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Financial Development and Innovation: Is There Evidence of a Schumpeterian Finance-Innovation Nexus?

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We study the effect of financial development on innovation for 51 countries between 1993 and 2008. Consistent with expectations from Schumpeterian models of finance, entrepreneurship and economic growth, we find that higher levels of financial development coincide with stronger innovative activity. We also study the role of banking crises in the finance-innovation nexus and do not find that banking crises matter. In sum, our findings suggests that financial intermediaries may indeed encourage investment in innovative entrepreneurial activity. Thus, economic policies that strengthen a country's financial system may also improve its innovative capacity, which in turn promotes economic growth.

Key Words: Financial development; Innovation; Banking crisis; Growth policy.
JEL Classification Numbers: G20, O16, O30.

1. INTRODUCTION

Theoretical contributions have long established that innovation promotes economic development (e.g., Aghion and Howitt, 1992; Romer, 1990; Temple, 1999; Aghion, 2004). For instance, Aghion and Howitt (1992) introduce a model in which innovation — endogenously generated by a competitive research sector — raises productivity through a process of Schumpeterian "creative destruction", consequently fostering economic growth. The empirical evidence similarly suggests that technological progress, national innovative capacity and the productivity gains associated with innovation are important sources of economic growth (e.g., Geroski, 1989; Färe et al., 1994; Fagerberg et al., 2007).

Due to the beneficial role of technological progress in economic growth and development, further scholarly contributions have set out to identify the national determinants of innovation. These studies have found that innovation is not only positively influenced by factors directly associated

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with the generation of new knowledge such as R&D spending, the quality of education and specialization in industrial clusters but also by a nation's common innovation infrastructure, i.e., the economic and politico-institutional innovation environment (Grilliches, 1990; Aghion, 2004; Furman et al., 2002; Varsakelis, 2006). For instance, existing research suggests that innovation may also be promoted by openness to international trade, a strong protection of property rights and sound institutions that encourage entrepreneurship (Lall, 1992; Furman et al., 2002; Varsakelis, 2006).

In this contribution we examine another element of a nation's innovation infrastructure, the financial system. Indeed, a number of theoretical contributions emphasize the beneficial effect of financial development on innovation and, ultimately, economic growth (e.g., King and Levine, 1993a; Morales, 2003). These models in turn build on earlier contributions that pioneered the idea of a nexus between finance and innovation, e.g., The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest and the Business Cycle by Schumpeter (1934). Schumpeter (1934: 74) describes the role of financial intermediaries in fostering innovation as follows:

> "[The banker] stands between those who wish to form new combinations and the possessors of productive means. [...] He makes possible the carrying out of new combinations, authorises people, in the name of the society as it were, to form them. He is the ephor of the exchange economy."

In line with these considerations, modern-day theories of a finance-innovation nexus suggest — broadly speaking — that the financial system fosters innovation by providing vital financial services (e.g., information acquisition and risk management) that lower transaction costs and consequently facilitate investment in risky — but potentially also very profitable — long-run innovative entrepreneurial activity (Levine, 1997). Curiously, though, there is little direct empirical evidence that financial development actually augments innovation. In particular, no cross-country evidence has so far studied the relationship between national levels of financial development and national levels of innovation. Acknowledging this research gap, we provide a cross-national study of the influence of financial development on innovation for 51 countries between 1993 and 2008. Our findings indeed show that the financial system is an important part of a nation's common innovation infrastructure which, together with other well-known elements such as sound institutions, a functioning educational system and effective R&D policies, favorably determines national innovative capacity. This effect is present even when we simultaneously control for the influence of banking crises on innovation, where the advent of banking crises is not found to have a detrimental effect on innovation. In sum, our findings suggest that economic policies that strengthen a country's financial system

may also pay off in terms of increased innovative activity, which in turn may result in improved economic performance.

This paper is organized as follows. In Section 2 we discuss the linkages between financial development and national innovative activity. In Section 3 we introduce the data and empirical methodology used to empirically analyze the finance-innovation nexus. Our empirical findings are presented, discussed and extended in Section 4. Section 5 concludes.

2. FINANCIAL DEVELOPMENT AND INNOVATION

As stressed in the introduction, the beneficial effect of technological change on economic progress, which has been established in theory and through empirical evidence (e.g., Romer, 1990; Aghion and Howitt, 1992; Färe et al., 1994; Fagerberg et al., 2007), calls for an identification of the determinants of innovation to guide economic policy accordingly. Here, previous empirical studies have found that R&D spending and the quality of education (i.e., inputs in the knowledge production function) but also a sound common innovation infrastructure (characterized by openness to international trade, strong protection of property rights and sound government institutions guaranteeing the rule of law and scientific and economic freedom) affect the national innovation output (e.g., Grilliches, 1990; Lall, 1992; Furman et al., 2002; Varsakelis, 2006).

