Financial innovation in banking

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Abstract

We study the determinants of financial innovation in 81 listed commercial banks in Europe and in the United States from 2005 to 2008. We use annual reports to identify six broad innovation categories, from the launch of a new product, to the implementation of a new organizational structure. We then investigate the impact of bank- and country-specific features on innovation. When banks hold higher market share in less concentrated and more efficient banking systems, innovation is stronger. In addition, banks with less volatile returns and a lower quality of loan portfolio exhibit a significantly higher level of innovation. The impact of the market share on innovation is higher for banks incorporated in the US, while lower quality of loan portfolio increases the incentive for European banks to innovate. When the financial crisis hits less risky banks take the lead on innovation.

JEL codes: G21, G28, O31, F36

Keywords: banks; financial innovation; regulation; international finance

'The only thing useful banks have invented in 20 years is the ATM' (P. Volcker)

1. Introduction

Innovation has been a core topic for scholars, because of its important contribution to economic growth and to the stability of financial systems (Levine, 1997; IMF, 2006; Lerner and Tufano, 2011). New financial products, such as the securitisation of assets, were believed to have tremendous potential for the diversification and efficient management of risk (Merton, 1992; Mendoza et al., 2009; Trichet, 2009). The financial crisis that started in 2007 changed those beliefs, as excessive risk taking in some specialized innovating products has brought down the financial system and produced the deepest and most prolonged economic crisis since the Great Depression. Recent studies now blame excessive growth of financial economy as detrimental to the growth of the real economy (Levine, 2005; Rajan, 2005; Piazza, 2010; Shin, 2010; Johnson and Kwak, 2012). Innovation is a double edged-sword: the right kind of innovation and favourable conditions that may spur banks to invest in new technologies would help the financial system fulfill its functions and, as a consequence, deliver growth; but too much of innovation or innovation which is not properly used can have serious consequences on the overall economy (Stiglitz, 2010; Beck et al., 2012).

The features of innovation in the banking sector are quite different from the characteristics usually encountered in other sectors. First, and in contrast to innovation in the manufacturing sector, financial innovation is hard to define. For Frame and White (2004) financial innovation is defined

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as product and organizational innovation, which allows cost or risk reduction for the single bank and/or an improvement of the services for the financial system as a whole. Second, banks are not the only developer of financial innovation. The banking sector is also an end user of innovations developed in other sectors. Sometimes banks jointly develop innovation with non-financial firms, such as software houses or specialized technology firms. Very often, innovation happens thanks to the interaction with clients, and so is spread over departments.

Because of these features, the measurement of financial innovation is quite a challenge. Studies of manufacturing innovation traditionally focus on research and development (R&D) spending. However, R&D is unlikely to be a satisfactory measure in banking, since banks do not usually have a R&D department that launches new products and services. Most new services are developed in an incremental way, often through "trial and error" and in all parts of the business.

A count based on the listings of new securities is not satisfactory either, since much of the innovation in financial services is not related to publicly traded securities, such as insurance and banking products (Lerner and Tufano, 2011). Furthermore, new securities are often minor variants of existing securities, issued by banks to differentiate themselves from competitors (Tufano, 2003).

Lerner (2006) develops a measure of financial innovation based on news items in the *Wall Street Journal* related to new financial products, services, or institutions. However, some innovation may not be reported in newspapers because it has no direct appeal to the reader. Some studies on innovation in the banking industry attempt to catalogue one particular type of innovation, such as credit default swaps or securitization (Tufano, 2003). However these results cannot be easily generalized to other products.

A recent suggestion is to consider patents by financial institutions (Hall et al. 2009; Hunt, 2008) but Boldrin and Levine (2013) point out that academic studies have typically failed to find much of a connection between patents, innovation and productivity growth.

In this paper we supplement existing research with an alternative measure for financial innovation based on bank's annual reports. The annual report is the main official document a firm has to communicate to the general public and offers broad information on bank's business. Following recent scandals, regulators and external auditors pay closer attention to the quality of information provided.[1] The accounting authorities have changed accounting rules in an attempt to provide investors with a more accurate picture of the firm (Lehnert, 2014).

We analyze more than 450 annual reports of 81 banks listed on the New York Stock Exchange (NYSE), on the London Stock Exchange (LSE), on Borsa Italiana, and on Euronext from 2005 to 2008, in search of innovations. In 2014, the total market capitalization is €25.2 trillion, of which about seven per cent comes from the banking industry. The banks comprised in the dataset, whose primary business is deposit-taking and loan-making, account for 85 per cent of total assets and 75 per cent of market capitalization of banks listed on the above mentioned stock exchanges and with similar specialisation.

We transform qualitative information on various innovations, from the launch of a new product, to the implementation of a new organizational structure, into a quantitative database that characterizes innovation in banking. Following Lerner (2006), we then browse news in the financial press and on the banks' websites, to capture innovations that might not have been mentioned in the

[1] Sarbanes-Oxley Act, passed in 2002, enhanced financial disclosure by US public firms. Similar legislation has been enacted in various European countries, such as Legge 262/2005 in Italy or Loi sur la Sécurité Financière in France in 2003.

annual reports. We provide significant descriptive traits characterizing banks which are more active in innovation.

Then we examine the determinants of innovation in a regression framework. When banks have a higher market share in less concentrated and more efficient banking systems, innovation is stronger. In addition, less volatile returns and a lower quality of loan portfolio are positively related to innovation. The impact of the market share on innovation is higher for banks incorporated in the US. Similar evidence is found for the impact of the quality of loan portfolio on innovation, which is significantly different between European and US banks. In particular, lower quality of loan portfolio increases the incentive for European banks to innovate, whereas it reduces innovation for US banks. If in normal times riskier banks innovate more, when the crisis hits less risky banks take the lead on innovation.

Two limitations should be acknowledged at the outset. The period covered in this study is relatively limited, but this protects from strong shifts in the demand for financial innovation and from the impact of the global financial crisis on all aspects of banks' business. In addition, from 2008 the supply for financial innovations dramatically dropped, since all major banks were highly concerned about solvency, liquidity, cost and capital adequacy, and adopted a conservative approach to innovation. The second limitations relates to the methodology employed. Since a unique definition of financial innovation is hard to find, we prefer to pursue a relatively simple method to identify financial innovation and to analyze its determinants.

2. Definition of financial innovation

In the literature financial innovation has been variously defined.[2] According to the European Central Bank (ECB 2003), financial innovation is primarily a product and organizational innovation, which allows cost or risk reduction for banks and/or a service improvement for the financial industry as a whole. Similar considerations can be found in Frame and White (2004) and in Tufano (2003), who define innovation employing a few key concepts, such as the completion of incomplete markets, the overcoming of agency problems and information asymmetries, the reduction of transaction, research, or marketing costs, the response to taxation and regulation changes and the link to globalization, risks and technological shocks. Financial innovation comes from the combination of two or more of the above-mentioned factors.

From the point of view of the impact on the industry, innovation may be radical, revolutionary or incremental (Gardner, 2009). Radical innovation changed the whole industry, but it has occurred from time to time in banking. Revolutionary innovation tend to be less risky than breakthroughs but also less profitable. Incremental innovation consists of a minor improvement of something already existing, has relatively lower risk and positive payback. It is far more common than radical and revolutionary one. Financial innovation can also be defined investigating its origins and it is usually considered as the bank's response to external economic forces (Llewellyn, 2009; Silber, 1983).

Against this background, to identify financial innovation in bank's annual report we focus on three features that have to be present simultaneously: strong discontinuity with the past, actual improvement of the service for clients, and profit enhancement. We exclude innovation promoted

[2] For a comprehensive review on financial innovation, see, among others, Frame and White (2004), and Lerner and Tufano (2011).

by changes in regulation or legal provisions, since usually it affects the banking system as a whole.[3] This choice skims the dataset from redundant observations.

