three-digit ISIC industry between 1980 and 1990.	Rajan and Zingales (1998), Compustat
RDI	RDI is measured by the R&D intensity for U.S. firms in each four-digit ISIC industry. The calculation uses weighted-average (based on firm size) R&D intensity (calculated as R&D expenditures divided by total asset) of all the firms with non-missing R&D intensity in each four-digit ISIC industry.	Compustat

Table 1. (continued)

HHI	To control for competition we use a Herfindahl index, defined as the sum of the squared shares of bank deposits to total deposits within a given country, averaged over the period 1996 to 2006.	BankScope
Government Bank Ownership	The percentage of total shares held by the government or state.	Barth, Caprio, and Levine (2008)
Foreign Bank Ownership	The percentage of total shares held by the foreign country.	Barth, Caprio, and Levine (2008)
Entry into Banking Requirements	The index is developed based on eight questions regarding whether various types of legal submission are required to obtain a banking license. Which of the following are legally required to be submitted before issuance of the banking license? (1) Draft by- laws? (2) Intended organization chart? (3) Financial projections for first three years? (4) Financial information on main potential shareholders? (5) Background/ experience of future directors? (6) Background/ experience of future managers? (7) Sources of funds to be disbursed in the capitalization of new bank? (8) Market differentiation intended for the new bank? The index ranges from zero (low entry requirement) to eight (high entry requirement). Higher values indicate greater stringency.	Barth, Caprio, and Levine (2001, 2006 and 2008)
Creditor Rights	The index measures the power of secured lenders in bankruptcy. A score of one is assigned when each of the following rights of secured lenders is defined in laws and regulations: First, there are restrictions, such as creditor consent, for a debtor to file reorganization. Second, secured creditors are able to seize their collateral after the reorganization petition is approved. Third, secured creditors are paid first out of the proceeds of liquidating a bankrupt firm. Last, management does not retain administration of its property pending the resolution of the reorganization. The index ranges from zero to four. Higher value indicates stronger creditor rights.	La Porta, Lopez-de-Silanes, Shleifer, and Vishny (1998), Djankov, McLiesh, and Shleifer (2007)
Depth of Credit information	An index that measures the information contents of the credit information. A value of one is added to the index when a country's information agencies have each of these characteristics: (1) both positive credit information (for example, loan amounts and pattern of on-time repayments) and negative information (for example, late payments, number and amount of defaults, and bankruptcies) are distributed; (2) data on both firms and individual borrowers are distributed; (3) data from retailers, trade creditors, or utilities, as well as from financial institutions, are distributed; (4) more than two years of historical data are distributed; (5) data are collected on all loans of value above 1% of income per capita; and (6) laws provide for borrowers' right to inspect their own data. The index ranges from 0–6, with higher values indicating the availability of more credit information, from either a public registry or a private bureau, to facilitate lending decisions.	Djankov, McLiesh, and Shleifer (2007), World Bank "Doing Business" database
Industry's Initial Share of Total Manufacturing VA	The industry's share of total value added in manufacturing in 1996 for each industry in each country, which corrects for base effects in industry growth.	UNIDO INDSTAT4, 2010
Bank Level Analysis Variables		
Log z-score	Equals to log of (ROA+CAR)/σ(ROA), where ROA=π/A is return on assets and CAR = E/A is capital-asset ratio, both over 1996-2007. σ(ROA) is standard deviation of ROA over a three-year non-overlapping window across 1996-2007. Higher z implies more stability.	BankScope
σ(ROA)	Equals to the standard deviation of return on asset of a bank, computed over a three-year non-overlapping window from 1996 to 2007.	BankScope
σ(ROE)	Equals to the standard deviation of retrun on equity of a bank, computed over a three-year non-overlapping window from 1996 to 2007.	BankScope
Change in ROA	ROA change between 2008 and 2006, which is calculated as ROA_{2008} - $ROA_{2006.}$	BankScope
Change in ROE	ROE change between 2008 and 2006, which is calculated as ROE_{2008} - $ROE_{2006.}$	BankScope
Sharpe Ratio	Constructed as ROE/ σ(ROE), where ROE is return on equity.	BankScope
Bank Market Share	The share of each bank's deposits to total deposits within a given country.	BankScope
Bank Growth	Total revenue growth rate of a bank.	BankScope
Loan to Asset Ratio	The ratio of loans to total assets.	BankScope
Too-big-to-fail	A dummy variable that takes a value of one if the bank's share in the country's total deposits exceeds 10%.	BankScope
HHI	To control for competition we use a Herfindahl index, defined as the sum of the squared shares of bank deposits to total deposits within a given country, over the period 1996 to 2007.	BankScope
Overall Activities Restrictions	The index measures the degree to which banks face regulatory restrictions on their activities in (a) securities markets, (b) insurance, (c) real-estate, and (d) owning shares in non-financial firms. For each of these four sub-categories, the value ranges from a 0 to 4, where a 4 indicates the most restrictive regulations on this sub-category of bank activity. Thus, the index of overall restrictions can potentially range from 0 to 16.	Barth, Caprio, and Levine (2001, 2006 and 2008)

Table 1. (continued)

Official Supervisory Power	Principal component indicator of 14 dummy variables. The index measures the degree to which the country's commercial bank supervisory agency has the authority to take specific actions. It is composed of information on many features of official supervision based on the questions such as: 1. Does the supervisory agency have the right to meet with external auditors to discuss their report without the approval of the bank? 2. Are auditors required by law to communicate directly to the supervisory agency any presumed involvement of bank directors or senior managers in illicit activities, fraud, or insider abuse? 3. Can supervisors take legal action against external auditors for negligence? 4. Can the supervisory authority force a bank to change its internal organizational structure? 5. Are off-balance sheet items disclosed to supervisors? The index has a maximum value of 14 and a minimum value of 0, where larger numbers indicate greater power.	Barth, Caprio, and Levine (2001, 2006 and 2008)
Entry into Banking Requirements	The index is developed based on eight questions regarding whether various types of legal submission are required to obtain a banking license. Which of the following are legally required to be submitted before issuance of the banking license? (1) Draft by- laws? (2) Intended organization chart? (3) Financial projections for first three years? (4) Financial information on main potential shareholders? (5) Background/ experience of future directors? (6) Background/ experience of future managers? (7) Sources of funds to be disbursed in the capitalization of new bank? (8) Market differentiation intended for the new bank? The index ranges from zero (low entry requirement) to eight (high entry requirement). Higher values indicate greater stringency.	Barth, Caprio, and Levine (2001, 2006 and 2008)
Tight Capital Regulation	It is a dummy variable which equals to one if the country's capital regulatory index is greater than the median value of the sample. The index capital regulatory is constructed from ten variables that indicate whether the capital requirement reflects certain risk elements and deducts certain market value losses from capital adequacy is determined, and whether certain funds may be used to initially capitalize a bank and whether they are officially verified. For example, this measure takes into account whether the minimum capital-asset ratio requirement is in line with the Basel guidelines; whether the minimum ratio varies as a function of an individual bank's credit risk and market risk; and whether the market value of loan losses not realized in accounting books, unrealized losses in securities portfolios, and/or unrealized foreign exchange losses are deducted from the book value of capital. Higher values indicating greater stringency.	Barth, Caprio, and Levine (2001, 2006 and 2008)
Financial Statement Transparency	The transparency of bank financial statements practices. It includes the information on whether accrued, though unpaid, interest/principal enter the income statement; whether financial institutions are required to produce consolidated accounts covering all bank and any non-bank financial subsidiaries; whether off-balance sheet items are disclosed to the public; whether banks are required to disclose their risk management procedures to the public; and whether bank directors are legally liable if information disclosed is erroneous or misleading. Higher values indicate better transparency.	Barth, Caprio, and Levine (2001, 2006 and 2008)
log GDP	Natural logarithm of the real GDP (US Dollars)	World Development Indicators (2010)
log GDP Per Capita	Natural logarithm of GDP per capita (US Dollars)	World Development Indicators (2010)
Real GDP Growth	Growth rates in real GDP.	World Development Indicators (2010)
R&D Intensity in Service Industry (IV Test)	Business enterprise R&D expenditure in the service industry excluding financial intermediation firms scaled by service sector excluding financial firm's total value added in the previous year in each country each year from 1996 to 2006. We further multiply by 100 to scale the estimated coefficients in our empirical results. The R&D data are presenting research and development expenditure statistics in service industry collected from enterprise surveys via the OECD/Eurostat International Survey of Resources Devoted to R&D from 32 nations in the world from 1996 to 2006. We complement the data by OECD Science, Technology and R&D Statistics for some missing data. R&D and related concepts follow internationally agreed standards defined by the Organization for Economic Cooperation and Development (OECD), published in the 'Frascati' Manual.	SourceOECD Statistics 2010
R&D Intensity in Manufacturing Industry (Placebo Test)	Manufacturing industry's business enterprise R&D expenditure scaled by manufacturing sector's total value added in the previous year in each country each year from 1996 to 2006 (reported in SourceOECD Statistics 2010). We further multiply by 100 to scale the estimated coefficients in our empirical results. The R&D data are presenting research and development expenditure statistics in manufacturing industry collected from enterprise surveys via the OECD/Eurostat International Survey of Resources Devoted to R&D from 32 nations in the world from 1996 to 2006. We complement the data by OECD Science, Technology and R&D Statistics for some missing data. R&D and related concepts follow internationally agreed standards defined by the Organization for Economic Cooperation and Development (OECD), published in the 'Frascati' Manual.	SourceOECD Statistics 2010

Table 2
Summary statistics

Panel A. Meausures of financial innovation 1996-2006

Variable	Mean	Standard Deviation	Min	Max	No. of Countries	No. of Obs.
Financial R&D Intensity (Value Added)	0.329%	0.392%	0	1.813%	32	345
Financial R&D Intensity (Cost)	1.179%	2.759%	0	15.833%	32	352

Panel B. Exogenous growth opportunity analysis 1997-2007

Variable	Mean	Standard Deviation	Min	Max	No. of Countries	No. of Obs.
Annual Real GDP Growth (5-year horizon)	0.017	0.021	-0.021	0.084	31	217
Annual Real Investment Growth (5-year horizon)	0.040	0.040	-0.046	0.176	31	207
GGO_MA	0.094	0.427	-0.395	2.785	31	217
Private Credit	4.284	0.760	2.234	5.258	31	204
Financial Liberalization	0.187	0.391	0	1	31	203

Note: The 31 countries include Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Germany, Greece, Hungary, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Singapore, South Africa, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States.