Another element of a nation's innovation infrastructure is its financial system. However, this element has been largely ignored in empirical research. In particular, while there is some micro-level evidence that access to finance matters to innovation on the firm level (e.g., Czarnitzki, 2006; Benfratello et al., 2008), there is no comparable macro-level evidence linking national levels of financial development to national levels of innovation. This is surprising, given the prominent role in the development process Schumpeter (1934) and others have assigned to the financial sector. In fact, the idea of an enabling effect of finance on innovation — and, consequently, economic growth — is central to a number of theoretical contributions that model the relationship between financial development, technological progress and economic development (King and Levine, 1993a; De La Fuente and Marin, 1996; Blackburn and Hung, 1998; Morales, 2003; Aghion et al., 2005). Furthermore, a host of empirical studies implicitly corroborate these theoretical considerations by finding that financial development tends to matter to economic growth (e.g., King and Levine, 1993b; Levine, 1997; Calderon and Liu, 2003; Shan and Jianhong, 2006; Gries et al., 2009, 2011).

How can a nation's financial system promote innovative activity? In theory, financial intermediaries (e.g., banks) emerge and evolve due to the presence of market imperfections (i.e., the absence of perfect information

and perfect competition). These frictions create transaction costs associated with, e.g., information acquisition, the exchange of goods and services and the enforcement of contracts (Levine, 1997). The financial sector (i.e., the sum of all institutions specialized in financial intermediation) provides specific financial services that help to reduce or overcome such market frictions, thereby reducing the associated transaction costs (Levine, 1997). Ultimately, the emergence and development of financial intermediation ought to contribute to more beneficial economic outcomes vis-à-vis a world without financial markets (e.g., Saint-Paul, 1992; Levine, 1997). Important to our study, financial intermediation may also favorably affect innovation. As we show below, innovative (entrepreneurial) activity is associated with specific market frictions and transaction costs which can be moderated by the activity of financial intermediaries and the provision of specific financial services, leading to more innovative activity.

(1) Investments in entrepreneurial innovative activity usually involve information acquisition costs. For the individual investor it tends to be very difficult (i.e., costly) to evaluate investment projects properly, e.g., with respect to the involved researchers and managers and overall market conditions (Levine, 1997). High information costs may lead to reluctance to invest on the part of the individual saver. This creates incentives for financial development. Financial intermediaries ought to acquire and process information about investment opportunities more efficiently through specialization and learning-by-doing effects (Lee, 1996; Levine, 1997), thus reducing the information costs for individual investors and making the identification of promising production technologies and innovative entrepreneurs more likely (King and Levine, 1993a; Blackburn and Hung, 1998). Consequently, these entrepreneurs ought to be more likely to receive sufficient resources to finance innovative activity, which in turn is expected to increase the aggregate (national) innovation output (King and Levine, 1993a; Blackburn and Hung, 1998).

(2) Besides information costs, investment decisions by individual savers usually also produce costs associated with liquidity and idiosyncratic risk. While liquidity risk is linked to the conversion of assets into mediums of exchange at a desired time and price, idiosyncratic risk refers to risk associated with specific investment projects such as the default risk due to economic downturns, political crisis or other market developments. Liquidity and idiosyncratic risk may especially constrain investment into innovative activity because such activity tends to necessitate long-run investment commitment (which negatively affects liquidity) and tends to involve high uncertainty about innovation outcomes (meaning higher idiosyncratic risk). Financial intermediation may help overcome these investment obstacles through the efficient management and diversification of risk. For one, financial intermediaries offer specific financial instruments (e.g., shares)

which can be inexpensively traded on specific financial markets (e.g., the stock exchange), making it possible for individual savers to efficiently overcome sudden liquidity shocks (reducing the liquidity risk). For another, financial intermediaries offer means to diversify the investment risk of individual investors (e.g., through portfolio diversification), which reduces the exposure of individual investors to risk associated with specific investment projects (reducing the idiosyncratic risk associated with these projects). Consequently, financial intermediation ought to make long-run investments into innovative activity more attractive and raise innovation, as it is expected to reduce both liquidity and idiosyncratic risk (Saint-Paul, 1992; King and Levine, 1993a).

(3) Innovative activity usually also entails high start-up and operating costs. Given that internal sources of finance are usually insufficient, this calls for the pooling of savings from multiple investors to provide access to sufficient (external) means of finance. Without external resources, there is the danger of economically inefficient scales that may constrain innovation (Levine, 1997). However, the mobilization and channeling of savings to entrepreneurs involves transaction costs. For instance, savings need to be collected from multiple savers and mutual trust between savers and lenders has to be established (Levine, 1997). Again, financial intermediaries can reduce the associated transaction costs. For example, through the establishment of financial institutions (e.g., banks) to collect savings financial intermediaries can economize on savings mobilization costs. The creation of specific financial instruments (e.g., shares) may further optimize the mobilization and pooling of savings, also by unlocking foreign sources of finance (Levine, 1997). Finally, formal financial institutions and instruments are likely to facilitate economic transactions between investors and entrepreneurs and consequently promote mutual trust between them. Through such mechanisms, financial development ought to aid the mobilization of savings and its efficient channeling to innovative entrepreneurs, which is anticipated to result in increased innovative activity (King and Levine, 1993a; Blackburn and Hung, 1998).