Finally, in labour intensive industry, such as the banking sector, the innovation process is dominated by "providers" (Pavitt, 1984). This industry grants a minor direct contribution to innovation. Most innovations are produced in other industries and then transferred into the banking sector, particularly as far as technology is concerned. This is the case, for example, of a bank implementing an internet platform for distribution of online services, thanks to new processors provided by software houses. The bank's innovation depends on a technological innovation produced by the supplier. In fact, banks do not simply copy suppliers' innovation but add financial contents to them. A major driver in financial innovation is the development of financial technology broadly defined (Frame and White, 2012; Wall, 2014). Advances in technology have been critical not only in retail banking (e.g. automatic teller machine), but also to obtain, store and process data required to estimate statistical models (e.g. valuation and risk management). Therefore, we include technological innovation as reported by banks in our investigation.

3. Data and methods

To select our sample we consider all domestic banks listed on the New York Stock Exchange, the London Stock Exchange, Borsa Italiana, and Euronext which were active at the end of 2008 (107 banks). Since we are interested in institutions that can be fairly referred to as deposit taking and loan making institutions, we drop those banks which are not classified as commercial banks, cooperative banks, Islamic banks, bank holding and holding companies in Bankscope.[4] Given our focus on bank characteristics that determine financial innovation, concentrating ing on banks that were continuously operating is all the more important. If banks merged during the period of observation we aggregate their financial statements and treat them as a single composite bank for the entire period (Casu et al. 2013). Table 1 presents 2008 figures on the final sample of 81 banks classified accordingly to the stock exchange where they are listed.

Twenty per cent of the sample is formed by banks listed on Euronext, 37 per cent on London Stock Exchange and Borsa Italiana (LSE), and 43 per cent on the New York Stock Exchange (NYSE). As for the average size, Euronext banks are larger per total assets but smaller in terms of market capitalization. However data are quite dispersed, since total assets span from 0.2 to more than 2,500 billion euro and market capitalization from 59 to 120,000 million euro. In 2008, profitability, measured by return on equity, has been negative on average for all banks, particularly for those listed on Euronext (-11 per cent). Banks listed on LSE have been more cost efficient than their peers on Euronext and NYSE (71 per cent versus 84 and 86 per cent cost to income ratio, respectively). On average, banks listed on NYSE have 64 per cent of their assets tied up in loans,

[3] For instance, the Single Euro Payments Area (SEPA) abolishes the distinction between national and cross-border payments within the Euro area (Directive 2007/64/EC). The new system has been generally adopted, becoming a standard (systemic innovation).

4 According to Bankscope classification, commercial banks are mainly active in a combination of retail banking (individuals, SMEs), wholesale banking (large corporates) and private banking (not belonging to groups of saving banks, co-operative banks). Cooperative banks have a cooperative ownership structure and are mainly active in retail banking (individuals, SMEs). An "Islamic bank is an institution that mobilises financial resources and invests them in an attempt to achieve predetermined islamically-acceptable social and financial objectives. Both mobilisation and investment of funds should be conducted in accordance with the principles of Islamic Shari'a". Bank holdings and holding companies are typically holding companies of bank groups. We are aware of differences among these groups, but for the sake of readability, we refer to them as commercial banks in the remaining of the paper.

compared to 55 per cent of institutions listed on LSE and 52 per cent on Euronext. This ratio could spot banks following the traditional business model of loan making and deposit taking.

Coding guidelines

The data were coded according to the content analysis methodology (Schwartz-Ziv and Weisbach, 2013; Krippendorff, 2004; Lieblich et al., 1998). The content analysis methodology is a "systematic replicable technique for comprising many words of text into fewer content categories, based on explicit rules of coding" (Stemler, 2001). This methodology involves constructing a quantitative database by categorizing or coding different aspects of qualitative information. We did all coding manually because the coding guidelines we define require a comprehensive understanding of the content of the annual reports to detect the three features mentioned in Section 2. The coding guidelines are as follows: (1) group organizational model: we include in this category innovating changes in the group structure, such as the acquisition of an asset-management company or a leasing company by a banking group not yet operating in the asset management or leasing businesses. The group may start the new business through an already existing subsidiary or division, or establishing a new, legally separated firm; (2) organizational structure: this category includes innovating organizational changes implying a new structure for the bank, but without any direct impact at group level; (3) operating systems: this category includes innovations in operating systems, processes, and internal controls, provided they are not tied to regulation changes; (4) information and communication technology (ICT): this category includes innovations with a primarily technological content, like, for example, new voice recognition software for telephone banking. While technological innovation can span over the different categories, it is included in this category only if the technology is clearly identifiable and prevalent; (5) delivery channel: this category includes innovation in delivery channels, like the launch of electronic banking in a bank which previously had only physical branches; (6) product: this category includes all new products launched by banks, such as the introduction of a new mortgage.

We coded data on innovation from bank's consolidated and unconsolidated annual reports, bank's websites and financial press, namely The Wall Street Journal, The Financial Times, Il Sole 24 Ore, The Economist, and Bloomberg Businessweek. If a bank and its holding are both listed, we investigate all reports and control for double counting of innovation. Innovation is thus a score variable ranging from zero to six per bank per year, depending upon the number of categories in which each bank innovates.[5]

We are aware that the score variable measures the range of innovation and not its intensity, but it is a good proxy of innovating activity. Indeed it is interesting to point out that different innovation categories have different "life cycles". Product innovation, which can be easily imitated by competitors, has a relatively short life cycle. It can be repeated over multiple periods, also over a short time horizon. Following Gardner (2009) it is typically an incremental innovation. Other innovations, including those referring to the organizational structure, have a longer life cycle and can hardly be repeated continuously. Some innovations are more recurrent in combination with particular events, including aggregations that characterized the banking industry since 2005. Thus we prefer to focus on banks innovating in various areas of their business and structure, rather than on those launching for instance 20 new bank accounts with slightly different features.

[5] If all 81 banks in the sample would innovate in all categories, the total score would have been 486 innovation per year, 1944 innovation over the four-year period.

Innovation features

Analyzing data on innovation obtained through the above-described coding guidelines, banks cover 783 innovation categories or areas (INN) over the four-year period (Table 2). On average each bank innovates in 2.4 categories per year. In fact, innovation decreases from 225 in 2005 to 165 in 2008. This reduction is explained not only by the lower number of innovation categories per bank (2.8 in 2005 vs. 2.0 in 2008, per bank on average) but also by the lower number of banks which innovate (86 percent in 2005 vs. 82 percent in 2008 of banks in the sample).

Among all categories, product innovation prevails (26 percent of total), followed by ICT innovation (18 percent of total). Group organizational model, operating systems and organizational structure are all about 15 percent, while innovation in delivery channel scores 11 percent of total.

If we now compare innovation promoted by European and US banks (46 versus 35 banks), product innovation prevails in both geographical areas and in all countries but Belgium. However, in the US innovation in group organizational model closely follows while delivery channel is at the bottom of the ranking.[6] In the European Union (EU) ICT innovation is the second area by number and operation systems is the last one.

Figure 1 presents the distribution of banks to the number of categories they innovate over the four-year period. We rank banks according to the total number of innovation categories they promoted from 2005 to 2008 and classify as innovating banks those credit institutions above the median (eight innovation categories) and as less-innovating banks those below the median. The first subsample is formed by 46 banks, while 35 institutions belong to the less-innovating group. Seventy per cent of innovating banks are located in the EU, and 60 per cent of less-innovating institutions are incorporated in the US. Two banks promoted innovation in all six categories every year, totaling the maximum score, equal to 24, two banks did not promote any innovation in the entire period. In the next section we describe the main features of innovating banks.

3.1. Bank-specific data

Size and age

The adoption and diffusion of innovation is related to size and to the age of bank (Table 3). Larger firms seem better suited to innovate, because innovation implies fixed costs that can be more efficiently recovered if firm is large (Schumpeter, 1943). Smaller firms could be better innovator, due to superior managerial control and less bureaucracy (Scherer and Ross, 1990; Lerner, 2006). In our sample innovating banks are significantly larger than less-innovating banks both in terms of total assets and market capitalization.[7] Size relative to the market is as well important.[8] Higher market share increases the incentive of banks to innovate (Bhattacharyya and Nanda, 2000). Innovating banks hold on average higher country market share (ten per cent) than less-innovating banks (one per cent).

[6] By construction, European banks are those incorporated in the EU, and listed on Euronext, London Stock Exchange or Borsa Italiana. US banks are those incorporated in the US and listed on the NYSE.