Panel C. Industrial growth and volatility analysis 1996-2006

Variable	Mean	Standard Deviation	Min	Max	No. of Countries	No. of Obs.
Average Growth Rate in Real Value Added	0.047%	11.516%	-40.104%	50.988%	28	735
Growth Volatility in Real Value Added	23.734%	25.969%	5.368%	196.629%	28	734
EFD	0.343	0.397	-0.450	1.490	28	751
RDI	0.031	0.025	0.002	0.109	28	1,134
HHI	0.370	0.232	0.121	0.878	28	1,134
Government Bank Ownership	0.107	0.145	0.000	0.495	28	1,134
Foreign Bank Ownership	0.226	0.284	0.000	0.991	28	1,134
Private Credit	4.300	0.721	2.551	5.307	28	1,134
Entry into Banking Requirements	7.413	0.888	4.091	8.000	28	1,134
Creditor Rights	2.093	1.015	0.000	4.000	28	1,134
Depth of Credit information	4.914	0.763	4.000	6.000	28	1,134
Industry's Initial Share of Total Manufacturing VA	0.023	0.022	0.000	0.101	28	1,134

Note: The 28 countries include Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Germany, Greece, Hungary, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Singapore, South Africa, Spain, Sweden, Turkey, and United Kingdom.

Table 2. (continued)

Panel D. Bank risk taking analysis 1996-2007

Variable	Mean	Standard Deviation	Min	Max	No. of Countries	No. of Obs. (Bank-time)
Bank Level Data						
Log z-score	3.928	1.288	0.101	7.000	32	4,166
ROA	0.010	0.019	-0.184	0.260	32	4,166
ROE	0.095	0.155	-3.094	1.521	32	4,166
CAR	0.107	0.102	0.012	0.821	32	4,166
σ(ROA)	0.011	0.322	1.540E-06	20.778	32	4,166
Bank Growth	0.143	0.221	-0.810	0.992	32	4,137
Too-big-to-fail	0.071	0.247	0	1	32	4,166
Bank Market Share	0.023	0.075	0	1.000	32	4,139
Loan to Asset Ratio	0.587	0.222	0.002	0.928	32	4,166
Country Level Data						
Overall Activities Restrictions	7.141	1.850	3	10	32	4,166
Official Supervisory Power	11.613	2.395	5	14.5	32	4,140
Entry into Banking Requirements	7.492	0.765	0	8	32	4,166
Tight Capital Regulation	0.426	0.495	0	1	32	4,166
Financial Statement Transparency	5.021	0.626	3	6	32	4,166
HHI	0.370	0.232	0.121	0.878	32	4,166
Information Sharing	0.946	0.226	0	1	32	4,166
Log GDP Per Capita	10.229	0.669	7.335	11.349	32	4,166
Log GDP	28.503	1.576	23.443	30.181	32	4,166
R&D Intensity in Manufacturing Industry (Placebo Test)	0.079	0.024	0.011	0.110	32	3,639

Note: The 32 countries include Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Singapore, South Africa, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States.

Table 2. (continued)

Panel E. Bank performance change during crisis period analysis

Variable	Mean	Standard Deviation	Min	Max	No. of Countries	No. of Obs. (Bank-time)
Bank Level Data						
Change in ROA (ROA_{2008} - ROA_{2006})	-0.012	0.026	-0.212	0.032	32	1,536
Change in ROE (ROE_{2008} - ROE_{2006})	-0.118	0.228	-1.240	0.454	32	1,533
Bank growth	0.168	0.458	-0.986	0.992	32	1,537
Too-big-to-fail	0.056	0.230	0	1	32	1,537
Bank Market Share	0.018	0.050	0	0.531	32	1,537
Loan to Asset Ratio	0.604	0.227	-0.004	0.990	32	1,537
Country Level Data						
Overall Activities Restrictions	6.881	1.769	3.273	9.727	32	1,537
Official Supervisory Power	11.119	2.338	6.364	14.13636	32	1,537
Entry into Banking Requirements	7.494	0.675	4.091	8.000	32	1,537
Tight Capital Regulation	0.674	0.469	0	1	32	1537
Financial Statement Transparency	4.984	0.571	3.636	6	32	1,537
HHI	0.098	0.063	0.045	0.2747755		
Creditor Rights	1.900	1.035	0.000	4.000	32	1,537
Information Sharing	0.945	0.213	0	1	32	1,537
Log GDP Per Capita	10.071	0.726	7.758	10.697	32	1,537
Log GDP	28.100	1.593	24.667	29.946	32	1,537
R&D Intensity in Manufacturing Industry (Placebo Test)	28.100	1.593	24.667	29.946	32	1,196

Note: The 32 countries include Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Singapore, South Africa, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States.

Table 3
Exogenous growth opportunities and financial innovation in predicting growth

The sample includes 31 countries between 1997 and 2007. The dependent variables are either the 5-year average growth rate of real per capita gross domestic product or investment. 5-year average is used to minimize the influence of higher frequency business cycles in our sample. We maximize the time-series content of our estimates by using overlapping 5-year periods. We measure exogenous growth opportunities as *GGO_MA*, estimated similarly as in Bekaert et al. (2007). Specifically, *GGO_MA* is the log of the inner product of the vector of global industry PE ratios and the vector of country-specific industry weights, less a 60-month moving average. Country-specific industry weights are determined by relative equity market capitalization. Data to construct these measures come from Datastream. Financial liberalization is an indicator with one indicating financial reform takes place in the year in the country. Specifically, it takes a value of one when the change of financial liberalization index is larger than zero (Abiad et al., 2008). Financial liberalization index recognizes the multifaceted nature of financial reform and records financial policy changes along seven different dimensions: credit controls and reserve requirements, interest rate controls, entry barriers, state ownership, policies on securities markets, banking regulations, and restrictions on the financial account. Liberalization scores for each category are then combined in a graded index. The index ranges from 0 to 21, with a larger number indicating larger extent of financial liberalization. The index covers 91 economies over the period 1973 – 2005. Private credit is a log of private credit divided by GDP, and initial log (GDP per capita) is a log of GDP per capita in 1996. Detailed variable definitions and descriptions can be found in Table 1. We include in the regressions, but do not report, country fixed effects. We report the coefficient on the growth opportunities measure and interaction terms with two measures of financial R&D intensity, private credit/GDP, and financial liberalization. Observations denote the number of country-years. The weighting matrix we employ in our GMM estimation corrects for cross-sectional heteroskedasticity. * Significant at 10%; ** significant at 5%; *** significant at 1%.

	Annual Real GDP Growth (5-Year Horizon)			Annual Real Investment Growth (5-Year Horizon)		
	OLS	GMM		OLS	GMM	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
GGO_MA	0.037**	0.075	-0.105***	0.034	0.343	-0.185
	[0.015]	[0.094]	[0.040]	[0.034]	[0.324]	[0.121]
GGO_MA × Financial R&D Intensity (Value Added)	0.021***	0.081**		0.073***	0.303***	
	[0.007]	[0.033]		[0.020]	[0.095]	
GGO_MA × Financial R&D Intensity (Cost)			0.005***			0.017***
			[0.001]			[0.004]
GGO_MA × Private Credit	-0.011**	-0.033	0.019**	-0.014	-0.132	0.028
	[0.004]	[0.026]	[0.009]	[0.009]	[0.082]	[0.030]
GGO_MA × Financial Liberalization	0.008**	0.006	0.023	0.021**	0.046	0.079*
	[0.004]	[0.047]	[0.018]	[0.008]	[0.136]	[0.043]
Financial R&D Intensity (Value Added)	0.008	0.008		0.029	0.100*	
	[0.013]	[0.018]		[0.028]	[0.051]	
Financial R&D Intensity (Cost)			-0.004***			-0.012***
			[0.001]			[0.003]
Private Credit	-0.002	0.002	-0.014***	-0.000	0.005	-0.054***
	[0.004]	[0.010]	[0.003]	[0.006]	[0.031]	[0.010]
Financial Liberalization	-0.015**	0.032**	0.025	-0.022	0.112**	0.139***
	[0.007]	[0.014]	[0.016]	[0.015]	[0.048]	[0.015]
Hansen's J Statistic P-value (Overidentification test)		0.272	0.719		0.820	0.666
Observations	199	169	176	192	163	170

Table 4
Financial innovation and industry growth

The dependent variable is the average growth rate in real value added or growth in average size across 1996-2006 for each ISIC industry in each country, using the data from UNIDO INDSTAT4, 2010. The sample excludes the industrial sectors in the US, which serves as the benchmark (Rajan and Zingales, 1998). This table reports the impacts of financial R&D intensity on sectoral growth. External Financial Dependence (EFD), firstly developed by Rajan and Zingales (1998), is the fraction of capital expenditures not financed with internal funds for U.S. firms in each three-digit ISIC industry between 1980 and 1990. R&D intensity (RDI) is measured by the R&D intensity for U.S. firms in each four-digit ISIC industry. The calculation uses weighted-average (based on firm size) R&D intensity of all the firms with non-missing R&D intensity in each four-digit ISIC industry. Industry's Initial Share of Total Manufacturing VA is the industry's share of total value added in manufacturing in 1996, which corrects for base effects in industry growth. Private credit is the log of private credit divided by GDP averaged over 1996 and 2006. Detailed variable definitions and descriptions can be found in Table 1. Country and industry specific fixed effects are included in the regressions but not reported. All regressions are cross-sectional with one observation per industry in each country. The sample size is reduced in some models due to data limitation. Heteroskedasticity-robust standard errors clustering within countries are reported in brackets. * Significant at 10%; ** significant at 5%; *** significant at 1%.