(4) Investment projects create additional information problems once they have been financed and launched. In particular, there exist informational asymmetries between investors and lenders. That is, there are incentives for insiders (e.g., researchers, managers) to misrepresent results (e.g., about the research output or returns to investment) to outsiders, i.e., investors (Shleifer and Vishny, 1997). Information asymmetry produces agency costs for individual investors, e.g., in the form of monitoring and enforcement costs which may make it less attractive to invest in innovative projects (Levine, 1997; Shleifer and Vishny, 1997). Financial development may help to reduce these transaction costs. For example, the individual investors may delegate the monitoring of investment projects and the exercise

of corporate control to a financial intermediary, which reduces overall costs by allowing the financial intermediary to economize on the associated monitoring costs (Levine, 1997). What is more, financial intermediaries — due to specialization — may more successfully design financial arrangements to moderate insider-outsider conflicts and create contractual incentives for insiders, so as to avoid misrepresentation by insiders in the first place. In sum, financial development is expected to reduce agency and monitoring costs, making investment in innovative activity comparatively more attractive, which consequently again ought to raise aggregate innovation (De La Fuente and Marin, 1996; Morales, 2003).

To summarize this section, financial intermediaries help to reduce or overcome transaction costs (e.g., information, savings mobilization and monitoring costs) that arise due to market imperfections. The transactions costs associated with specific market imperfections would otherwise constrain investment especially in innovative projects, given that such projects tend to entail a comparatively large demand for capital, long-term commitments and uncertainty about the eventual research and innovation results. Consequently, we expect financial development to promote innovation. Thus, our main hypothesis is as follows:

> *Hypothesis:* A higher level of (national) financial development is associated with a higher level of (national) innovative activity.

3. DATA AND METHODOLOGY

To test our hypothesis that a well-functioning financial system is — together with a set of other factors — part of a nation's innovation infrastructure that favorably determines national innovative capacity, we collect data on innovative activity, financial development and a number of control variables for 51 countries for the period between 1993 and 2008.[1] A list of countries is given in the appendix. The summary statistics are reported in Table 1.

3.1. Dependent Variable

Following earlier studies on the determinants of national innovation activity (e.g., Varsakelis, 2006), we use patent count data to indicate national innovative activity. This choice is further supported by Hagedoorn and Cloodt (2003: 1368) who argue that "patent counts are generally accepted as one of the most appropriate indicators that enable researchers

[1]Note that the sample is restricted to these countries and this observation period as data on innovation, financial development and institutional conditions are only fragmentary for many countries.

TABLE 1.

Summary Statistics

Variable	N*T	Mean	Std. Dev.	Min.	Max.
Patents per Thousand Residents	816	0.201	0.461	0.001	3.032
Liquid Liabilities to GDP	800	72.407	54.731	12.855	399.116
Private Credit by Money Banks to GDP	800	67.302	47.470	6.838	272.809
Economic Rights Protection	816	0.715	0.201	0.201	1
R&D Expenditures to GDP*	816	1.228	1.047	0.051	4.058
Tertiary School Enrollment*	816	40.488	20.707	2.648	81.147
Rule of Law	816	0.752	0.225	0.167	1
Trade Openness**	816	22.847	38.536	2.3	281.29
Political Instability	816	0.166	0.160	0	0.965
Real Per Capita Income	816	18832.820	14049.670	685.460	89814.250

Notes: (*) data averaged over 1993-2008 period due to data constraints. (**) variable is time-invariant.

to compare the inventive or innovative performance [...] in terms of new technologies, new processes and new products".

Specifically, for our study we use data on patent applications by residents of a country per thousand residents as our proxy of national innovative activity. The patent application data is normalized by population size to factor in population growth, so as to construct a measure of innovation that is consistent over time. The data on population size are from the PENN World Table (Heston et al., 2011). Data on patent applications by residents of a country are drawn from the World Development Indicators (World Bank, 2013). This dataset aggregates patent application data provided by the World Intellectual Property Organization. Here, patent applications refer to worldwide patent applications by residents of a country filed through the Patent Cooperation Treaty procedure or with a national patent office.