[7] We gather balance sheet and market data for banks on Bureau Van Dijk's Bankscope and Thomson Reuters Datastream.

[8] Data available on bank size on comparable standards do not distinguish between domestic and foreign assets. As a consequence, we are forced to ascribe to the country of incorporation assets which may be located in another country. However truly global players are less than five are in our sample.

Older firms seem better placed at extending existing product lines than at creating new ones. Nevertheless their advantage of experience stimulate innovation (Lerner, 2006; Prusa and Schmitz, 1994; Arrow, 1962). However literature typically suggests that younger firms are more likely to innovate, since they have long term horizon to recover from the initial investment, a lower chance of cannibalization of existing products or services, and fewer scope diseconomies (Aaron and Lazear, 1990). Indeed, innovating banks are younger than their less-innovating peers.

Efficiency

Innovations are not easy or cheap to develop and diffuse. Banks retain many highly compensated-highly skilled employees to design new products and services (Lerner and Tufano, 2011). Internal human capital is a key for any innovation policy (Mohen and Roeller, 2005). In addition, the distribution of new products requires considerable resources invested in marketing, sales and delivery channels. In fact, personnel expenses and overheads are lower in innovating banks, but cost to income ratio (CI) is higher. The cost to income ratio, which shows the ability of the institution to generate gross profits from a given revenue stream, is considered one of the most important efficiency based indicators (ECB, 2010).

To understand different level of cost-efficiency, the major element of which is usually the personnel expenses, it is useful to investigate bank labour productivity. Core deposits are the primary funding source for most banks and, as a result, have a significant effect on a bank's liquidity. Banks place great significance on deposits because favourable operating results depend, in part, on a core deposit base. Therefore, banks try to retain and prudently expand the deposit base (The Federal Reserve Board, 2013). As reported in Table 3, the customer deposits per worker ratio is higher in innovating banks, indicating a higher efficiency in managing the deposit base. In addition, cost per employee is lower in innovating banks. Banks use deposits in a variety of ways, primarily to fund loans and investments. Innovating banks' employees generate more gross loans per worker, but lower net intermediation margin, which in part could be explained by lower quality of loan portfolio.

Profitability

The impact of innovation on profitability is thus cumbersome. If investing in financial innovation is a rational response to a lagging competitive position, it is not surprising that less profitable firms tend to be innovators (Silber, 1983; Lerner, 2006). However, considering the high initial investment, more profitable firms seem to be better placed at innovating. In fact, our preliminary analysis confirms that more innovating banks are less profitable. We test the mean of various profitability measures but only few of them significantly differ between the two groups. Return on assets (ROA) compare bank net income to its assets. Innovating banks underperform less-innovating banks (0,59 per cent versus 1,06 per cent).[9] We wish to capture a measure of relative profitability which is not affected by capital structure choices, thus we measure the net interest margin to total asset ratio. The lower profitability of innovating banks is confirmed also by a broader ratio, the net intermediation margin to total asset ratio. Following Lerner (2006) we also test the ratio of earnings before interest, debt, taxes, depreciation, and amortization (EBITDA) to

[9] Traditionally, ROA is considered a more reliable profitability indicator than ROE, in terms of efficiency performance, since it is adjusted for the leverage effect. However, this ratio is quite flat across time (ECB, 2010).

revenues. We measure revenues both in terms of net interest margin and net intermediation margin, but none of these ratios shows significant differences among the two groups.

The significant market measure of profitability is price to earnings ratio (P/E). Less-innovating banks seems overpriced (19,65 P/E versus 13,62). However a higher ratio may also suggest lower bank risk. Earnings per share (EPS), price to book value (PBV) and stock abnormal return do not significantly differ among the two groups.[10]

The financial crisis has highlighted the relevance of risk when investigating banks' performance. Therefore, simple performance measures, such as return on equity (ROE), are limited because they are not risk-sensitive. Return on equity failed to discriminate the best performing banks from the others in terms of sustainability of their results during the crisis (ECB, 2010). One possible refinement to our performance analysis would be to rely on risk-adjusted returns instead of plain returns. Indicators could be related to the total return of an investment, the most popular one being economic value added (EVA), or to the underlying level of risk associated with banks' activity, such as the risk-adjusted return on capital (RAROC). However, it is difficult to calculate these indicators without having access to banks' internal data, this being out of the scope of the present work. We therefore use a proxy and compute the ratio of return on equity to its volatility for each bank over the sample period. The test for equality of means is not significant.

Risk

A recent strand of literature argues that banks particularly active in innovation have been riskier than their less innovating peers (Diamond and Rajan, 2009, and Bebchuk and Spamann, 2010). Risk-adverse firms are often reluctant to invest in innovating projects, even if these projects are value-enhancing (Xiao and Zhao, 2012). Therefore, we would expect the innovating banks to be riskier than the less-innovating ones.

We first measure risk computing banks' total asset growth. Asset growth should be funded by a commensurate amount of additional capital. Persistently high growth of assets can be an alarming signal. Excessive asset growth can imply excessive risk-taking and a build-up of vulnerabilities, which would eventually jeopardise sustainable growth (ECB, 2010). In particular, microeconomic evidence from large international banks suggests that loan growth represents an important driver of risk (Altunbas et al., 2011; Foos et al., 2010; Laeven and Majnoni, 2003; Keeton, 1999). Indeed innovating banks experiment a faster total asset growth. High volatility of returns can be a second signal of bank instability and risk. We then test the volatility of return on equity but difference among the two groups of banks is not significant.

The crisis has highlighted the crucial importance of banks' liquidity and funding capacity (Demirguc-Kunt et al., 2010; Shleifer and Vishny, 2010; Beltratti and Stultz, 2012). The deregulation and financial innovation developments led banks to increase their dependence on markets for their funding (Altunbas et al., 2011). As a third measure for risk, we include the interbank ratio, which is the money lent to other banks divided by the money borrowed from other banks. Once more, innovating banks show a significant higher risk, and lower liquidity. On the contrary, less-innovating banks are net placer of funds in the market place, and therefore more liquid (the ratio is greater than 100).[11]

[10] To compute stock abnormal returns we use historical betas, computed using monthly returns on a 5-year rolling window.

[11] Data are available only for EU banks.

The primary function of equity is to support the bank's operations, act as a cushion to absorb unanticipated losses and declines in asset values that could otherwise cause a bank to fail (The Federal Reserve Board, 2013). A bank's solvency promotes public confidence in the bank and the banking system as a whole by providing continued assurance that the bank will honor its obligations and provide banking services. By exposing stockholders to a larger percentage of any potential loss, higher equity levels also reduce the subsidy provided to banks by deposit insurance and other elements of the safety net. Innovating banks equity to total asset ratio is lower than their less-innovating peers, thus suggesting lower capital adequacy and higher risk.

Business mix

Alternative approaches to measuring banks' risk-adjusted performance may require a deeper analysis of the way in which banks run their business. We thus investigate the quality of loan portfolio, measured as the ratio of loan loss reserves to gross loans, which indicates how much of total portfolio has been provided but not charged off. It is a reserve for losses expressed as percentage of gross loans. Given a similar charge-off policy, the higher the ratio the poorer the quality of the loan portfolio will be, but differences are not statistically significant between the two groups of banks.[12]

The existing product mix influences bank's strategic innovation, in particular product innovation. Specialisation is proved to enhance the probability of innovation in the financial sector (Boot and Thakor, 1997). Bank business model typically suggest that bank assets can be invested in lending, and in securities. If investment in lending prevails, usually banks follow the traditional deposit-taking and loan-making business model. We investigate what percentage of assets of the bank are invested in loans computing the gross-loans-to-total-assets ratio. Less-innovating banks invest a higher percentage of assets (60 per cent) in loans than their innovating peers (55 per cent). In contrast, differences in securities investment are not significant between the two groups.[13]

Geographical area

Firms located in regions with more financial innovations innovate more (Krugman, 1991; Lerner, 2006). Knowledge spillovers are likely to be concentrated geographically, also because financial innovation can be easily copied. We test whether European and US banks statistically differ.[14] European banks are on average younger, larger and less profitable than their US peers. They are more cost-efficient and enjoy a higher labour productivity. The lower quality of loan portfolio and larger total asset growth suggest that EU banks are riskier. They invest less in loans

[12] We also test the net loans-to-total-asset ratio, which indicates the relevance of the loan portfolio as a percentage of bank's total asset or, alternatively, the percentage of total assets tied up in loans, and the loan loss provisions on net interest margin, which is the relationship between provisions in the profit and loss account and the interest income over the same period. Ideally this ratio should be as low as possible and in a well-run bank if the lending book is higher risk this should be reflected by higher interest margins. None of these ratios seem to provide significant information.

