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BANKING AND INNOVATION: A REVIEW

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Abstract

We summarize the major findings of empirical studies that examine the effect of banking development on innovation and highlight their relative contributions to our understanding of the various roles the banking sector plays in determining innovation. We reassess the effect of banking development and innovation, extending the scope of analysis to more granular dimensions of innovation and to Asian economies where financial markets are less developed. We find that while theoretical implications are generally indefinite about the effect of banking development on innovation, empirical findings are less ambiguous given their distinct focus of sample firms and the underlying channels investigated. The development conditions of financial markets also matter in drawing implications for the effect of financial institutions on innovation. Specifically, when the stock market is relatively less developed, as in most Asian economies, banks play a significant role in financing and promoting innovation. Therefore, it seems plausible for policy makers in these regions to strengthen the development of the banking sector and to improve the depth of the credit market.

In this survey, we will summarize the major findings of the empirical studies that examine the effect of banking development on innovation and highlight their relative contributions to our understanding about the various roles that the banking sector plays in determining innovation. Then, we will reassess the effect of banking development and innovation.

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Contents

Does banking development promote innovation? Theories provide contrasting answers to this question. In line with Schumpeter (1911)'s view on the essential role of a well-functioning financial system for technological innovation, more recent work by King and Levine (1993) and Laeven, Levine, and Michalopoulos (2015) have been modeled on the services of financial intermediaries that help evaluate and screen entrepreneurs, channel resources to productive uses, and diversify risks of innovative projects, advertising a beneficial effect of banking development on innovation. On the other hand, Aghion and Tirole (1994) and Rajan and Zingales (2003) suggest that bank debt financing discourages firms from investing in innovative projects because novel projects have large *ex ante* uncertainty that is undesired for banks to collect information under relationship lending. In this regard, banking development and reliance on bank financing can impact negatively on innovation. The prediction becomes more ambiguous as banking development leads to changes in other market structures, such as the competitive landscape of the banking sector. Theories have had differing implications for the relation between banks' market power and the provision of credit for small, opaque, and arguably innovative firms (e.g., Berger 2010; Petersen and Rajan 1995). Therefore, it is ultimately an empirical question as to whether banking development promotes innovation.

Empirical studies draw on various inferences from the theories and approaches to answering the question through different lenses. While they offer mixed evidence, which mirrors the theoretical ambiguity, the differences can be potentially explained by the nature of the banking development they focus on and the different channels they dig out. In this survey, we will summarize the major findings of the empirical studies that examine the effect of banking development on innovation and highlight their relative contributions to our understanding about the various roles that the banking sector plays in determining innovation. Then, we will reassess the effect of banking development and innovation, extending the scope of analysis to more granular dimensions of innovation and to Asian economies where financial markets are less developed. As innovation is a vital source of long-term economic growth (Solow 1957), the survey will help reconcatenate the empirical findings toward a systematic view on the channels through which banking development affects economic growth, and provide potential policy implications for the emerging economies.

1. BANKING DEVELOPMENT AND INNOVATION: EVIDENCE FROM EXISTING STUDIES

In this section, we provide a detailed survey on nine papers that empirically investigate the effect of banking development on innovation.[1] Six papers focus on national and regional banking deregulation, four of which make use of the waves of intrastate and/or interstate banking deregulation in the US spanning from the 1970s to the 1990s (Amore, Schneider, and Žaldokas 2013; Chava et al. 2013; Cornaggia et al. 2015; Hombert and Matray 2016), and two of which use banking deregulation in Italy over the 1990s (Benfratello, Schiantarelli, and Sembenelli 2008; Maria Herrera and Minetti 2007). Two papers provide cross-country evidence on banking development and innovation (Ayyagari, Demirgüç-Kunt, Maksimovic 2011; Hsu, Tian, and Xu 2014).

[1] This survey mainly focuses on the inputs (e.g., R&D, innovators, etc.) and outputs (e.g., patent, product, etc.) of innovation and thus does not review the effect of banking development on industrial organization related to creative destruction and entrepreneurship (e.g., Black and Strahan 2002; Kerr and Nanda 2009).

Finally, the paper by Nanda and Nicholas (2014) explores the relation between bank distress and corporate innovation during the Great Depression in the US.