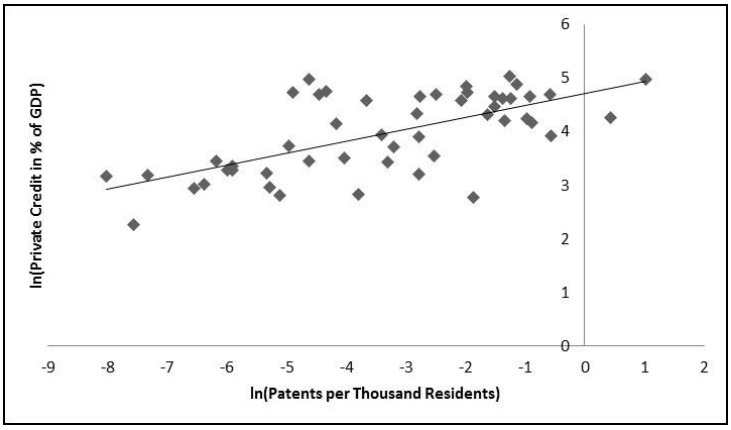
3.2. Main Explanatory Variables

For our study we use two indicators to measure financial development, so as to arrive at more robust findings. Our financial development indicators are the ratio of liquid liabilities to GDP and the ratio of private credit by deposit money banks to GDP. The former indicator measures the overall size of the financial system (i.e., financial depth), where Beck et al. (2000: 600) argue that it is the "broadest available indicator of financial intermediation" as it does not distinguish between the different parts of the financial system. The latter indicator is specifically linked to the banking sector and measures "one of the main activities of financial intermediaries: channeling savings to investors" (Beck et al., 2000: 601). Both financial development variables are drawn from the most recent update of

the Financial Development and Structure Dataset introduced by Beck et al. (2000). We chose the aforementioned financial development proxies for two reasons. First, these data series are available for a large number of countries and years and usually do not exhibit large gaps. By contrast, data on other aspects of financial development (e.g., on stock market development) is only available for shorter time spans and fewer countries.[2] Second, previous empirical research indicates that both the ratio of liquid liabilities to GDP and the ratio of private credit by deposit money banks to GDP are strongly associated with economic development (e.g., King and Levine, 1993b; Levine, 1997). Potentially, this relationship results from the positive effect of financial development on innovation, which in turn stimulates economic growth.

Indeed, as shown in Figure 1, financial development and innovation appear to correlate positively. Between 1993 and 2008 countries with a higher level of financial development on average also exhibited a higher innovation output. The Pearson product-moment correlation coefficients are $r = 0.46$ ($p < 0.01$) for the correlation between the patent count and liquid liabilities to GDP and $r = 0.59$ ($p < 0.01$) for the correlation between the patent count and private credit to GDP, respectively.

FIG. 1. Relationship between the Average Level of Financial Development (Private Credit) and Innovation, 1993-2008



[2]Future research may consider the role of other aspects of financial development in innovation once the data become available. For instance, it may be interesting to see whether and in which way stock market development influences a country's innovative activity.

3.3. Control Variables

Clearly, however, Figure 1 and the bivariate correlation analysis are only a first indication that a finance-innovation nexus may actually exist. The regression analysis approach we employ in this study calls for the inclusion of control variables to establish a robust relationship between financial development and innovation, as the inclusion of controls prevents us from detecting only spurious effects of finance on knowledge production. Our choice of adequate controls follows the existing research on the national determinants of innovation. Below, we discuss the individual controls in more detail. The appendix provides an overview of the definition, operationalization and data source of the control variables.[3]

First, we control for variables that directly matter to the output of the knowledge production function. For one, we consider the effect of R&D expenditures on innovation output. Intuitively, a higher level of R&D intensity ought to be positively associated with innovation (e.g., Furman et al., 2002). Similarly, we expect education to play a major role in promoting innovation. For instance, Varsakelis (2006) argues that education ought to fuel innovation by creating to a larger pool of scientists, skilled workers and innovative entrepreneurs. Indeed, the empirical evidence suggests that both R&D spending and education matter strongly to the national innovation output (e.g., Grilliches, 1990; Furman et al., 2002; Varsakelis, 2006).

Second, while it is highly intuitive that the innovative output positively reacts to more input into the knowledge production function (e.g., in the form of better educated and funded scientists), further academic research suggests that a nation's common innovation infrastructure also matters, where a more developed infrastructure ought to be conducive to innovation. Given that we expect the financial system to be an important element of this infrastructure, it is important to also consider other potentially relevant infrastructure elements to avoid detecting only spurious associations between financial development and innovation. Here, we consider the role of the rule of law and the protection of property rights. These variables reflect the quality of (government) institutions associated with, inter alia, the security of investments, the protection of patents and the commitment to economic and scientific freedom. Sound institutions create incentives to engage in innovative entrepreneurial activity. For instance, an effective judicial system ought to interact beneficially with a sound protection of intellectual property rights, both of which foster innovation by ensuring that entrepreneurs are able to fully enjoy the fruits of their innovative ac-

[3]Note that due to data constraints some variables are averaged over the 1993-2008 period or are time-invariant constants. These variables are indicated accordingly in the appendix and Table 1.

tivity. Indeed, Varsakelis (2006) shows that sound institutions encourage innovation.

Lall (1992) and Furman et al. (2002) stress the role of international trade in promoting innovation. For instance, trade may facilitate the international diffusion of technological progress. Also, trade may increase (domestic and international) competition, which in turn may stimulate innovation by market participants (Lall, 1992). We factor in these lines of reasoning by controlling for the level of openness to international trade.

Svennson (1998) argues that political instability may constrain investment (and thus innovative activity). He argues that instability does not create sufficient incentives to properly protect property rights. Given the important role the protection of intellectual property rights usually plays in promoting innovation (Varsakelis, 2006), it seems plausible that instability may reduce innovation by eroding property rights protection. Also, political instability has obvious negative effects on the size and attractiveness of domestic markets, which in turn ought to further deter investment and innovation (Lall, 1992).