[13] Bankscope data definitions identify the asset side of bank balance sheet into loans, other earning assets and non-earning assets. Loans include residential mortgage loans, other mortgage loans, other consumer/retail loans, corporate and commercial loans and other loans. Other earning assets include reverse repos and cash collateral, trading securities, derivatives, available for sale securities, held to maturity securities, at-equity investments, and other securities. Non-earning assets include cash and due from banks, fixed assets, goodwill and other intangibles.

[14] We do not perform single country t-test since the number of banks belonging to innovating and to less-innovating groups is too low to infer statistically meaningful results. The only exceptions are Italy and the US.

but more in securities than US banks. European banks thus show features which are typical of the innovating group.[15]

3.2. Country-specific data

We investigate additional set of factors specific to each banking system and to each country, which is expected to affect the capacity of banks to innovate. Table 4 shows the result of the test for mean differences.[16]

Banking system

Lower concentration in the banking system should enhance the likelihood to innovate, as banks, which compete harvest to retain customer base and get new clients, are pushed to launch new product, or to be more efficient through process innovation. Nevertheless, innovation may arise in higher concentrated markets. There is a time lag between the moment of investing in innovation and the payback. This gap disconnects the innovation effort from the actual business outcome (Gardner, 2009). Banks in higher concentrated markets may have more money to invest, thank to rents deriving from a dominant position, and lower pressure to positive outcome, which might convey innovations in the end. Both the Herfindahl-Hirschman Index, which refers the size of the bank in relation to the industry, and the market share of the five largest banks, suggest that innovating banks work in highly concentrated markets.[17]

We complement this information investigating the size of the banking system, which is often used as an indicator of potential development and helps to explain the likelihood of innovation in the countries under scrutiny (Dermine, 2006). We measure the total assets of all credit institutions-to-gross domestic product (GDP), and the number of bank employees to the number of banks ratio per year per country. These measures indicate that innovating banks are located in smaller and overstaffed banking systems, thus being the big fish in the smaller (and highly concentrated) pond. Such preeminent position might be beneficial in terms of innovation and lead to greater investment.

Country-specific

Innovation can be spurred by a higher level of education and a higher rate of participation to the workforce (Nickerson and Sullivan, 2003; Kroll and Stahlecker, 2009). Higher education makes clients more receptive to innovation, while at the same time, it boosts the education level of the labour force, so raising productivity. In fact, innovating banks are located in countries with lower tertiary education participation rate and lower employment rate. This is consistent with banks not usually having a research and development department and sometimes using innovations developed in other sectors. The place where innovation is applied does not necessarily coincide with the place where research is performed.

We finally include a set of controls. The GDP growth and long-term yield are often used as indicators of potential development of the financial sector. We investigate the country of incorporation of banks using dummies, which aim at capturing country specificity, as in reporting.

[15] Results of the test for equality of means are available from the authors.

[16] Data are gathered from Eurostat, the European Central Bank Structural Indicators, the International Monetary Fund World Economic Outlook database, the Federal Deposit Insurance Corporation and the Bureau for Labour Statistics.

[17] Both ratios are computed at country level, thus all banks incorporated in the same country show the same ratio per year.

Portuguese banks' annual reports are clear and comprehensive, whereas other countries provide more concise reports. Since we coded data starting from information available on annual reports, their clarity and length may affect our analysis. Alternatively, we use a dummy of the main stock exchange on which bank is listed, since transparency and accountability of annual reports may be enhanced by specific market regulation.

We use a trend variable to check whether innovation may be growing or shrinking over time for reasons essentially unrelated to our set of explanatory variables. We also control for a financial crisis effect, which would reduce innovation, using a dummy.

4. Research design

We previously investigate financial innovation on an anecdotal level (Table 2 and Figure 1). To better understand the drivers leading banks to innovate, we construct a score dependent variable on innovation (*INN*) which ranges from zero to six according to the number of categories where bank *i* innovates in country *j*, in year *t*. We identify the determinants of innovation adoption by bank *i* in market *j* at some point in time ($INN_{i,j,t}$) by bank's profitability, efficiency, risk and product mix variables ($X_{i,t}$), presented in the previous section and summarized in Table 3. The idea is to see whether, in the aggregate, the decision to innovate is linked to some specific characteristics of the bank. Equation (1) below recognizes that, for both temporal and business reasons, innovation would not immediately result from changes in bank's variables. Thus, we allow some bank's variable to affect *INN* with an annual lag ($X_{i,t-1}$).[18]

We control for a set of banking system ($Y_{j,t}$) and country-specific ($Z_{j,t}$) variables as summarized in Table 4.

Table 5 reports correlation among bank-specific variables of interest. Our variable correlations are within the conventional limits and, as a consequence, we continue to include them in our full model.

We would like to estimate the following model:

$$INN_{i,j,t} = \alpha_i + \beta_i X_{i,t} + \delta_i X_{i,t-1} + \sigma_j Y_{j,t} + \tau_j Z_{j,t} + \varepsilon_{i,t} \qquad (1)$$

We estimate (1) by random effects since we have reason to believe that differences across banks have some influence on the degree of innovation. Using random effects we may include time-constant controls among the explanatory variables or slow changing variables over time.[19] This specification requires that bank's characteristics which may or may not influence the independent variables are clearly identified. The problem with this is that some variables may not be available,

[18] Having lagged explanatory variables however reduces the number of observations to 169 and the number of banks under scrutiny to 54.

[19] We report theta (θ) to check whether the random effects estimator is biased and rho (ρ) to control whether the random effects estimates are close to the pooled OLS estimates. As θ goes to one, the bias term goes to zero and, as a consequence, the random effects estimator tends to the fixed effects estimator. If theta is close to zero, a larger fraction of the unobserved effect is left in the error term and the random effect estimator is biased and identical with the pooled OLS estimator. We compute the Hausman test which fails to reject the null hypothesis, meaning that the random effects and fixed effects estimates are sufficiently close so that it does not matter which one is used (Wooldridge, 2009). Focusing on rho, if it is close to zero the random effects estimates are closed to the pooled OLS estimates. We then compute the Breusch-Pagan Lagrange multiplier, which helps to decide between a random effects regression and a simple OLS regression, and we reject the null, finding that random effects regression is appropriate.

therefore leading to omitted variables bias in the specification. We compute the Ramsey's test for omitted variables and results indicate that our specifications have no omitted variables.

Considering Equation (1), in which innovation is the dependent variable and bank characteristics are the independent variables, we could face an additional problem. Banks with low profits would spend relatively little on innovations, and the variations across such banks would be small. For more profitable or larger banks the amount of discretionary investments would be higher. The average amount spent on innovation would be higher, and there would also be greater variability among such banks, resulting in heteroskedasticity (HS). We use both Breusch-Pagan and White's tests for HS and since we fail to reject the null hypothesis of homoskedasticity at any reasonable level of significance, HS does not appear to be a problem.

We finally compute variance inflation factors (VIFs) of our regression coefficients. They are all below conventional thresholds which would indicate a problem with multicollinearity (Neter et al., 1989).

4.1 Results

The results from estimating equation (1) are presented in Table 6. Column 1 reports the findings of the baseline model which investigates the bank-specific determinants of innovation. The main variable of interest is bank size relative to the market. We find that bank market share is significant with a positive sign. Holding other variables fixed, if a bank increases its market share by one per cent, innovation increases by five per cent. Our result shows that a larger market share allows the innovating commercial bank to derive greater margins from a given innovation and, as a consequence, gives it greater incentives to engage in innovating activity. This is consistent with previous evidence on investment banks.