	Growth in Real Value Added			
	EFD ×		RDI ×	
	Model 1	Model 2	Model 3	Model 4
EFD (or RDI) × Financial R&D Intensity (Value Added)	0.051**		1.903**	
	[0.023]		[0.907]	
EFD (or RDI) × Financial R&D Intensity (Cost)		0.008***		0.513***
		[0.002]		[0.165]
EFD (or RDI) × HHI	-0.026	-0.011	1.622*	2.082**
	[0.041]	[0.045]	[0.930]	[0.859]
EFD (or RDI) × Government Bank Ownership	-0.075	-0.079	1.175	1.674
	[0.067]	[0.078]	[2.195]	[2.298]
EFD (or RDI) × Foreign Bank Ownership	0.061**	0.055*	0.204	0.313
	[0.029]	[0.029]	[1.024]	[1.072]
EFD (or RDI) × Private Credit	-0.007	-0.004	-0.053	-0.159
	[0.014]	[0.015]	[0.727]	[0.745]
EFD (or RDI) × Entry into Banking Requirements	-0.025**	-0.019**	-0.776*	-0.910**
	[0.010]	[0.008]	[0.449]	[0.411]
EFD (or RDI) × Creditor Rights	0.011	0.009	-0.184	-0.241
	[0.007]	[0.007]	[0.197]	[0.196]
EFD (or RDI) × Depth of Credit information	-0.002	-0.005	0.426	0.502
	[0.007]	[0.007]	[0.330]	[0.314]
Industry's Initial Share of Total Manufacturing VA	-0.586**	-0.590**	0.273	0.209
	[0.275]	[0.275]	[0.781]	[0.777]
Country Fixed Effects	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
Observations	707	707	1,134	1,134
Adjusted R^2	0.385	0.385	0.321	0.322

Table 5
Financial innovation and industry growth volatility

The dependent variable is the standard deviation of the annual growth rate in real value added across 1996-2006 for each ISIC industry in each country, using the data from UNIDO INDSTAT4, 2010. The sample excludes the industrial sectors in the US, which serves as the benchmark (Rajan and Zingales, 1998). This table reports the impacts of financial R&D intensity on sectoral growth volatility. External Financial Dependence (EFD), firstly developed by Rajan and Zingales (1998), is the fraction of capital expenditures not financed with internal funds for U.S. firms in each three-digit ISIC industry between 1980 and 1990. R&D intensity (RDI) is measured by the R&D intensity for U.S. firms in each four-digit ISIC industry. The calculation uses weighted-average (based on firm size) R&D intensity of all the firms with non-missing R&D intensity in each four-digit ISIC industry. Industry's Initial Share of Total Manufacturing VA is the industry's share of total value added in manufacturing in 1996, which corrects for base effects in industry growth. Private credit is the log of private credit divided by GDP averaged over 1996 and 2006. Detailed variable definitions and descriptions can be found in Table 1. Country and industry specific fixed effects are included in the regressions but not reported. All regressions are cross-sectional with one observation per industry in each country. The sample size is reduced in some models due to data limitation. Heteroskedasticity-robust standard errors clustering within countries are reported in brackets. * Significant at 10%; ** significant at 5%; *** significant at 1%.

	Volatility in Real Value Added Growth			
	EFD ×		RDI ×	
	Model 1	Model 2	Model 3	Model 4
EFD (or RDI) × Financial R&D Intensity (Value Added)	0.134*		4.825**	
	[0.066]		[2.247]	
EFD (or RDI) × Financial R&D Intensity (Cost)		0.035***		1.442***
		[0.006]		[0.328]
EFD (or RDI) × HHI	-0.088	-0.023	4.616*	5.892***
	[0.068]	[0.071]	[2.247]	[2.053]
EFD (or RDI) × Government Bank Ownership	-0.083	-0.024	3.073	4.647
	[0.107]	[0.132]	[5.272]	[5.221]
EFD (or RDI) × Foreign Bank Ownership	0.080*	0.082*	0.574	0.969
	[0.045]	[0.044]	[2.032]	[2.003]
EFD (or RDI) × Private Credit	-0.029	-0.013	0.804	0.474
	[0.020]	[0.022]	[1.395]	[1.405]
EFD (or RDI) × Entry into Banking Requirements	-0.041**	-0.027**	-1.583	-2.068**
	[0.016]	[0.010]	[0.951]	[0.833]
EFD (or RDI) × Creditor Rights	-0.010	-0.020	-1.140**	-1.313***
	[0.013]	[0.012]	[0.541]	[0.447]
EFD (or RDI) × Depth of Credit information	-0.004	-0.003	1.522*	1.789**
	[0.018]	[0.021]	[0.880]	[0.759]
Industry's Initial Share of Total Manufacturing VA	-2.035**	-2.029**	-0.836	-1.002
	[0.776]	[0.784]	[1.969]	[1.970]
Country Fixed Effects	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
Observations	706	706	1,128	1,128
Adjusted R^2	0.272	0.275	0.255	0.258

Table 6
Financial innovation and Z-score: OLS and IV regressions

The sample period is from 1996 to 2007, which has a total of 12 years and provides four three-year non-overlapping sub-periods. The dependent variable is log z-score. Z-score= (ROA+CAR)/ σ(ROA), where ROA= π/A as return on asset, and CAR= E/A as capital-asset ratio. σ(ROA) is standard deviation of ROA over a 3-year window. Higher z-score implies more stability and less bank risk taking. Bank market share is the share of each bank's deposits to total deposits within a given country. Bank growth is the total revenue growth rate of a bank. Loan to asset ratio is defined as the ratio of loans to total assets. Too-big-to-fail is a dummy variable that takes a value of one if the bank's share in the country's total deposits exceeds 10%. HHI is the Herfindahl index, defined as the sum of the squared shares of bank deposits to total deposits within a given country. Other country controls include log GDP, log GDP per capita, and information sharing. Detailed variable definitions and descriptions can be found in Table 1. This table reports the impacts of financial R&D intensity on bank risk taking across around 4,000 bank-time observations in 32 countries. Two scaling schemes are applied in the measures of financial R&D intensity. We control for unobserved heterogeneity at the country and time level by including country and time fixed effects and the coefficients are not reported for brevity. The estimation is based on OLS in Models 1 and 2, and IV estimation using GMM in Models 3 and 4. The instrumental variables utilized are intellectual property rights protection index, and the R&D intensity in the service industry excluding financial intermediation firms. Intellectual property rights protection index is measured by a score that describes a country's overall protection degree of intellectual property rights in year t, available from the World Competitiveness Yearbook of the IMD, which is compiled from a comprehensive questionnaire among executives worldwide every year. Each executive is asked to assign a score from 0 (lowest) to 10 (highest) to measure the extent to which "intellectual property rights are adequately enforced." All regressions are cross-sectional time-series with one observation per bank each time period. Heteroskedasticity-robust standard errors clustering within countries and time (double clustering) are reported in brackets. * Significant at 10%; ** significant at 5%; *** significant at 1%.

	OLS		IV	
	Model 1	Model 2	Model 3	Model 4
Financial R&D Intensity (Value Added)	-0.610***		-2.682***	
	[0.232]		[0.917]	
Financial R&D Intensity (Cost)		-0.228**		-0.304**
		[0.092]		[0.123]
Overall Activities Restrictions	-0.019	-0.014	-0.051	-0.069
	[0.059]	[0.051]	[0.051]	[0.047]
Entry into Banking Requirements	-0.091	-0.127**	-0.006	-0.113*
	[0.056]	[0.055]	[0.065]	[0.058]
Official Supervisory Power	0.034	0.076	0.051	0.099***
	[0.042]	[0.058]	[0.035]	[0.035]
Tight Capital Regulation	-0.149	-0.200*	-0.346**	-0.185**
	[0.101]	[0.107]	[0.144]	[0.091]
Financial Statement Transparency	0.128	0.038	0.168	-0.148*
	[0.080]	[0.100]	[0.123]	[0.089]
Bank Market Share	0.275	0.523	-0.056	0.436
	[0.628]	[0.477]	[0.610]	[0.569]
Bank Growth	1.046***	1.098***	1.142***	1.188***
	[0.157]	[0.206]	[0.068]	[0.064]
Loan to Asset Ratio	0.906***	0.875***	0.915***	0.890***
	[0.235]	[0.235]	[0.097]	[0.095]
Too-Big-To-Fail	-0.075	-0.187	0.013	-0.181
	[0.171]	[0.142]	[0.164]	[0.159]
HHI	0.803	0.515	2.097***	1.061*
	[0.551]	[0.601]	[0.705]	[0.592]

Foreign Bank Ownership	0.255 [0.298]	-0.081 [0.673]	0.198 [0.661]	0.697 [0.471]
Other Country Controls	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes
Observations	3925	4112	3542	3729
1st-stage F-test Statistic			84.25	194.96
1st-stage F-test (p-value)			0.000	0.000
Hansen's J Statistic (Overidentification test)			2.059	2.121
Hansen's J P-value			0.151	0.145
Adjusted R^2	0.237	0.253	0.188	0.224