Finally, Lall (1992) also argues that a country's level of macroeconomic development matters to its innovative output. For instance, a higher level of economic development opens up markets for innovative (i.e., costly) products, creating incentives to innovate accordingly. Thus, we also consider the influence of the level of economic development on innovation in some specifications.

3.4. Estimation Model and Empirical Methodology

To test our hypothesis that financial development is conducive to innovation (net of the influence of the control variables), we run a series of regression models of the following form (Eq. 1):

$$\ln(\text{patents})_{i,t} = \alpha + \beta_1 \ln(\text{FINDEV})_{jt,t-1} + \beta_2' X'_{i,t-1} + \mu_{i,t} \qquad (1)$$

Here, patents refers to the ratio of the sum of patent applications by residents of country i in relation to a country's population size at time t. FINDEV is our j-th measure of financial development (i.e., either the ratio of liquid liabilities to GDP or the ratio of private credit by deposit money banks to GDP). X' refers to a vector of control variables indicating R&D expenditures, tertiary education, institutional quality (i.e., the rule of law and property rights protection), trade openness, political instability and economic development, where the vector of controls may differ across different specifications. α is the constant and μ refers to a well-behaved error term. Note that the explanatory variables enter the model in lagged form to make a stronger causal argument about the effect of financial development and the other controls on innovation. Finally, also note that some variables are logged to make the estimations more robust to outliers.

Initial tests indicate the presence of autocorrelation, heteroskedasticity and cross-sectional dependence, as it is common for time-series cross-sectional data with country-year observations.[4] We therefore run a series of OLS regressions with Driscoll-Kraay standard errors that are robust to these traits of the data (Driscoll and Kraay, 1998).

4. EMPIRICAL RESULTS AND DISCUSSION

4.1. Main Findings

Our empirical findings regarding an effect of financial development on the national innovation output are reported in Table 2. They suggest that financial development is positively associated with innovative activity in the subsequent year. We arrive at this result regardless of whether financial development is measured in terms of the ratio of liquid liabilities to GDP or the ratio of private credit by deposit money banks to GDP. Our finding is robust to the inclusion of a variety of control variables that may also plausibly sway a country's innovative capacity and activity. While the introduction of the controls reduces the size of the regression coefficients corresponding to the financial development proxies, the effect of finance on innovation nevertheless remains statistically significant. The impact of financial development on innovation is also economically substantive. For instance, for the full model specifications (7) and (8) a one percent increase in the ratio of liquid liabilities to GDP (the ratio of private credit by deposit money banks to GDP) results in a 0.34 (0.21) percent increase in the national innovation output in the subsequent year. In sum, our findings thus provide robust support for our main hypothesis of a finance-innovation nexus.

[4]We test for the presence of cross-sectional dependence using the test proposed by Frees (1995). While it is common to test and correct for heteroskedasticity and autocorrelation, the issue of cross-sectional dependence has received less attention in the empirical literature. Cross-sectional dependence refers to the spatial dependence of a non-random sample of cross-sectional units (in our case, countries) due to both observable and unobservable common shocks. Not accounting for this dependence may yield inconsistent estimates of the standard errors of these parameters and therefore affect hypothesis testing (Driscoll and Kraay, 1998).

TABLE 2.

Effect of Financial Development on Innovation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Liquid Liabilities$_{t-1}$	1.601		0.616		0.454		0.339	
	$(34.55)^{***}$		$(10.40)^{***}$		$(4.25)^{***}$		$(3.73)^{***}$	
Private Credit$_{t-1}$		1.635		0.490		0.357		0.212
		$(25.24)^{***}$		$(11.50)^{***}$		$(6.09)^{***}$		$(4.91)^{***}$
R&D Expenditures			0.941	0.951	0.880	0.878	0.853	0.863
			$(19.33)^{***}$	$(17.56)^{***}$	$(18.64)^{***}$	$(18.79)^{***}$	$(19.48)^{***}$	$(20.54)^{***}$
Tertiary Education			0.046	0.042	0.042	0.040	0.031	0.029
			$(73.35)^{***}$	$(34.42)^{***}$	$(23.86)^{***}$	$(19.03)^{***}$	$(14.36)^{***}$	$(11.37)^{***}$
Rule of Law$_{t-1}$					0.983	0.945	0.027	0.052
					$(5.49)^{***}$	$(5.36)^{***}$	(0.14)	(0.24)
Economic Rights			0.551	0.659	0.646	0.669	0.290	0.370
Protection$_{t-1}$			$(4.24)^{***}$	$(4.42)^{***}$	$(5.66)^{***}$	$(5.36)^{***}$	$(1.99)^{*}$	$(2.93)^{**}$
Trade Openness					0.001	0.002	-0.002	-0.001
					(0.54)	(1.63)	(1.00)	(0.67)
Political Instability$_{t-1}$							-1.410	-1.412
							$(4.18)^{***}$	$(3.61)^{***}$
Per Capita Income$_{t-1}$							0.416	0.443
							$(12.26)^{***}$	$(13.91)^{***}$
Adjusted R^2	0.210	0.348	0.791	0.795	0.796	0.801	0.811	0.817
Mean VIF			1.55	1.61	1.95	1.98	2.62	2.71
No. of Countries	50	50	50	50	50	50	50	50
No. of Observations	750	750	750	750	750	750	750	750