Contrary to expectations the age of the bank, its efficiency or profitability are not related to innovation. Among bank risk variables, total asset growth and the volatility of returns appear with one lag in our regression framework. Both variables are significant at 10 per cent level. As for the annual rate of growth of bank's total assets, if it increases from 10 to 11 per cent (+10 per cent), innovation increases immediately by 7.2 per cent, then after one year, by 8.9 per cent. The decision to innovate is positively linked to the percentage variation of total assets, since fast growing banks increases their market share relative to competitors, thus enjoying greater benefits from a given innovation.

Banks showing higher volatility of actual (i.e. accounting) profits are also those accumulating less innovation. The practical effect on innovation is however modest, since one per cent increase in the standard deviation of ROE immediately reduces innovation by 0.04 per cent, whereas the first lag variable has no significance impact on innovation. In an industry where funds are scarce, banks with a stable pattern of returns may devote more resources to innovation. Consistent with this interpretation, we find that risk adverse banks innovate more.

When we investigate equity to total asset ratio, we do not find any relation of this risk measure with innovation. The level of equity cannot be easily reshuffled on a short-term horizon, thus being unrelated to the decision to innovate.

We test the quality of loan portfolio measured by the reserves for impaired loans to gross loans. The relation is significantly positive at five per cent level with a lag and the magnitude of the coefficient gives an idea of the economic importance: if the ratio increases from 10 to 11 per cent (+10 per cent), innovation increases by 390 per cent after one year. If reserves for impaired loans

increase more than gross loans, either the bank covers loan losses adequately, and, if margins are satisfactory, can sustain the cost of innovating; or has a lower quality of loan portfolio, and decide to pursue innovation trying to reduce impaired loans, for example launching new products, or changing its organizational structure or technology.

When we add banking system variables (Table 6, Column 2), results hold, but the immediate relation of total asset growth with innovation. Concentration in the banking system, as measured by the HHI, is negatively related to innovation at 5 per cent significance level. Banks located in less concentrated markets compete harvest to retain customer base and get new clients, and, as a consequence, have stronger incentives to launch new product, or to be more efficient through process innovation. The economic impact is however modest. As in the case of Belgium, when banking system concentration decreases by 10 per cent from 2007 to 2008, innovation increases by 0.014 per cent.

Another variable of interest is the average number of bank employees, computed using country level data. A higher number of employees is usually related to traditional banking systems where clients still prefer bank branches and physical interaction, or, because of generally higher personnel expenses, to banking system which are less cost efficient. Consistent with this latter interpretation, we find that the average number of bank employees is negatively related to innovation at 5 per cent significance. One per cent increase in the average number of bank employees decreases innovation by 0.001 per cent. When banks have a higher market share and grow faster in less concentrated and more efficient banking systems, they enjoy a preeminent position which leads to innovation.

In Table 6, Column 3 we include a set of controls for the economic cycle and the level of interest yield.[20] We find that the equity to total asset ratio is negatively related with innovation at ten per cent significance level. Holding all other variables fixed, if a bank increases equity ratio by one per cent, thus increasing the protection afforded to the bank by the equity invested in it, innovation falls by 5.6 per cent. Riskier banks are the best candidate to innovation, since they try to reduce risk through innovation.

Finally, in Table 6, Column 4 we control for the phenomenon of finding a relationship between two or more trending variables simply because each is growing over time (Wooldridge, 2009). Allowing for a time trend in Equation (1) explicitly recognizes that innovation may be growing or shrinking over time for reasons essentially unrelated to the explanatory variables.[21] The story is quite the same but for total asset growth, which is not statistically significant anymore. The time trend is statistically significant at 5 per cent level and its coefficient implies an approximate 0.2 per cent decrease in innovation per year, on average. Previous results show a spurious relationship between innovation and total asset growth due to the fact that both are trending downward over time.

4.2 Additional tests

As reported in Table 6 we have a main sample of 54 banks and 169 observations. In Table 7 we repeat the same exercise on three different sub-samples to assess the robustness of our results.

[20] R-squared between is larger omitting Agebank, which therefore has been dropped.

[21] For instance, total asset growth may have a trend. If we regress total asset growth on trend, we obtain a coefficient on the trend equal to -0.003. Although the standard errors on the trend coefficient are not necessarily reliable, the coefficient estimate reveals a downward trend. The joint significance test between Agebank and trend is not significant and R-squared between is larger if Agebank is dropped.

Recalling Figure 1, which presents the distribution of banks to the number of categories they innovate over the four-year period, we rank banks according to the total number of innovation categories they promoted from 2005 to 2008 and we drop less-innovating banks according to various thresholds. First, in Column 1 to 4 we drop banks belonging to the 1st decile of innovation distribution, and we estimate Equation (1) on a reduced sample of 47 banks and 145 observations. Then we drop banks that have not innovated in any categories over the four-year period under scrutiny (Column 5 to 8), and, as a consequence, the sub-sample is formed by 46 banks and 141 observations. Finally, we exclude banks up to the 1st quartile of innovation distribution (Column 9 and 10) and report results on a sub-sample of 42 banks and 125 observations.[22]

Our results remain unchanged in the specifications with banking system and trend variables for all sub-samples (Columns 2, 4, 6, 8, 9 and 10). In the baseline model (Column 1 and 5) total asset growth has still a positive effect on innovation but significant only at 11 per cent level. When we add the set of country-specific control variables (Column 3 and 7), both volatility of returns and equity to total asset ratio have negative signs but are no more significant at the usual levels.

4.3 Geographical and financial crisis effect

Our finding of Section 4.1 is that banks with larger market share, a lower volatility of returns and quality of loan portfolio innovate more. In Section 3 we pointed out that geographical effect encouraging innovation may exist. Financial innovation can be easily copied by competitors and peer pressure pushes innovating banks to innovate more to keep their leading position. Thus it is not unlikely that banks located in regions with more financial innovation innovate more.

We also observe that innovation is trending downward over time. In an industry where funds are scarce, banks feel the need to be more liquid, and reducing innovation is a possible response to this need. Consistent with this interpretation, the number of innovation categories dramatically dropped from 2008.

We try to capture the geographical effect interacting a dummy for bank incorporated in the US with selected independent variables (Table 8, Column 1).[23] The idea is that significant independent variables might have a different effect for banks who are incorporated in the United States rather than in the EU. We are interested in the effects of bank market share, quality of loan portfolio and volatility of returns on innovation. The estimated impact of the market share on innovation for EU banks is 7.01, for US banks it is 20.02, holding other variables fixed. The difference (+13) is economically large and statistically significant. Thus we conclude that there is evidence against the hypothesis that the impact of the market share on innovation is the same for EU and US banks. Indeed, the impact of the market share on innovation is lower for banks incorporated in the EU. Similar evidence is found for the impact of the quality of loan portfolio on innovation, which is significantly different between European and US banks. In particular, lower quality of loan portfolio increases the incentive for European banks to innovate, whereas it reduces innovation for US banks. When we look at the volatility of returns we do not find any significant difference in the impact on innovation among banks incorporated in the EU or in the US.

[22] We could not test the baseline model and the model with country-specific variables on this last sub-sample because of heteroskedasticity (the sub-sample is too small). The same issue apply to a sub-sample formed by banks above the median of the innovation distribution.

[23] We could not use a geographical dummy for each country under scrutiny because of the paucity of data.

We finally investigate the financial crisis effect interacting a year dummy for 2008 with markets share and equity to total asset ratio (Table 8, Column 2).[24] The coefficient of the year dummy is negatively significant and explains the difference in innovation between the crisis and the pre-crisis period, holding other variables fixed. Thus, not surprisingly, the coefficient of the year dummy determine that, for the same level of other factors, during the financial crisis banks innovated less than the pre-crisis period. All major banks were highly concerned about the turmoil and adopted a conservative approach to innovation As for banks market share, the difference between the two periods is economically large (-35 per cent) but not statistically significant at the usual levels. We then interact the financial crisis effect with equity to total asset ratio. As a measure for bank risk, this ratio should be affected by the financial turmoil. Indeed the pre-crisis impact of equity to total asset on innovation is -8.75, whereas in 2008 it is +0.28 (or about 30 per cent). The difference between the two periods is large (+9) and statistically significant, and it means that before the financial crisis riskier banks innovate more, but when the crisis hits less risky banks take the lead on innovation. Riskier banks were more deeply affected by the crisis, and as a consequence, were less focused on innovating activity.