We summarize the key findings of the papers in Appendix 1. While all the papers we surveyed focus on the effect of banking development on innovation, their findings do not seem to render a consistent interpretation of the role of the banking sector in fostering innovation. Several facts emerge. First, banking development of different natures, such as the intrastate and interstate banking deregulation and the interstate branching deregulation in the US, can have different and even contrasting effects on innovation. Second, the effect of banking development on innovation differs across countries. Third, the role of the banking sector evolves over time; hence the effect of banking development can have different implications for innovation today compared to a century ago during the Great Depression. In the following sections, we will delve into these differences with a view to understanding the different arguments, channels, empirical designs, and accordingly the generalizability and scope of applicability of the seemingly contradictory findings.

1.1 Banking Development and Innovation: Evidence from the US

In this section, we present a survey of four papers that examine the effect of banking deregulation in the US on innovation. Banking deregulation in the US went through several stages from the 1970s to the 1990s, which gradually removed the restrictions on banking and branching activities within and across states. All four papers collect patent information from the United States Patent and Trademark Office (USPTO) and measure innovation using patenting metrics and/or innovator characteristics. They adopt similar empirical designs, such as the difference-in-differences method, fixed-effect analysis, and dynamic regressions, which exploit several staggered waves of deregulatory events to identify a causal effect of banking development on corporate innovation. Despite the common research theme, the papers do not present consistent findings when they focus on different waves of deregulatory reforms, different types of firms, and different aspects of financial market development. In the following discussion, we will focus on the major differences and compare their sample firms, arguments, findings, and explanations of channels in details.

Amore, Schneider, and Žaldokas (2013)

This paper studies the effect of banking development on the quantity and quality of innovation by *public manufacturing firms* in the US. The authors exploit staggered deregulation of banking activities across US states, specifically the deregulation of the *interstate banking* restrictions that allows out-of-state banks to enter local credit markets, generating exogenous variations in banking development across states to identify the causal effect on corporate innovation. They document a positive relation between banking development and innovation, which is consistent with the *channel* that banks are more willing to take risks and lend to innovative firms when they become more able to diversify their risks geographically after deregulation.

The authors are motivated by the literature on the relation between financial market development and economic and technological growth (e.g., Schumpeter 1911) and the established role of venture capital and private equity in fostering innovation (e.g., Lerner, Sørensen, and Strömberg 2011). They focus on banks in particular because of the theoretical ambiguity and empirical debate concerning the effect of banks on innovation. On the one hand, banking development can promote innovation by increasing the credit supply and improving the screening and monitoring of borrowers (e.g., Demyanyk, Østergaard, and Sørensen 2007). In addition, an increased credit supply from banks prevents innovative firms from disclosing private information to their competitors inevitably if they raise capital from the public market (e.g., Maksimovic and Pichler 2001), and due to greater tolerance of failure of private versus public debt (e.g., Ferreira, Manso, and Silva 2014), firms are more incentivized to conduct innovation. On the other hand, private bank debt can discourage innovation because debt contracts are not suitable for financing innovative activities, which involve high risk and high uncertainty by nature (e.g., Atanassov, Nanda, and Seru 2007). Therefore, the authors employ staggered deregulation of interstate banking restrictions and perform empirical tests on the effect of banking deregulation, as an exogenous shock to regional banking development, on corporate innovation.

The authors compile a sample of public manufacturing firms from 1976 to 1995, which covers all waves of interstate banking deregulation. They use patent data (for granted patent applications) to measure innovative activities and construct two major variables to gauge the intensity and quality of innovation: namely, patent count and citation-weighted patent count. Based on a sample of 18,066 firm-year observations, they find a positive relation between interstate banking deregulation and innovation by publicly traded manufacturing firms. In a count data model with firm and year fixed effects, industry trend, and an assortment of contemporaneous control variables, they find the number of patents increases by 12.6% after deregulation; innovation quality also improves as shown by a 10.1% increase in citation-weighted patent count as well as an increase in the originality and generality index of patents. The improvement of innovation quality is in line with the interpretation that firms need to develop high-quality patents as collateral for debt financing as previous lending relations with incumbent banks were weakened after out-of-state banks entered. In addition, patenting risk increases after deregulation as indicated by the increased dispersion of citation-weighted patent counts and the greater number of zero-citation patents. Collectively, the results suggest that banking deregulation leads to increased innovation intensity, especially innovation activities of higher quality and greater risk.