Table 7
Financial innovation and Z-score: interaction analysis

The sample period is from 1996 to 2007, which has a total of 12 years and provides four three-year non-overlapping sub-periods. The dependent variable is log z-score. Z-score= (ROA+CAR)/ σ(ROA), where ROA= π/A as return on asset, and CAR= E/A as capital-asset ratio. σ(ROA) is standard deviation of ROA over a 3-year window. Higher z-score implies more stability and less bank risk taking. Bank market share is the share of each bank's deposits to total deposits within a given country. Bank growth is the total revenue growth rate of a bank. Loan to asset ratio is defined as the ratio of loans to total assets. Tight Capital Regulation is a dummy variable which equals to one if the country's capital regulatory index is greater than the median value of the sample. Too-big-to-fail is a dummy variable that takes a value of one if the bank's share in the country's total deposits exceeds 10%. HHI is the Herfindahl index, defined as the sum of the squared shares of bank deposits to total deposits within a given country. Other country controls include log GDP, log GDP per capita, and information sharing. Detailed variable definitions and descriptions can be found in Table 1. This table reports the impacts of financial R&D intensity and its interactions with bank characteristics on bank risk taking across around 4,000 bank-time observations in 32 countries. Two scaling schemes are applied in the measures of financial R&D intensity. We control for unobserved heterogeneity at the country and time level by including country and time fixed effects and the coefficients are not reported for brevity. The estimation is based on OLS. All regressions are cross-sectional time-series with one observation per bank each time period. Heteroskedasticity-robust standard errors clustering within countries and time (double clustering) are reported in brackets. * Significant at 10%; ** significant at 5%; *** significant at 1%.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Financial R&D Intensity (Value Added)	-0.673***	-0.448**	-1.268***	-1.197***	-0.583***	
	[0.241]	[0.223]	[0.358]	[0.392]	[0.199]	
Overall Activities Restrictions	-0.015	-0.015	-0.017	-0.010	-0.030	
	[0.059]	[0.060]	[0.058]	[0.059]	[0.061]	
Entry into Banking Requirements	-0.098*	-0.091	-0.084	-0.090	-0.092	
	[0.058]	[0.060]	[0.056]	[0.062]	[0.058]	
Official Supervisory Power	0.033	0.037	0.031	0.032	0.028	
	[0.042]	[0.042]	[0.041]	[0.041]	[0.043]	
Financial R&D Intensity (Value Added) × Tight Capital Regulation					-0.441**	
					[0.179]	
Tight Capital Regulation	-0.156	-0.155	-0.145	-0.158	-0.043	
	[0.101]	[0.100]	[0.103]	[0.102]	[0.111]	
Financial Statement Transparency	0.129	0.114	0.142*	0.128	0.111	
	[0.084]	[0.075]	[0.076]	[0.079]	[0.072]	
Financial R&D Intensity (Value Added) × Bank Market Share	1.013***			0.939**		1.017**
	[0.321]			[0.377]		[0.499]
Financial R&D Intensity (Value Added) × Bank Growth		-0.617		-0.680*		-0.725**
		[0.383]		[0.351]		[0.358]
Financial R&D Intensity (Value Added) × Loan to Asset Ratio			1.133**	1.216**		1.229***
			[0.487]	[0.512]		[0.463]
Bank Market Share	-0.149	0.316	0.218	-0.133	0.331	-0.059
	[0.660]	[0.703]	[0.653]	[0.712]	[0.626]	[1.096]
Bank Growth	1.045***	1.198***	1.039***	1.205***	1.049***	1.205***
	[0.158]	[0.258]	[0.159]	[0.251]	[0.160]	[0.223]
Loan to Asset Ratio	0.901***	0.913***	0.531*	0.507*	0.901***	0.490**
	[0.246]	[0.230]	[0.282]	[0.295]	[0.239]	[0.232]
Too-Big-To-Fail	-0.058	-0.084	-0.071	-0.064	-0.091	-0.097

	[0.184]	[0.184]	[0.177]	[0.202]	[0.177]	[0.192]
HHI	0.886	0.671	0.832	0.765	0.649	
	[0.558]	[0.518]	[0.550]	[0.523]	[0.621]	
Foreign Bank Ownership	0.237	0.220	0.199	0.140	0.099	
	[0.301]	[0.285]	[0.299]	[0.286]	[0.312]	
Other Country Controls	Yes	Yes	Yes	Yes	Yes	No
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	No
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	No
Country-Time Fixed Effects	No	No	No	No	No	Yes
Observations	3925	3925	3925	3925	3925	4053
Adjusted R^2	0.238	0.240	0.241	0.244	0.238	0.263

Table 8

Financial innovation and alternative measures of bank fragility

The sample period is from 1996 to 2007, which has a total of 12 years and provides four three-year non-overlapping sub-periods. The dependent variables are σ(ROA), σ(ROE) and Sharpe ratio respectively. σ(ROA) and σ(ROE) represent standard deviation of return on asset and return on equity over a 3-year window. Sharpe ratio is constructed as ROE/ σ(ROE). Bank market share is the share of each bank's deposits to total deposits within a given country. Bank growth is the total revenue growth rate of a bank. Loan to asset ratio is defined as the ratio of loans to total assets. Too-big-to-fail is a dummy variable that takes a value of one if the bank's share in the country's total deposits exceeds 10%. HHI is the Herfindahl index, defined as the sum of the squared shares of bank deposits to total deposits within a given country. Other country controls include log GDP, log GDP per capita, and information sharing. Detailed variable definitions and descriptions can be found in Table 1. This table reports the impacts of financial R&D intensity on bank risk taking across around 4,000 bank-time observations in 32 countries. Two scaling schemes are applied in the measures of financial R&D intensity. We control for unobserved heterogeneity at the country and time level by including country and time fixed effects and the coefficients are not reported for brevity. The estimation is based on OLS. All regressions are cross-sectional time-series with one observation per bank each time period. Heteroskedasticity-robust standard errors clustering within countries and time (double clustering) are reported in brackets. * Significant at 10%; ** significant at 5%; *** significant at 1%.

	ROA		CAR		σ(ROA)		σ(ROE)		Sharpe Ratio	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Financial R&D Intensity (Value Added)	-0.003		-0.014		0.414		0.457**		-0.522*	
	[0.004]		[0.028]		[0.359]		[0.197]		[0.291]	
Financial R&D Intensity (Cost)		-0.001		0.004		0.205**		0.161***		-0.170***
		[0.001]		[0.004]		[0.092]		[0.061]		[0.040]
Overall Activities Restrictions	0.000	0.000	0.004	0.006**	0.027	0.034	0.034	0.033	-0.029	-0.022
	[0.000]	[0.000]	[0.003]	[0.002]	[0.054]	[0.047]	[0.051]	[0.052]	[0.031]	[0.027]
Entry into Banking Requirements	-0.000	-0.001	0.001	0.002	0.085	0.119	0.104**	0.124**	-0.147***	-0.182***
	[0.000]	[0.001]	[0.005]	[0.005]	[0.074]	[0.075]	[0.051]	[0.056]	[0.054]	[0.052]
Official Supervisory Power	0.000	0.000	0.003	0.003	-0.012	-0.045	-0.044	-0.080*	-0.018	0.003
	[0.000]	[0.000]	[0.002]	[0.002]	[0.050]	[0.057]	[0.031]	[0.049]	[0.030]	[0.030]
Tight Capital Regulation	-0.000	-0.001	0.000	0.005	0.143	0.209*	0.127	0.171*	-0.260***	-0.271***
	[0.001]	[0.001]	[0.007]	[0.007]	[0.108]	[0.124]	[0.095]	[0.097]	[0.096]	[0.088]
Financial Statement Transparency	0.001	0.001	-0.004	-0.004	-0.147	-0.074	-0.122**	-0.050	0.118**	0.046
	[0.001]	[0.001]	[0.006]	[0.005]	[0.115]	[0.117]	[0.049]	[0.063]	[0.050]	[0.046]
Bank Market Share	-0.028*	-0.025	-0.347***	-0.356***	-2.419***	-2.708***	-0.048	-0.269	0.632	0.647
	[0.016]	[0.015]	[0.103]	[0.099]	[0.854]	[0.696]	[0.708]	[0.557]	[0.939]	[0.889]

Bank Growth	0.009***	0.008***	-0.008	-0.005	-0.925***	-0.954***	-0.948***	-1.012***	1.123***	1.186***
	[0.002]	[0.002]	[0.012]	[0.011]	[0.134]	[0.171]	[0.141]	[0.211]	[0.194]	[0.194]
Loan to Asset Ratio	-0.007	-0.006	-0.088***	-0.091***	-1.203***	-1.205***	-0.940***	-0.898***	0.798***	0.810***
	[0.005]	[0.007]	[0.029]	[0.027]	[0.372]	[0.355]	[0.219]	[0.233]	[0.106]	[0.117]
Too-Big-To-Fail	0.004	0.003	0.033*	0.034*	0.206	0.318**	0.055	0.158	0.009	-0.009
	[0.003]	[0.003]	[0.019]	[0.018]	[0.202]	[0.158]	[0.193]	[0.151]	[0.246]	[0.234]
HHI	0.016	0.012	0.238***	0.241***	0.823*	1.117*	-0.921	-0.695	0.772	0.863
	[0.012]	[0.012]	[0.065]	[0.067]	[0.472]	[0.643]	[0.585]	[0.583]	[0.610]	[0.633]
Foreign Bank Ownership	0.009*	0.006	0.053**	0.064***	0.216	0.548	-0.160	0.113	0.070	-0.014
	[0.005]	[0.004]	[0.023]	[0.022]	[0.305]	[0.596]	[0.309]	[0.596]	[0.220]	[0.253]
Other Country Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3925	4112	3925	4112	3925	4112	3925	4112	3641	3736
Adjusted R^2	0.183	0.192	0.159	0.154	0.235	0.235	0.208	0.221	0.210	0.226

Table 9

Financial innovation and bank performance change in crisis period

The dependent variable is the performance change (ROA/ ROE) between 2008 and 2006 for each bank, calculated as the difference of ROA/ ROE value between 2008 and 2006. ROA refers to return on asset and ROE refers to return on equity. All the measures of financial innovation and other independent variables are averaged from 1996 to 2006. Two scaling schemes are applied. Bank market share is the share of each bank's deposits to total deposits within a given country. Bank growth is the total revenue growth rate of a bank. Loan to asset ratio is defined as the ratio of loans to total assets. Too-big-to-fail is a dummy variable that takes a value of one if the bank's share in the country's total deposits exceeds 10%. HHI is the Herfindahl index, defined as the sum of the squared shares of bank deposits to total deposits within a given country. Other country controls include log GDP, log GDP per capita, creditor rights, and information sharing. Detailed variable definitions and descriptions can be found in Table 1. This table reports the impacts of financial R&D intensity on changes of ROA and ROE across more than 1,500 banks in 32 countries. Heteroskedasticity-consistent standard errors clustered at the firm level are reported in parentheses. *, **, *** represent statistical significance at the 10%, 5% and 1% level respectively.