5. Conclusion

We propose an alternative measure for financial innovation, based on bank's annual reports. To identify financial innovation we focus on three features that have to be present simultaneously: strong discontinuity with the past, actual improvement of the service for clients, and profit enhancement. This is the kind of innovation which should be encouraged by regulators, since it enhances the functions of the banking system, and, as a consequence, leads to the growth of the real economy. We find that product innovation prevails both in Europe and in the US, but innovation falls from 2005. Not only banks innovate in less categories, but also less banks engage in innovation.

Using test of equality of means we show that innovating banks hold on average a larger market share, are younger, more cost-efficient but less profitable than less-innovating peers. Bank risk, as measured by various ratios, is higher for innovating banks, which invest a lower percentage of their assets in traditional lending activity. These results are partly consistent with the previous literature on financial innovation.

We then study the drivers of innovation in a regression framework and find that when banks have a higher market share in less concentrated and more efficient banking systems, they enjoy a preeminent position which leads to innovation. A stable pattern of returns allows banks to devote more resources to innovation. In addition a lower quality of loan portfolio increases the incentive for the bank to invest in innovation. This may derive by a more adequate coverage of loan losses, which once again allow banks to invest in innovation; or by the need to improve quality of portfolio thorough innovative products and processes.

The impact of the market share on innovation is higher for banks incorporated in the US. Similar evidence is found for the impact of the quality of loan portfolio on innovation, which is significantly different between European and US banks. In particular, lower quality of loan portfolio increases the incentive for European banks to innovate, whereas it reduces innovation for

[24] We do not include time trend since it is correlated with the year dummy.

US banks. As a final remark if in normal times riskier banks innovate more, when the crisis hits less risky banks take the lead on innovation.

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Table 1 – Summary statistics for banks (year 2008)

This table provides descriptive statistics for key bank-specific features at the end of 2008. Banks are grouped by the stock exchange they are listed on.

Stock Exchanges	Number of banks	Total assets (bn euro)				Average market capitalisation (mn euro)			
		Mean	*Min*	*Max*	*St. dev.*	*Mean*	*Min*	*Max*	*St. dev.*
Euronext	16	467.1	2.3	2,075.6	654.3	12,641.3	197.7	3,213.2	15,375.6
LSE	30	348.0	0.2	2,515.7	670.4	14,659.7	58.5	120,260.1	25,585.8
NYSE	35	179.9	1.5	1,478.8	406.7	14,205.9	81.6	97,068.9	27,217.8
Total	81	299.8	0.2	2,515.7	573.0	14,061.3	58.5	120,260.1	24,358.4
		Return on equity (%)				Cost to income ratio (%)			
		Mean	*Min*	*Max*	*St. dev.*	*Mean*	*Min*	*Max*	*St. dev.*
Euronext	16	-11.0	-134.9	13.3	37.1	84.2	52.6	185.4	32.7
LSE	30	-7.2	-111.8	15.9	29.2	70.9	30.5	214.3	31.2
NYSE	35	-2.4	-47.7	24.9	17.9	86.1	51.0	386.4	59.6
Total	81	-5.9	-134.9	24.9	26.7	80.1	30.5	386.4	46.0
		Net loans to total assets ratio (%)							
		Mean	*Min*	*Max*	*St. dev.*				
Euronext	16	52.0	2.7	82.5	26.8				
LSE	30	55.3	4.4	90.5	24.6				
NYSE	35	63.9	18.1	82.3	13.9				
Total	81	58.3	2.7	90.5	21.5				

Table 2 – Innovation areas per year (all banks)

This table describes the coding guidelines for innovation areas (*INN)*, defined as a score variable which ranges from zero to six according to the number of categories where bank *i* innovates in year *t*.

Year	Innovation areas (*INN*)							*INN* per bank per year (avg)
	Group organisational model (1)	Organisational structure (2)	Operating systems (3)	Information and communication technology (4)	Delivery channel (5)	Product (6)	Total	
2005	32	34	40	39	28	52	225	2.8
2006	34	35	29	43	23	50	214	2.6
2007	29	22	23	36	19	50	179	2.2
2008	28	26	19	25	19	48	165	2.0
Total	123	117	111	143	89	200	783	2.4
(%)	*16%*	*15%*	*14%*	*18%*	*11%*	*26%*		

Figure 1 – Distribution of number of banks to total innovation areas (all years)

This table shows the distribution of the number of banks to total number of areas where they innovate over the four-year period. Asterisk (*) indicates the median of the distribution.

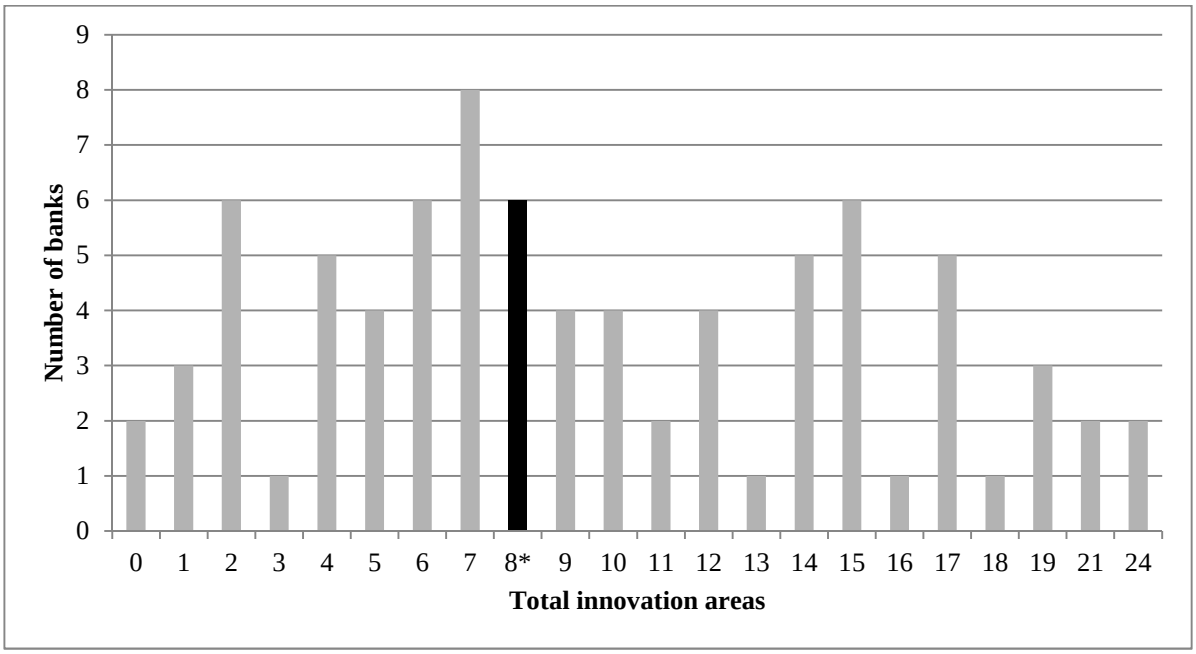

Table 3 – Test for equality of means – bank specific variables. Innovating and less-innovating banks

This table presents results of the test for equality of means between innovating (above the median of the distribution of number of banks to total innovation areas) and less-innovating (below the median of the distribution of number of banks to total innovation areas) banks for bank-specific variables. */**/*** indicate significance at 10, 5, and 1 per cent level.