Notes: Constant not reported. Dependent variable: natural logarithm of the sum of patent applications per thousand residents. Absolute t-values in parentheses based on Driscoll-Kraay standard errors. Mean VIF: mean variance inflation factor, indicating the presence of multicollinearity if larger than 3. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

With respect to the control variables, our findings are largely in line with previous research. First, R&D expenditures and tertiary education are positively related to innovative productivity, as previously found by Furman et al. (2002) and Varsakelis (2006). This suggests that inputs in the knowledge production function matter to the national innovation output, as argued by Grilliches (1990). Second, we find that institutional quality (i.e., the protection of economic rights and a sound rule of law) positively affects innovation, supporting the empirical findings of Varsakelis (2006). As expected, our findings suggest that institutions are part of a nation's common innovation infrastructure, where an effective judicial system and a sound protection of (intellectual) property rights and economic freedom are conducive to investment, entrepreneurship and, in consequence, innovation. Third, while we do not find that trade openness fosters innovation, our results indicate that higher levels of economic development create incentives for innovative activity.[5] This supports the ideas of Lall (1992) who argues that macroeconomic variables affecting market structure and size matter to the patterns of innovation. Finally, we find that political instability reduces innovation, presumably as it constrains investment and institutional quality, as argued by, e.g., Svennson (1998).[6]

4.2. Robustness Checks

Our main findings are robust to several methodological and data changes.[7] First, using other estimation methods (e.g., OLS with only heteroskedasticity and autocorrelation-robust standard errors, panel random-effects models) yields results similar to those reported above. Second, adding further control variables (such as regional and time dummies or variables indicating government size, aggregate investment or democratic accountability) to our model specifications does not affect our main findings. Third, dropping outliers from our sample does not change our main empirical results. For instance, this can be observed when we drop data for Japan as an outlier in terms of innovative activity and data for Hong Kong and Luxembourg as outliers in terms of the level of financial development, given the role of the latter (rather small) countries play as regional financial hubs.

[5]Note that while our measure of trade openness does not affect innovation, this does not rule out any beneficial effect of international economic integration on innovation (e.g., due to increased competition). Possibly, other measures of integration (most importantly, foreign direct investment) are more relevant to a nexus between economic openness and innovative activity. This may be a fruitful area of future research.

[6]Note that partial multicollinearity (due to the high correlation between institutional quality, political instability and per capita income) affects our findings for the full model specifications and renders the effect of the rule of law on innovation statistically insignificant.

[7]All robustness checks are available upon request.

4.3. Extension: Banking Crises, Financial Development and Innovation

As an extension to our empirical analysis, in this subsection we study the role of banking crises in the finance-innovation nexus. This extension is motivated especially by the events associated with the 2007-2008 global financial crisis.[8] Possibly, banking and financial crises may negatively affect innovation through their detrimental effect on financial development. For one, the advent of banking crises is characterized by bank illiquidity, i.e., the collapse of some financial institutions and a general reluctance of banks to provide credit to one another and other borrowers (Dell' Ariccia et al., 2008). This credit rationing effect ought to be felt the strongest by industries strongly dependent on external finance (Dell' Ariccia et al., 2008). As argued above, innovative industrial sectors tend to rely rather strongly on external finance (Levine, 1997). Reduced financial activity — induced by a banking crisis — may therefore hurt innovative activity. For another, financial crises usually produce large negative macroeconomic repercussions, e.g., in the form of reduced economic activity and industrial output (Reinhart and Rogoff, 2009), which may also matter to otherwise healthy financial institutions. Here, reduced real sector activity is likely to reduce financial sector activity (e.g., by means of reduced demand for financial services). This additional contraction of the financial sector may further amplify the negative effect of banking crises on innovation.

To empirically capture the effect of banking crises on the financeinnovation nexus, we amend our empirical model introduced above with a variable indicating the prevalence of a banking crisis. The corresponding data are drawn from Laeven and Valencia (2012). Laeven and Valencia (2012: 4) define a banking crisis as an event characterized by significant signs of distress in the banking system (in the form of, e.g., bank runs) and major policy interventions in response to this distress (in the form of, e.g., bank nationalizations). Laeven and Valencia (2012: 1) stress that their dataset includes all systemic banking crises that occurred during our observation period.

Our empirical findings are reported in Table 3. In short, they suggest that banking crises do not negatively affect innovation, while a country's level of financial development remains a robust and positive predictor of innovative activity. That is, there is evidence for a finance-innovation nexus even after taking into account banking crises effects. The results for the control variables are very similar to those reported in Table 2.