	Change in ROA		Change in ROE	
	Model 1	Model 2	Model 3	Model 4
Financial R&D Intensity (Value Added)	-0.014***		-0.076***	
	[0.003]		[0.029]	
Financial R&D Intensity (Cost)		-0.001***		-0.006*
		[0.000]		[0.003]
Overall Activities Restrictions	-0.000	0.000	-0.002	0.000
	[0.000]	[0.000]	[0.005]	[0.005]
Entry into Banking Requirements	0.000	0.000	0.007	0.005
	[0.001]	[0.001]	[0.013]	[0.013]
Official Supervisory Power	-0.000	-0.001*	-0.002	-0.004
	[0.000]	[0.000]	[0.004]	[0.004]
Tight Capital Regulation	0.000	-0.002	0.014	0.003
	[0.002]	[0.002]	[0.021]	[0.025]
Financial Statement Transparency	0.000	0.001	0.030***	0.032***
	[0.001]	[0.001]	[0.011]	[0.012]
Bank Market Share	0.039***	0.041***	-0.308	-0.296
	[0.012]	[0.012]	[0.244]	[0.244]
Bank Growth	-0.005***	-0.005**	-0.061***	-0.060***
	[0.002]	[0.002]	[0.017]	[0.017]
Loan to Asset Ratio	0.021***	0.022***	0.043	0.044
	[0.004]	[0.004]	[0.034]	[0.034]
Too-Big-To-Fail	-0.001	-0.001	0.014	0.012
	[0.003]	[0.003]	[0.043]	[0.042]
HHI	-0.028	-0.081***	-0.098	-0.386
	[0.025]	[0.024]	[0.304]	[0.316]
Foreign Bank Ownership	0.003	0.004	0.042	0.055
	[0.003]	[0.004]	[0.043]	[0.044]
Constant	0.014	0.056***	0.443*	0.675***
	[0.021]	[0.019]	[0.252]	[0.254]
Other Country Controls	Yes	Yes	Yes	Yes
Observations	1536	1536	1533	1533
Adjusted R^2	0.060	0.058	0.040	0.038

Table 10
Financial innovation and bank performance change in crisis period: interaction analysis

The dependent variable is the performance change (ROA/ ROE) between 2008 and 2006 for each bank. All the measures of financial innovation and other independent variables are averaged from 1996 to 2006. Two scaling schemes are applied. Bank market share is the share of each bank's deposits to total deposits within a given country. Bank growth is the total revenue growth rate of a bank. Loan to asset ratio is defined as the ratio of loans to total assets. Tight Capital Regulation is a dummy variable which equals to one if the country's capital regulatory index is greater than the median value of the sample. Too-big-to-fail is a dummy variable that takes a value of one if the bank's share in the country's total deposits exceeds 10%. HHI is the Herfindahl index, defined as the sum of the squared shares of bank deposits to total deposits within a given country. Other country controls include log GDP, log GDP per capita, creditor rights, and information sharing. Detailed variable definitions and descriptions can be found in Table 1. This table reports the impacts of financial R&D intensity and its interactions with bank characteristics on changes of ROA across more than 1,500 banks in 32 countries. Heteroskedasticity-consistent standard errors clustered at the firm level are reported in parentheses. *, **, *** represent statistical significance at the 10%, 5% and 1% level respectively.

	Change in ROA				Change in ROE			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Financial R&D Intensity (Value Added)	-0.033***		-0.018***		-0.266***		-0.146***	
	[0.012]		[0.005]		[0.103]		[0.048]	
Financial R&D Intensity (Cost)		-0.004***		-0.007**		-0.014		-0.037
		[0.001]		[0.003]		[0.009]		[0.024]
Overall Activities Restrictions	-0.000	0.001	-0.000	0.000	-0.001	0.003	-0.000	0.002
	[0.000]	[0.000]	[0.000]	[0.000]	[0.005]	[0.006]	[0.005]	[0.006]
Entry into Banking Requirements	0.000	-0.000	0.001	0.001	0.007	0.002	0.008	0.006
	[0.000]	[0.001]	[0.001]	[0.001]	[0.013]	[0.013]	[0.012]	[0.013]
Official Supervisory Power	-0.000	-0.001	-0.001	-0.001	-0.006	-0.006	-0.008*	-0.007
	[0.000]	[0.000]	[0.000]	[0.000]	[0.005]	[0.005]	[0.005]	[0.005]
Financial R&D Intensity (Value Added) × Tight Capital Regulation			0.004				0.045	
			[0.004]				[0.049]	
Financial R&D Intensity (Cost) × Tight Capital Regulation				0.006**				0.030
				[0.003]				[0.024]
Tight Capital Regulation	0.001	-0.000	0.000	-0.003	0.035*	0.017	0.027	0.007
	[0.002]	[0.002]	[0.002]	[0.002]	[0.020]	[0.025]	[0.020]	[0.025]
Financial Statement Transparency	0.001	0.002*	0.000	0.001	0.032***	0.033***	0.025***	0.031***
	[0.001]	[0.001]	[0.001]	[0.001]	[0.010]	[0.011]	[0.009]	[0.011]
Financial R&D Intensity (Value Added) × Bank Market Share	0.062**				0.412			

	[0.027]				[0.319]			
Financial R&D Intensity (Cost) × Bank Market Share		0.014***				0.115**		
		[0.004]				[0.052]		
Financial R&D Intensity (Value Added) × Bank Growth	-0.003				0.005			
	[0.008]				[0.058]			
Financial R&D Intensity (Cost) × Bank Growth		-0.002				-0.000		
		[0.002]				[0.010]		
Financial R&D Intensity (Value Added) × Loan to Asset Ratio	0.026				0.220			
	[0.017]				[0.162]			
Financial R&D Intensity (Cost) × Loan to Asset Ratio		0.004***				0.003		
		[0.001]				[0.013]		
Bank Market Share	0.011	0.027**	0.040***	0.041***	-0.492	-0.409	-0.311	-0.297
	[0.016]	[0.013]	[0.012]	[0.012]	[0.309]	[0.264]	[0.244]	[0.245]
Bank Growth	-0.004*	-0.004*	-0.005***	-0.005**	-0.062***	-0.060***	-0.063***	-0.061***
	[0.002]	[0.002]	[0.002]	[0.002]	[0.023]	[0.019]	[0.018]	[0.018]
Loan to Asset Ratio	0.013*	0.017***	0.021***	0.022***	-0.033	0.038	0.039	0.042
	[0.007]	[0.005]	[0.004]	[0.004]	[0.065]	[0.038]	[0.033]	[0.034]
Too-Big-To-Fail	0.000	-0.001	-0.001	-0.001	0.022	0.009	0.016	0.015
	[0.003]	[0.003]	[0.003]	[0.003]	[0.043]	[0.041]	[0.042]	[0.042]
HHI	-0.023	-0.078***	-0.026	-0.067***	-0.103	-0.429	-0.113	-0.409
	[0.022]	[0.021]	[0.021]	[0.021]	[0.300]	[0.311]	[0.291]	[0.327]
Foreign Bank Ownership	0.003	0.005	0.002	0.002	0.038	0.061	0.036	0.044
	[0.003]	[0.003]	[0.003]	[0.004]	[0.043]	[0.043]	[0.039]	[0.043]
Constant	0.019	0.051***	0.015	0.043**	0.609**	0.764***	0.569**	0.753***
	[0.017]	[0.017]	[0.015]	[0.019]	[0.262]	[0.260]	[0.248]	[0.269]
Other Country Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1536	1536	1536	1536	1533	1533	1533	1533
Adjusted R^2	0.064	0.064	0.060	0.058	0.045	0.041	0.042	0.039

Appendix Table A1

Summary statistics for financial R&D expenditure across countries over 1996-2006

The table reports the summary statistics for financial R&D expenditure (in Million USD) across 32 countries, over the period from 1996 to 2006.

Country	Country Code	Mean	SD
Australia	AUS	364.23	263.60
Austria	AUT	31.69	10.63
Belgium	BEL	41.86	25.44
Canada	CAN	227.19	72.69
Czech Republic	CZE	9.57	19.51
Denmark	DNK	102.69	74.76
Germany	DEU	83.22	83.46
Greece	GRC	2.86	3.32
Hungary	HUN	1.01	0.98
Iceland	ISL	1.74	0.93
Ireland	IRL	6.13	7.77
Israel	ISR	5.37	0.96
Italy	ITA	166.02	93.42
Japan	JPN	16.08	5.78
Korea	KOR	3.43	4.77
Luxembourg	LUX	58.32	15.32
Mexico	MEX	60.72	49.94
Netherlands	NLD	88.88	34.44
New Zealand	NZL	3.44	2.17
Norway	NOR	48.25	28.23
Poland	POL	4.10	4.80
Portugal	PRT	47.33	38.67
Romania	ROM	0.56	0.52
Russian Federation	RUS	0.36	0.59
Singapore	SGP	25.96	35.35
South Africa	ZAF	250.53	152.01
Spain	ESP	78.41	80.25
Sweden	SWE	89.79	8.48
Switzerland	CHE	94.05	19.76
Turkey	TUR	38.38	24.21
United Kingdom	GBR	1358.27	1258.72
United States	USA	2042.43	825.53

Appendix Table A2
Correlation matrix

This table reports the correlation matrix between measures of financial R&D intensity and other variables in our analysis. Observations are for each country each year from 1996 to 2006. Detailed variable definitions and descriptions can be found in Table 1. P-values are reported in the parentheses below the correlation coefficients. *, **, *** represent statistical significance at the 10%, 5% and 1% level respectively.