Variable	Description	Variable name	Obs	Mean (t) of banks below the median (less-innovating banks)	Obs	Mean (t) of banks above the median (innovating banks)	Test for equality of means (p-value)
Bank specific							
Size	Logarithm total assets	size	137	16.17	179	18.22	0.0000***
Market capitalization	Market capitalization (yearly average)	emktcap	139	6,387.98	174	28,731.08	0.0000***
Relative size (%)	Bank total asset/country credit institutions total asset	rize	137	1.00	179	10.00	0.0000***
Age of the bank	Logarithm (2008 – year of establishment of bank)	agebank	140	4.50	184	4.01	0.0001***
Efficiency							
Labour cost	Personnell expenses/total assets	cost2	136	0.02	173	0.01	0.0132**
Cost to total assets	Overheads/total assets	cost	131	0.20	172	0.09	0.0359**
Cost to Income	Cost to income ratio (%)	ci	136	62.85	173	73.69	0.0197**
Bank labour productivity	Customer deposits/number of employees (standardised)	sblp3	110	-0.19	133	0.14	0.0119**
	Overheads/number of employees (standardised)	scpc	110	0.12	130	-0.14	0.0377**
	Gross loans/number of employees (standardised)	sblp1	110	-0.14	133	0.17	0.0219**
	Net intermediation margin/number of employees (standardised)	sblp	114	0.14	135	-0.14	0.0254**
Profitability							
Return on assets	ROA (%)	roa	131	1.06	167	0.59	0.0135**
Profitability index	Net interest margin/total assets	pindex	131	0.20	172	0.09	0.0359**
EBITDA to revenues ratio	EBITDA/net interest margin	ebitda	107	4.58	129	0.07	0.2968
Price earnings	Price to earnings ratio	pe	113	19.65	127	13.62	0.0004***
Risk-adjusted performance	Average return on equity (ROE)/standard deviation ROE	riskadj	109	25.29	115	22.27	0.6586
Risk							
Total asset growth	Annual growth rate of total assets	tag	136	0.09	172	0.18	0.0020***
Volatility of returns	Standard deviation ROE	roev	133	2.81	152	3.92	0.2245

Liquidity risk	Interbank ratio (%) (only for EU banks)	liq	48	125.32	116	87.18	0.0064***
Equity	Equity to total asset ratio	capital	137	0.13	175	0.07	0.0000***
Business mix							
Quality of loan portfolio	Reserves for impaired loans/gross loans	loq3	119	0.02	164	0.02	0.6008
	Net loans/total assets (%)	loq	132	57.95	176	57.35	0.7987
	Loan loss provisions/net interest margin	loq2	131	0.14	175	0.13	0.8820
Investment in loans	Gross loans/total assets	mix2	131	0.60	177	0.55	0.0227**
Investment in securities	Other earning assets/total assets	mix	136	0.356	177	0.355	0.9488

Table 4 – Test for equality of means – banking system and country specific variables. Innovating and less-innovating banks

This table presents results of the test for equality of means between innovating (above the median of the distribution of number of banks to total innovation areas) and less-innovating (below the median of the distribution of number of banks to total innovation areas) banks for banking system and country-specific variables. */**/*** indicate significance at 10, 5, and 1 per cent level.

Variable	Description	Variable name	Obs	Mean (t) of banks below the median (less-innovating banks)	Obs	Mean (t) of banks above the median (innovating banks)	Test for equality of means (p-value)
Banking system							
Concentration of the banking system	Herfindahl-Hirschman index	hhi	140	249.99	184	564.25	0.0000***
	Share of the five largest banks (%)	c5	140	25.72	184	39.68	0.0000***
Size of the banking system	Total assets of all credit institutions (standardised)	scta	140	0.31	184	-0.21	0.0000***
	Number of employees/number of banks	nenb	140	441.70	184	506.70	0.0266**
Country specific							
Education	Tertiary education participation rate (%)	edr	140	4.94	184	4.25	0.0000***
Employment	Total employment rate (%)	emr	140	45.23	184	44.29	0.0566*
Macroeconomic	GDP growth	ggdp	140	1.55	184	1.36	0.0000***
	Long term yield	yrate	140	4.48	184	4.39	0.1824

Table 5 – Correlation matrix

This table reports correlation coefficients and their significance between selected bank specific variables of interest; */**/*** indicate p<0.05, p<0.01 and p<0.001 respectively. Variables are as those described in Table 3.

		1	2	3	4	5	6	7	8
1	Age	1							
2	Relative size	-0.138**	1						
3	EBITDA to revenues	0.154*	0.021	1					
4	Cost income	-0.216***	-0.051	-0.050	1				
5	Reserves for impaired to gross loans	-0.104	-0.038	-0.006	0.158**	1			
6	Equity to total asset	-0.144**	-0.274***	0.057	0.127*	0.396***	1		
7	Total asset growth	-0.021	0.144**	-0.010	-0.030	0.000	-0.035	1	
8	Volatility of ROE	-0.141**	0.068	-0.073	0.252***	0.225***	0.028	-0.003	1

Table 6 – Bank-specific, banking system and country-specific determinants of innovation

This table reports results from a panel random effects model of *INN* (defined as a score variable which ranges from zero to six according to the number of categories where bank *i* innovates in year *t*) on a baseline vector of bank characteristics (Column 1), banking system variables (Column 2), country-specific variables (Column 3), and a model including a time trend (Column 4). Panel model standard errors are reported between brackets. Asterisks indicate significance at 1 per cent (***), 5 per cent (**) and 10 per cent (*) levels. Column 3 and 4 present heteroskedasticity robust standard errors.

Independent variables	(1) Baseline model	(2) with banking system	(3) with country-specific	(4) with trend
Constant	0.61	2.96**	1.68	2.89***
	[1.044]	*[1.249]*	*[1.182]*	*[0.574]*
Age	0.22	-0.08		
	[0.182]	*[0.198]*		
Relative size	4.97***	9.26***	8.95***	9.11***
	[1.808]	*[2.419]*	*[2.459]*	*[2.509]*
Cost income	-0.00	-0.00	-0.00	-0.00
	[0.004]	*[0.004]*	*[0.002]*	*[0.002]*
EBITDA to revenues	0.00	-0.00	-0.00	-0.00
	[0.013]	*[0.012]*	*[0.005]*	*[0.005]*
Total asset growth	0.72*	0.68	0.79*	0.57
	[0.423]	*[0.428]*	*[0.467]*	*[0.395]*
Total asset growth (lag)	0.89*	0.83*	0.69	0.45
	[0.474]	*[0.487]*	*[0.534]*	*[0.553]*
Volatility of ROE	-0.04*	-0.04*	-0.03**	-0.03**
	[0.022]	*[0.022]*	*[0.017]*	*[0.015]*
Volatility of ROE (lag)	0.01	0.01	0.02	0.02
	[0.056]	*[0.055]*	*[0.048]*	*[0.049]*
Equity to total assets	-4.14	-5.38	-5.61*	-5.29
	[4.038]	*[3.875]*	*[3.246]*	*[3.250]*
Reserves for impaired to gross loans	-4.95	-2.99	-3.49	-2.69
	[8.771]	*[8.426]*	*[5.550]*	*[5.460]*
Reserves for impaired to gross loans (lag)	39.04**	44.77***	49.52**	45.47**
	[17.884]	*[17.056]*	*[20.190]*	*[19.692]*
HHI		-0.00**	-0.00*	-0.00*
		[0.001]	*[0.001]*	*[0.001]*
Number of employees to number of banks ratio		-0.00**	-0.00***	-0.00**
		[0.001]	*[0.001]*	*[0.000]*
GDP growth			0.08	
			[0.075]	
Long term yield			0.14	
			[0.268]	
Time trend				-0.19**
				[0.082]
Observations (*bank*)	169 *(54)*	169 *(54)*	169 *(54)*	169 *(54)*
R-squared between	0.48	0.58	0.59	0.58
Ramsey's test (Prob>F)	0.2624	0.3252	0.1173	0.1082

Theta (median)	0.55	0.49	0.48	0.50
Rho	0.50	0.42	0.41	0.43
White's test (Prob>chi2)	0.1922	0.3127	0.7381	0.8914
Mean VIF	1.93	2.26	2.15	2.14

Table 7 – Robustness test

This table reports results from a panel random effects model of *INN* (defined as a score variable which ranges from zero to six according to the number of categories where bank *i* innovates in year *t*) on a baseline vector of bank characteristics (Column 1 and 5), banking system variables (Column 2, 6 and 9), country-specific variables (Column 3 and 7), and a model including a time trend (Column 4, 8 and 10). Column 1 to 4 report results on a sub-sample where banks up to the 1st decile of innovation distribution have been dropped. Column 5 to 8, report results on a sub-sample formed by banks which innovate at least in one category over the four-year period under scrutiny. Column 9 and 10 report results on a sub-sample where banks up to the 1st quartile of innovation distribution have been dropped. Panel model standard errors are reported between brackets. Asterisks indicate significance at 1 per cent (***), 5 per cent (**) and 10 per cent (*) levels. Column 3, 4, 7, 8 and 10 present heteroskedasticity robust standard errors.