[8] However, the countries in the sample also saw other financial crises during the observation period. Examples include the Finnish banking crisis of the 1990s, the Mexican Tequila crisis of 1994-1995 and the Asian financial crisis of 1997-1998.

TABLE 3.

Banking Crises, Financial Development and Innovation

	(1)	(2)	(3)	(4)	(5)	(6)
Liquid Liabilities$_{t-1}$	1.598			0.336		
	(32.61)***			(3.48)***		
Private Credit$_{t-1}$		1.633			0.203	
		(25.25)***			(3.85)***	
Banking Crisis$_{t-1}$	−0.126	−0.110	−0.273	0.062	0.160	0.142
	(0.26)	(0.24)	(0.76)	(0.42)	(1.40)	(1.21)
R&D Expenditures				0.853	0.864	0.870
				(19.74)***	(20.61)***	(23.93)***
Tertiary Education				0.031	0.029	0.026
				(14.93)***	(11.56)***	(9.73)***
Economic Rights				0.312	0.427	0.524
Protection$_{t-1}$				(1.62)	(2.64)**	(3.04)***
Rule of Law$_{t-1}$				0.043	0.097	0.416
				(0.20)	(0.40)	(1.75)*
Trade Openness				0.002	−0.001	−0.002
				(0.98)	(0.67)	(0.91)
Political Instability$_{t-1}$				−1.396	1.369	−1.562
				(3.94)***	(3.27)***	(3.67)***
Per Capita Income$_{t-1}$				0.417	0.448	0.490
				(13.15)***	(15.17)***	(9.73)***
Adjusted R^2	0.211	0.348	0.001	0.811	0.817	0.804
Mean VIF	1.01	1.01		2.47	2.55	2.42
No. of Countries	51	51	51	51	51	51
No. of Observations	765	765	765	765	765	765

Notes: Constant not reported. Dependent variable: natural logarithm of the sum of patent applications per thousand residents. Absolute t-values in parentheses based on Driscoll-Kraay standard errors. Mean VIF: mean variance inflation factor, indicating the presence of multicollinearity if larger than 3. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Our results are somewhat suprising, given the substantial distress banking crises tend to produce in the real and financial sector of an economy (Dell' Ariccia et al., 2008; Reinhart and Rogoff, 2009). Yet, there are several explanations for our findings, where these explanation approaches may also hint at interesting avenues for future research on the finance-innovation-crisis nexus. First, our analysis does not fully cover the aftermath of the most serious financial crisis, the global financial crisis that started in 2007, given that our observation period — due to data constraints — ends in 2008. Potentially, the adverse effects of the 2007-2008 global financial crisis would only feed through to reduced innovative activity after 2008. Second, the innovative sector may be protected from the

negative consequences of banking crises due to public R&D subsidies. Possibly, such subsidies compensate (at least, partly) for the reduced access to financial resources provided by the private financial sector during times of financial-economic crises (e.g., Czarnitzki, 2006). Finally, Dell' Ariccia et al. (2008) show that banking crises are less likely to produce strong negative economic effects in developed countries, presumably as advanced economies are able to implement anti-crisis policies (e.g., financial sector regulation, monetary policy and/or fiscal stimuli) more effectively, thereby reducing the duration of crises and minimizing their negative effects. Consequently, in advanced economies the effect of banking crises on innovation — as on economic activity in general — is less severe, making it less likely to detect a statistically significant and economically substantive effect of banking crisis on innovation in our regression analysis framework.

4.4. Discussion

In line with our hypothesis, our empirical findings strongly suggest that financial development is positively associated with subsequent innovative activity, net of the influence of further relevant control variables and irrespective of the prevalence of banking crises. Our results are thus consistent with theories of a finance-innovation nexus. That is, they support the idea that financial intermediaries help reduce or overcome market imperfections that are especially relevant to innovative entrepreneurial activity (due to a comparatively large demand for investment capital, long-term commitments and uncertainty about innovation results) and which produce transaction costs (e.g., information, savings mobilization and monitoring costs). For instance, financial development reduces information acquisition costs that potentially constrain investments in innovative entrepreneurial activity. Through specialization and learning-by-doing effects financial intermediaries make it more likely that information problems are overcome, so that promising production technologies and innovative entrepreneurs can be better identified and supplied with resources, which in turn ought to augment the aggregate innovation output (King and Levine, 1993a; Lee, 1996; Levine, 1997; Blackburn and Hung, 1998).

Our empirical finding of a positive effect of financial development on innovation has important theoretical and policy implications. First, it suggest that the financial system is — together with sound institutions, a functioning educational system, effective R&D policies etc. — part of a nation's innovation infrastructure that favorably determines national innovative capacity. Strengthening the financial system through economic policy therefore also ought to benefit innovative activity. For instance, economic policies that favorably affect the financial sector may involve a sound regulation of the financial system, so as to ensure financial sector stability and competition (Demirg-Kunt, 2008).