	1	2	3	4	5
Financial R&D Intensity (Value Added)	1.000				
R&D Intensity in Service Industry	0.418***	1.000			
	(0.000)				
R&D Intensity in Manufacturing Industry	0.418***	0.213***	1.000		
	(0.000)	(0.001)			
Financial Development (Private Credit)	0.321***	0.205***	0.522***	1.000	
	(0.000)	(0.001)	(0.000)		
Log GDP Per Capita	0.343***	0.398***	0.603***	0.648***	1.000
	(0.000)	(0.000)	(0.000)	(0.000)	

Appendix Table A3

Placebo test

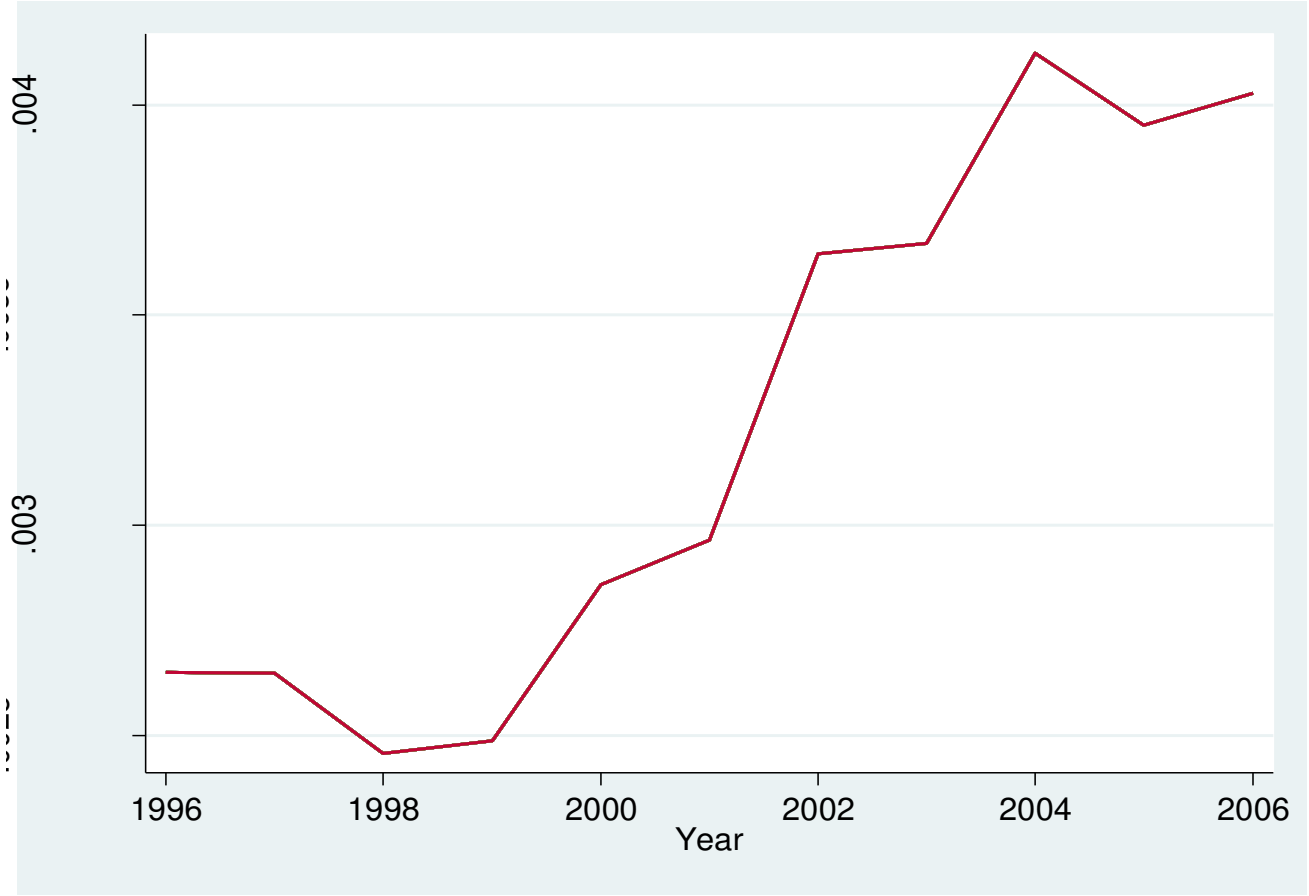
This table reports the placebo test, using R&D intensity in manufacturing industry as the measure instead of Financial R&D Intensity. The dependent variables are Z-score as in Table 6 and ROA Change and ROE Change as in Table 9. Detailed variable definitions and descriptions can be found in Table 1. The sample size is reduced in some models due to data limitation. Heteroskedasticity-robust standard errors clustering within countries are reported in brackets. * Significant at 10%; ** significant at 5%; *** significant at 1%.

	Z-score	ROA Change	ROE Change
	Model 1	Model 2	Model 3
R&D Intensity in Manufacturing Industry	10.081	0.021	0.297
	[15.163]	[0.017]	[0.463]
Overall Activities Restrictions	-0.045	0.001***	0.014***
	[0.064]	[0.000]	[0.006]
Entry into Banking Requirements	-0.088	0.002***	0.023
	[0.072]	[0.001]	[0.017]
Official Supervisory Power	0.071*	-0.002***	-0.029***
	[0.037]	[0.001]	[0.008]
Tight Capital Regulation	-0.089	0.002***	0.024***
	[0.201]	[0.000]	[0.007]
Financial Statement Transparency	-0.159	-0.005***	-0.008
	[0.123]	[0.001]	[0.024]
Bank Market Share	0.700	0.045***	-0.254
	[0.812]	[0.017]	[0.299]
Bank Growth	1.228***	-0.004*	-0.051**
	[0.244]	[0.002]	[0.020]
Loan to Asset Ratio	0.823***	0.016***	0.046
	[0.278]	[0.004]	[0.048]
Too-Big-To-Fail	-0.221	-0.004	0.004
	[0.270]	[0.004]	[0.070]
HHI	0.295	-0.056***	-0.763**
	[0.891]	[0.020]	[0.336]
Foreign Bank Ownership	1.427	-0.005	0.132*
	[0.935]	[0.005]	[0.072]
Other Country Controls	Yes	Yes	Yes
Country Fixed Effects	Yes	No	No
Time Fixed Effects	Yes	No	No
Observations	3,605	1196	1193
Adjusted R^2	0.234	0.050	0.037

Appendix Figure A1

Overall trend of average financial R&D intensity in 32 countries from 1996 to 2006

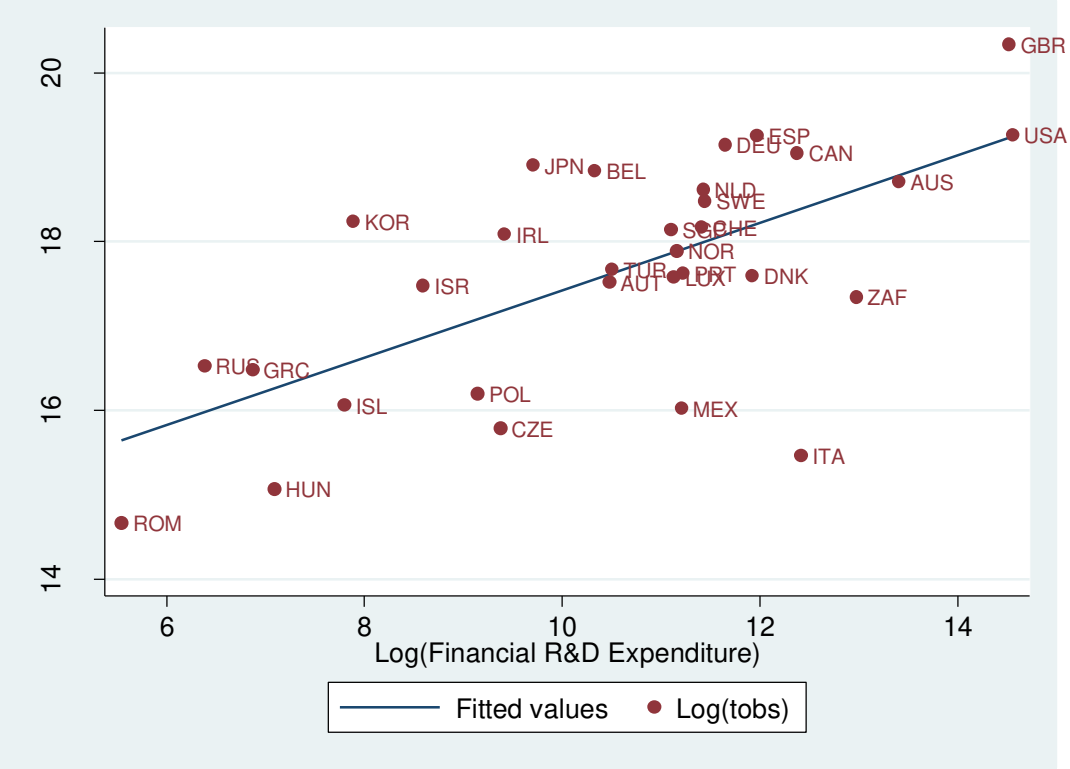
The figure shows the overall trend of averaged financial R&D intensity (value added) in 32 countries over the period from 1996 to 2006. The 32 countries include Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Singapore, South Africa, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States.



Appendix Figure A2

Log (Off-balance-sheet items) and Log (Financial R&D expenditure)

The figure shows the correlation between natural logarithm of off-balance-sheet items (in US$ thousands) and natural logarithm of financial R&D expenditure (in US$ thousands). The vertical axis is the natural logarithm of the total value of off-balance-sheet items among all the individual banks averaged over 1996-2006 per country, and the horizontal axis is the natural logarithm of financial R&D expenditures of all banks averaged over 1996-2006 per country. The data of off-balance-sheet items come from BankScope. Observations are labeled with country codes, as defined in Appendix Table A1.



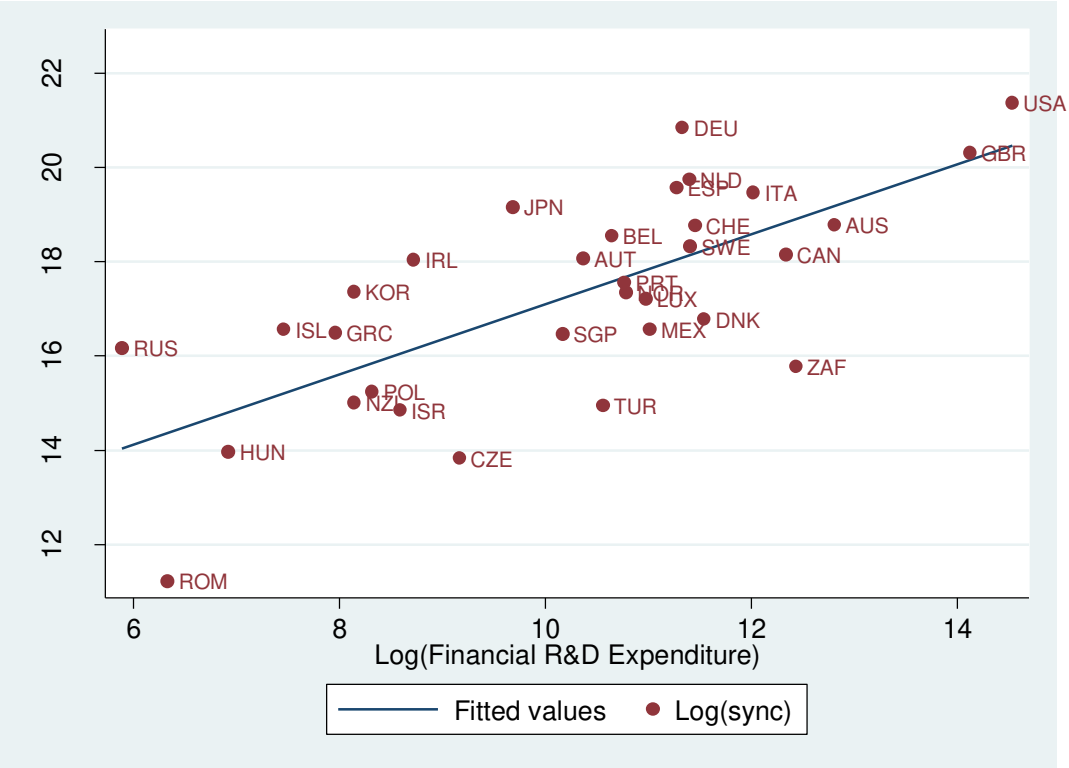
Note: Correlation coefficient: 0.6546; P-value: 0.0001