	Dropped banks up to 1st decile of innovation				Dropped banks with zero innovation over the 4-year period				Dropped banks up to 1st quartile of innovation	
Independent variables	(1) Baseline model	(2) with banking system	(3) with country-specific	(4) with trend	(5) Baseline model	(6) with banking system	(7) with country-specific	(8) with trend	(9) with banking system	(10) with trend
Constant	1.11	4.18***	1.21	3.43***	1.06	4.14***	1.32	3.51***	4.70***	4.11***
	[1.102]	*[1.260]*	*[1.336]*	*[0.628]*	*[1.104]*	*[1.259]*	*[1.339]*	*[0.641]*	*[1.238]*	*[0.734]*
Age	0.14	-0.23			0.15	-0.21			-0.19	
	[0.188]	*[0.193]*			*[0.188]*	*[0.193]*			*[0.185]*	
Relative size	4.59**	9.77***	8.88***	9.02***	4.59**	9.72***	8.90***	9.01***	9.01***	8.44***
	[1.903]	*[2.357]*	*[2.227]*	*[2.447]*	*[1.909]*	*[2.356]*	*[2.220]*	*[2.426]*	*[2.276]*	*[2.341]*
Cost income	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
	[0.004]	*[0.004]*	*[0.004]*	*[0.002]*	*[0.004]*	*[0.004]*	*[0.004]*	*[0.002]*	*[0.004]*	*[0.002]*
EBITDA to revenues	0.00	-0.01	-0.01	-0.00	0.00	-0.01	-0.01	-0.00	-0.01	-0.01
	[0.013]	*[0.012]*	*[0.011]*	*[0.005]*	*[0.013]*	*[0.012]*	*[0.011]*	*[0.005]*	*[0.011]*	*[0.006]*
Total asset growth	0.75	0.69	0.91*	0.58	0.76	0.70	0.90*	0.58	0.35	0.27
	[0.467]	*[0.467]*	*[0.485]*	*[0.434]*	*[0.471]*	*[0.472]*	*[0.489]*	*[0.443]*	*[0.477]*	*[0.391]*
Total asset growth (lag)	1.17**	1.13**	0.91	0.62	1.07**	1.04*	0.83	0.55	1.02*	0.66
	[0.537]	*[0.545]*	*[0.553]*	*[0.537]*	*[0.543]*	*[0.550]*	*[0.557]*	*[0.535]*	*[0.557]*	*[0.532]*
Volatility of ROE	-0.05*	-0.05**	-0.04	-0.04**	-0.05*	-0.05**	-0.04	-0.04**	-0.06**	-0.05***
	[0.026]	*[0.025]*	*[0.026]*	*[0.018]*	*[0.026]*	*[0.025]*	*[0.027]*	*[0.018]*	*[0.025]*	*[0.018]*

Volatility of ROE (lag)	0.01	0.00	0.02	0.02	-0.00	-0.00	0.02	0.01	-0.01	0.00
	[0.061]	*[0.059]*	*[0.059]*	*[0.058]*	*[0.062]*	*[0.059]*	*[0.059]*	*[0.058]*	*[0.058]*	*[0.058]*
Equity to total assets	-0.52	-3.49	-5.09	-4.42	-0.28	-3.42	-5.09	-4.45	-6.31	-7.31
	[5.240]	*[4.873]*	*[4.712]*	*[4.285]*	*[5.255]*	*[4.875]*	*[4.700]*	*[4.329]*	*[4.841]*	*[4.501]*
Reserves for impaired to gross loans	-7.38	-3.25	-2.91	-2.03	-7.22	-2.97	-2.66	-1.86	1.62	2.66
	[9.826]	*[9.171]*	*[8.936]*	*[6.282]*	*[9.844]*	*[9.174]*	*[8.922]*	*[6.339]*	*[9.070]*	*[5.979]*
Reserves for impaired to gross loans (lag)	36.17*	40.87**	48.27***	40.92**	35.58*	40.02**	47.32***	40.29**	30.62*	31.17*
	[19.459]	*[17.775]*	*[17.716]*	*[18.992]*	*[19.520]*	*[17.806]*	*[17.717]*	*[18.873]*	*[17.587]*	*[17.288]*
HHI		-0.00***	-0.00**	-0.00**		-0.00***	-0.00**	-0.00**	-0.00***	-0.00**
		[0.001]	*[0.001]*	*[0.001]*		*[0.001]*	*[0.001]*	*[0.001]*	*[0.001]*	*[0.001]*
Number of employees to number of banks ratio		-0.00***	-0.00***	-0.00***		-0.00***	-0.00***	-0.00***	-0.00***	-0.00***
		[0.001]	*[0.001]*	*[0.001]*		*[0.001]*	*[0.001]*	*[0.001]*	*[0.001]*	*[0.001]*
GDP growth			0.14*				0.14*			
			[0.075]				*[0.076]*			
Long term yield			0.30				0.30			
			[0.261]				*[0.262]*			
Time trend				-0.26***				-0.26***		-0.20**
				[0.074]				*[0.076]*		*[0.085]*
Observations *(bank)*	145 *(47)*	145 *(47)*	145 *(47)*	145 *(47)*	141 *(46)*	141 *(46)*	141 *(46)*	141 *(46)*	125 *(42)*	125 *(42)*
R-squared between	0.44	0.60	0.62	0.60	0.43	0.60	0.62	0.61	0.64	0.65

Table 8 – Geographical and financial crisis effects on innovation

This table reports results from a panel random effects model of *INN* (defined as a score variable which ranges from zero to six according to the number of categories where bank *i* innovates in year *t*) on a vector of bank characteristics, banking system variables and interaction effect between selected significant variables and a geographical dummy for bank incorporated in the US (Column 1); and a year dummy for 2008 (Column 2). Panel model standard errors are reported between brackets. Asterisks indicate significance at 1 per cent (***), 5 per cent (**) and 10 per cent (*) levels.

Independent variables	(1) geographical effect	*standard error*	(2) financial crisis effect	*standard error*
Constant	3.43***	*[0.920]*	3.29**	*[1.287]*
Age			-0.09	*[0.203]*
Relative size	7.01***	*[2.493]*	9.65***	*[2.651]*
Cost income	-0.00	*[0.005]*	-0.00	*[0.004]*
EBITDA to revenues	-0.01	*[0.014]*	-0.00	*[0.012]*
Total asset growth	0.51	*[0.425]*	0.82*	*[0.429]*
Total asset growth (lag)	0.27	*[0.528]*	0.72	*[0.485]*
Volatility of ROE	-0.03	*[0.026]*	-0.02	*[0.024]*
Volatility of ROE (lag)	0.03	*[0.056]*	0.02	*[0.055]*
Equity to total assets	-6.51*	*[3.861]*	-8.75**	*[4.203]*
Reserves for impaired to gross loans	-0.39	*[8.467]*	-10.71	*[9.052]*
Reserves for impaired to gross loans (lag)	36.49*	*[19.657]*	54.09***	*[17.398]*
HHI	-0.00	*[0.001]*	-0.00**	*[0.001]*
Number of employees to number of banks ratio	-0.00**	*[0.001]*	-0.00**	*[0.001]*
Time trend	-0.17*	*[0.089]*		
Geographical effect (dummy US)	-0.05	*[0.613]*		
interaction with relative size	13.01**	*[5.482]*		
interaction with reserves for impaired to gross loans	-44.47*	*[23.390]*		
interaction with volatility of ROE	0.03	*[0.045]*		
Financial crisis effect (dummy year 2008)			-1.10**	*[0.513]*
interaction with relative size			-0.35	*[1.997]*
interaction with equity to total asset			9.03*	*[4.642]*
Observations *(bank)*	169 *(54)*		169 *(54)*	
R-squared between	0.61		0.59	