Second, the usually beneficial effect of financial development on innovation has further implications for economic development, given that a host of theoretical and empirical contributions suggest that innovation (e.g., through productivity gains) is an important source of economic growth (e.g., Romer, 1990; Aghion and Howitt; 1992; Färe et al., 1994; Fagerberg et al., 2007). Strengthening the financial system through adequate economic policies may thus also pay off in terms of accelerated economic growth, which could be particularly important to developing and emerging economies. This is in line with a number of growth models suggesting that financial development promotes economic growth precisely via its stimulating effect on innovation (King and Levine, 1993a; De La Fuente and Marin, 1996; Blackburn and Hung, 1998; Morales, 2003; Aghion et al., 2005).

5. CONCLUSION

This contribution examined the effect of financial development on innovative activity, using cross-sectional time-series data for 51 developed and emerging countries for the period between 1993 and 2008. This study was motivated by earlier theoretical contributions — going back to Schumpeter (1934) and others — that emphasize the role of financial development in fostering innovation (which in turn works as a source of Schumpeterian economic growth) and the lack of cross-country evidence regarding this relationship. As an extension, this contribution also studied the role of banking crises in the finance-innovation nexus.

Our empirical findings suggest that the financial system is indeed an important component of a nation's innovation infrastructure and may therefore favorably determine national innovative capacity. By contrast, banking crises — even though they are likely to produce other adverse macroeconomic effects — are not found to reduce innovative activity, at least not for our country sample and observation period. In the light of our findings of a beneficial finance-innovation nexus, we argue that the financial system may foster innovation by providing vital financial services (e.g., linked to information acquisition and risk management) that lower transaction costs and facilitate investment in risky — but potentially also very profitable — long-run innovative entrepreneurial activity. In addition to this novel empirical finding, we also provide support for earlier empirical contributions that have stressed the role of non-finance factors (e.g., sound institutions, a functioning education system and effective R&D policies) in promoting innovation (e.g., Grilliches, 1990; Furman et al., 2002; Varsakelis, 2006).

To the extent that finance promotes innovation, it may consequently also produce productivity gains, increase aggregate investment and promote economic growth. Thus, our findings suggest that strengthening the financial system through adequate economic policies may benefit a country's

innovative capacity and, ultimately, economic performance. For instance, as outlined by Demirgüç-Kunt (2008), such policies may include a sound regulation and supervision of the financial system to provide financial sector stability and competition, consistent corruption and inflation control and prudent financial liberalization (i.e., the opening up of domestic financial markets to international capital).

APPENDIX: A. LIST OF COUNTRIES ($N = 51$)

Argentina, Austria, Belgium, Brazil, Bulgaria, Canada, China, Colombia, Czech Republic, Denmark, Ecuador, Egypt, Finland, France, Germany, Greece, Guatemala, Hong Kong, Hungary, Iceland, India, Ireland, Israel, Japan, Korea (South), Luxembourg, Madagascar, Malaysia, Mexico, Netherlands, New Zealand, Norway, Pakistan, Peru, Philippines, Poland, Portugal, Romania (only liquid liabilities data series available), Russia, Saudi Arabia, Slovak Republic (only private credit data series available), South Africa, Spain, Sri Lanka, Sweden, Switzerland, Thailand, Turkey, United Kingdom, United States, Uruguay.

APPENDIX: B. CONTROL VARIABLES

Economic Rights Protection – Source: International Country Risk Guide (2009). Definition: Assessment of factors affecting the risk to investment that are not covered by other political, economic and financial risk components. Risk rating assigned is the sum of three subcomponents (contract viability/expropriation, profits repatriation, payment delays). Unit: Score, rescaled to values in $[0, 1]$, with higher values indicating better property rights protection.

R&D Expenditures – Source: World Development Indicators (World Bank, 2013). Definition: Current and capital (public and private) expenditures on creative work undertaken systematically to increase knowledge. R&D covers basic research, applied research, and experimental development. Unit: Share as percentage of GDP, 1993-2008 average (due to data constraints).

Tertiary School Enrollment – Source: World Development Indicators. Definition: Ratio of total tertiary school (i.e., university) enrollment, regardless of age, to the population of the age group that officially corresponds to the level of tertiary education. Unit: Gross enrollment rate 1993-2008 average (due to data constraints).

Rule of Law – Source: International Country Risk Guide (2009). Definition: An assessment of the strength and impartiality of the legal system and of the popular observance of the law. Unit: Score, rescaled to values in $[0, 1]$, with higher values meaning a stronger rule of law.

Trade Openness – Source: Frankel and Romer (1999). Definition: Constructed measure of trade openness based on a country's geographical characteristics (proximity, location, country size) to identify the exogenous element of trade not affected by economic and institutional variables (e.g., income, government policies). Unit: Constructed trade share, constant.

Political Instability – Source: International Country Risk Guide (2009). Definition: Assessment of political violence in a country and its actual or potential impact on governance. Risk rating assigned is the sum of three subcomponents (civil war/coup threat, terrorism/political violence, civil disorder). Unit: Score, rescaled to values in [0,1], with higher values indicating higher level of instability.

Per Capita Income – Source: PENN World Table (Heston et al., 2011). Definition: Real per capita income. Unit: Income in constant 2005 International US Dollars, logged.

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