Appendix Figure A3

International syndicated credit facilities, domestic and international debt securities, and financial R&D expenditure

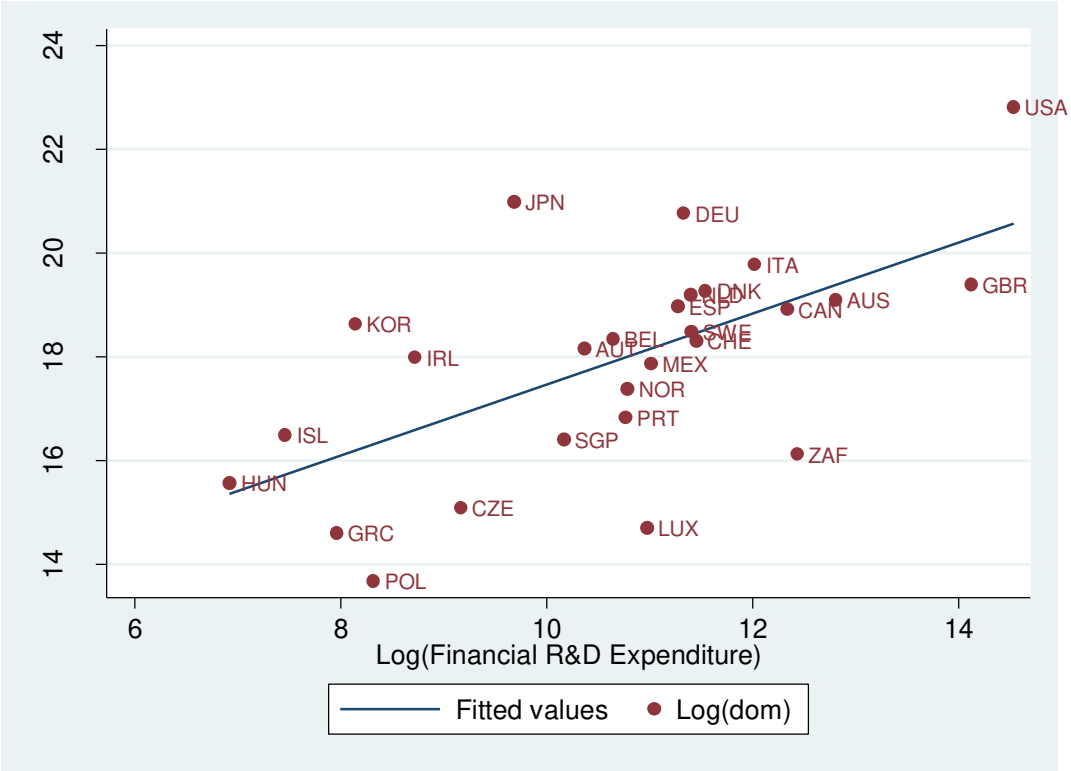
The figure shows the correlation between natural logarithm of international syndicated credit facilities (in US$ thousands), (Panel A), domestic (Panel B) and international (Panel C) debt securities (in US$ thousands) issued by financial institutions and natural logarithm of financial R&D expenditure (in US$ thousands). The vertical axis is the natural logarithm of the total value of signed international syndicated credit facilities in Panel A, total amounts outstanding of domestic debt securities in Panel B, and of international debt securities in Panel C, averaged over 1996-2006 per country, and the horizontal axis is the natural logarithm of financial R&D expenditures of all banks averaged over 1996-2006 per country. The data of international syndicated credit facilities, domestic and international debt securities come from Bank for International Settlement Statistics. Observations are labeled with country codes, as defined in Appendix Table A1.

Panel A. International syndicated credit facilities



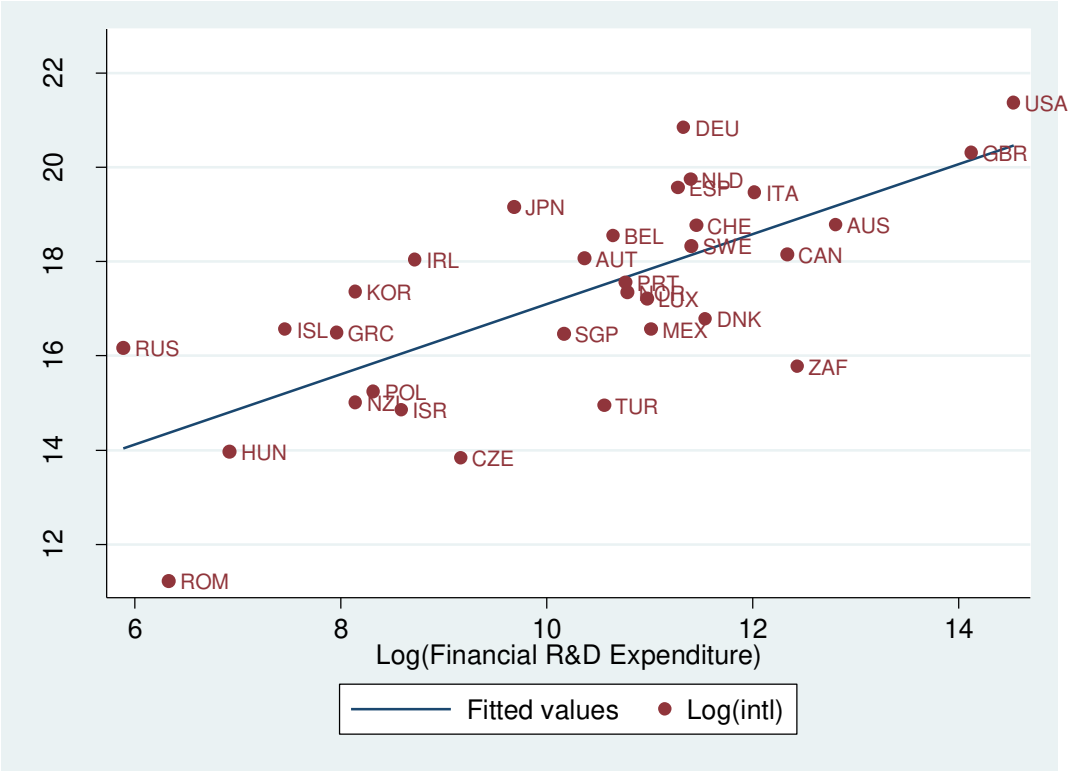
Note: Correlation coefficient: 0.6974; P-value: 0.0000

Panel B. Domestic debt securities



Note: Correlation coefficient: 0.6118; P-value: 0.0007

Panel C. International debt securities

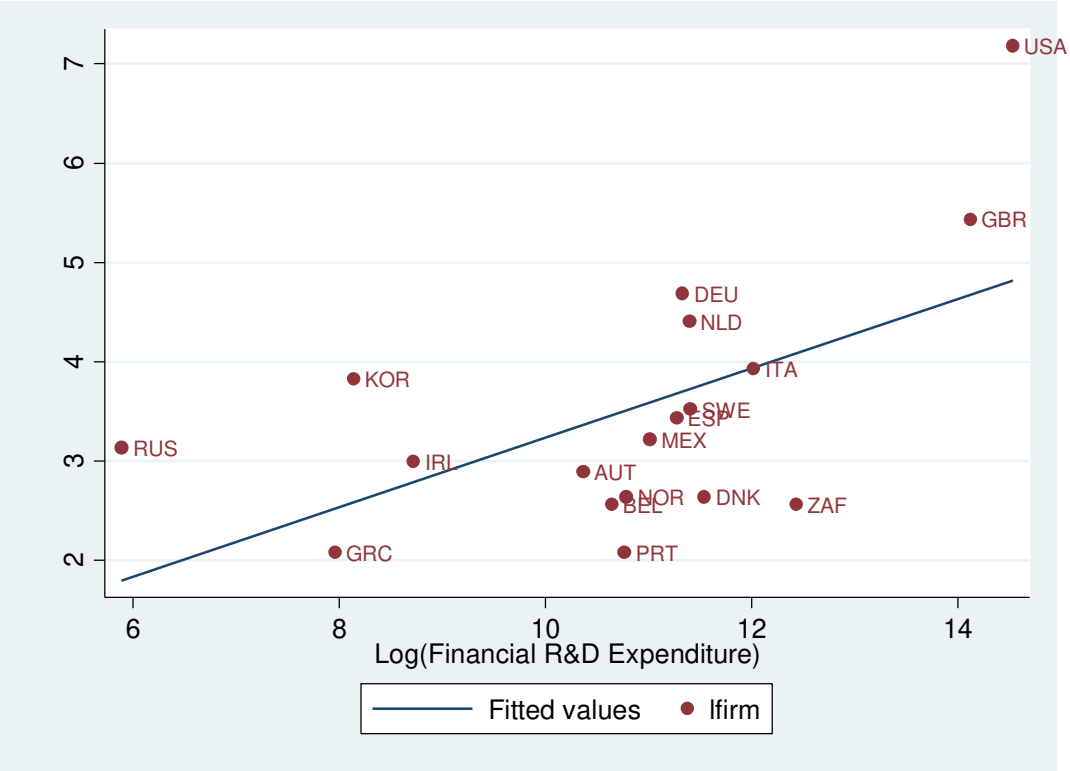


Note: Correlation coefficient: 0.7086; P-value: 0.0000

Appendix Figure A4
CDS and Log (Financial R&D expenditure)

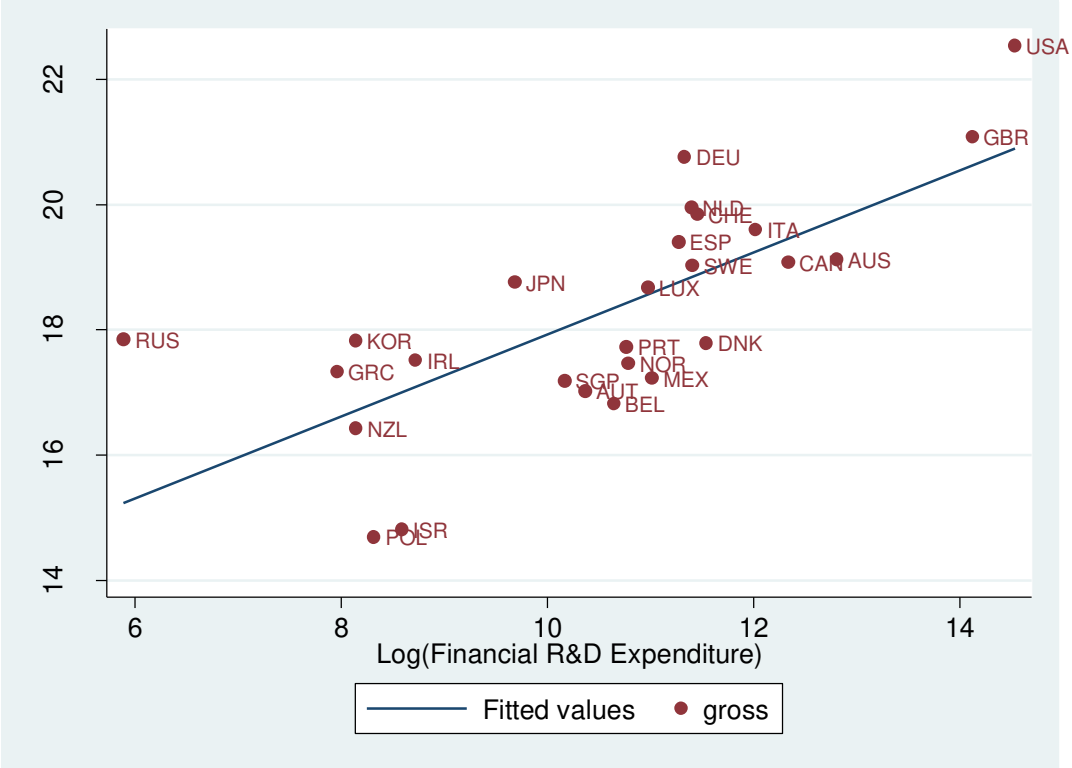
The figure shows the correlation between CDS and natural logarithm of financial R&D expenditure (in US$ thousands). The vertical axis in Panel A is the natural logarithm of the number of reference entities holding CDS for each country in 2008, and the data is from Markit. The vertical axis is the natural logarithm of the gross notional value of CDS in Panel B and the natural logarithm of the net notional value of CDS in Panel C in aggregate for each country in 2008, and the data is provided by the Depository Trust & Clearing Corporation (DTCC). Gross notional values are the sum of CDS contracts bought (or equivalently sold) for all Warehouse contracts in aggregate. Aggregate gross notional value and contract data provided are calculated on a per-trade basis. Net notional value with respect to any single reference entity is the sum of the net protection bought by net buyers (or equivalently net protection sold by net sellers). The aggregate net notional data provided is calculated based on counterparty family. In all the panels, the horizontal axis is the natural logarithm of financial R&D expenditures of all banks averaged over 1996-2006 per country. Observations are labeled with country codes, as defined in Appendix Table A1.

Panel A. Log (# of Reference Entities Holding CDS)



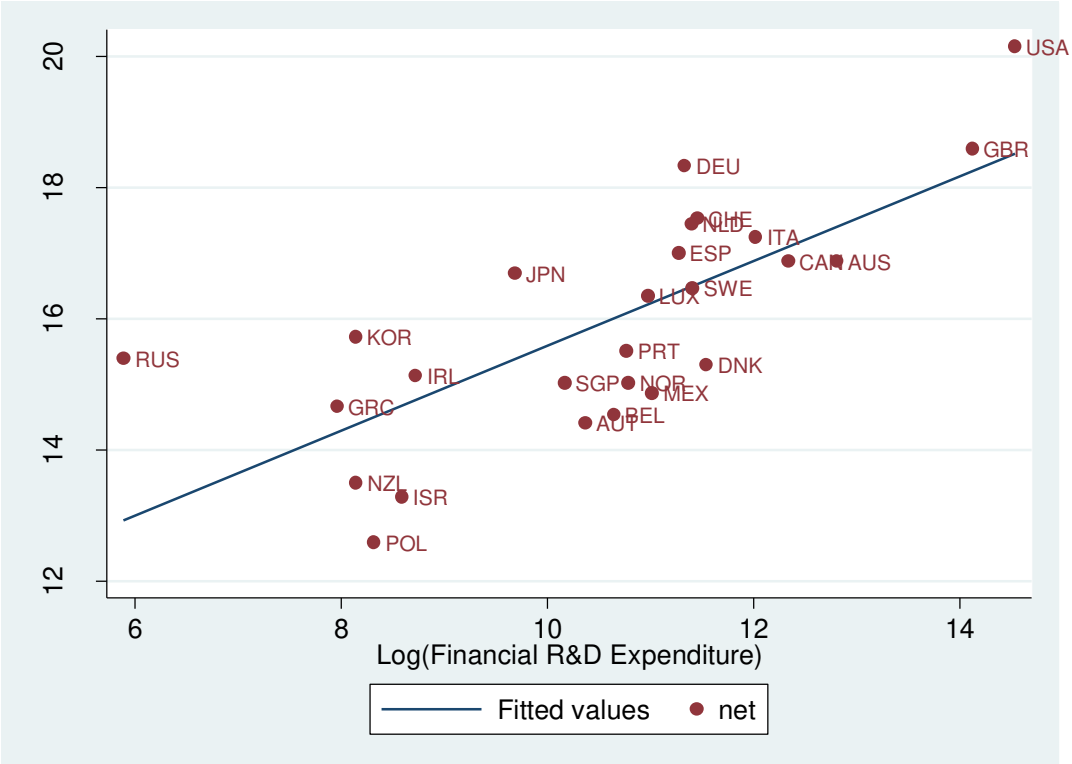
Note: Correlation coefficient: 0.5711; P-value: 0.0133

Panel B. Log (Gross Notional Value of CDS)



Note: Correlation coefficient: 0.7217; P-value: 0.0000

Panel C. Log (Net Notional Value of CDS)

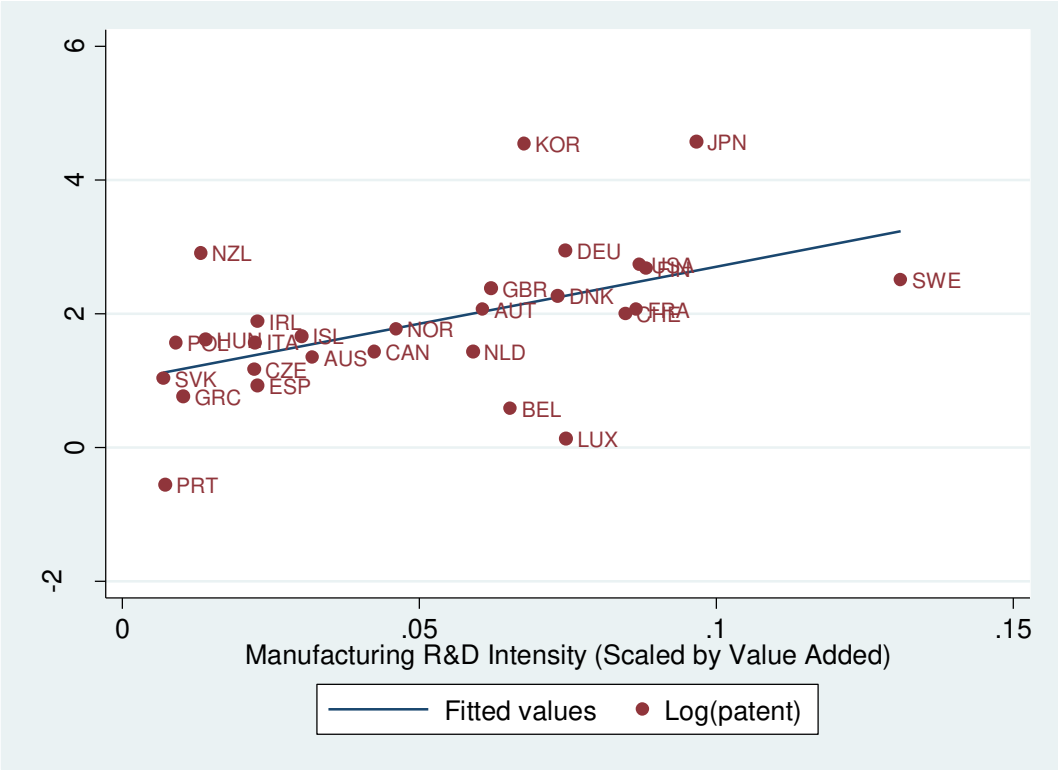


Note: Correlation coefficient: 0.7331; P-value: 0.0000

Appendix Figure A5

Log (#patents filings per $billion GDP) and manufacturing R&D intensity

The figure shows the correlation between Log (#patents filings per $billion GDP) and manufacturing R&D intensity. The vertical axis is a log of the number of patents filings per $Billion GDP averaged over the period 1997-2007 per country, and the horizontal axis is R&D intensity in manufacturing sector scaled by value added in manufacturing, averaged over 1996-2006. Patents data come from the World Intellectual Property Organization (WIPO) Statistics Database. Observations are labeled with country codes, as defined in Appendix Table A1.



Note: Correlation coefficient: 0.5097; P-value: 0.0056