The authors have posited and tested several channels underlying the relation. First, the results are consistent with a credit supply hypothesis that firms become more innovative because of better access to bank finance. Specifically, the positive relation between interstate banking deregulation and innovation is more pronounced for firms with greater dependence on external finance and greater proximity to newly entering banks. Second, they identify better geographical diversification of bank risk after deregulation as a reason for the increase in riskier innovative projects. When firms are operating in a state where economic activity is less correlated with other states or the state of the entering bank, the improvement of innovation is greater, because these states provide larger diversification benefits for the entering banks, which in turn enables the entering banks to provide more credit to finance risky innovative projects in the deregulated states.

In sum, this paper has identified a positive causal effect of banking development on publicly traded manufacturing firms in the US by exploiting staggered passages of interstate banking deregulation in the 1980s and 1990s. The findings are consistent with the channels that banking development spurs innovation by: 1) increasing the credit supply for innovative firms, especially for firms dependent on external finance; and 2) enabling banks to diversify their credit risk geographically for better financing of risky innovative projects.

Chava et al. (2013)

This paper provides empirical support for the link between financial sector deregulation and economic growth via innovation. Rather than a unanimous positive relation, it documents contrasting effects of *intrastate and interstate banking deregulations* on innovation by *young, private firms* – intrastate banking deregulation decreases innovation while interstate banking deregulation increases innovation. Accordingly, the two forms of deregulation have led to contrasting effects on economic growth. The findings are in line with a competition *channel* that banks that have their market power increased by intrastate banking deregulation are less incentivized to provide credit for innovative firms, whereas banks that have their market power decreased by interstate banking deregulation are more willing to finance innovation. The results highlight the fact that financial deregulations of different natures can play a different role in determining corporate innovation and influencing real economy.

This research is closely related to literature that examines the real effects of financial development and the impact of banking consolidation on economic performance. Specifically, it contributes to the literature by analyzing the impact of banks' bargaining power on the availability of credit to young firms and their innovation. The paper rests on the fact that intrastate banking deregulation has increased the bargaining power of banks compared to young, private firms due to the increased market share of efficient, large banks, and interstate banking deregulation reduces banks' bargaining power by lowering the entry barriers of out-of-state banks and increasing external competition. Therefore, the effect of banking deregulations on innovation depends on the effect of banks' market power on innovation. According to Berger, Hasan, and Klapper (2004), an increase in banks' market power reduces the credit supply for innovation and constrains the risk of innovation at the same time. Greater market power for banks may also discourage innovation by squeezing out the rents for entrepreneurs (e.g., Grossman and Hart 1986). However, the literature on relationship banking (e.g., Rajan 1992) suggests that a higher bargaining power for banks can encourage innovation by increasing credit to relationship borrowers. To disentangle these conflicting arguments, the paper proposes two testable hypotheses and confirms them with empirical tests.

The paper uses the number of patents filed and granted by the USPTO and the number of citations made to these patents as proxies for the level of innovation, and it decomposes the number of patents with high and low citations as measures of the risk of innovation. The main sample consists of state-year observations from 51 states and spans from 1975 to 2005. Based on a fixed-effect count model, the paper documents a negative (positive) relation between intrastate (interstate) deregulation of the banking sector and the level and risk of innovation, which confirms the hypotheses. The paper further explores the effect of deregulation on path-breaking innovation as a critical stimulus of economic growth. It finds that changes in banks' market power lead to a greater effect on explorative innovation than on exploitative innovation; and the effects are also larger for product innovation than process innovation. The results are strengthened in the channel tests where the change in banks' bargaining power has a disproportionately larger effect in states comprising a greater number of smaller firms. Finally, the paper provides additional evidence on the differential effects of banking deregulation on economic growth, which is consistent with the effects on innovation.

To sum up, this paper documents contrasting effects of banking deregulation on the level and risk of innovation by young, private firms using state-year observations, where intrastate deregulation has a negative effect while interstate deregulation has a positive effect. The effects are contributed to by different changes in the bargaining power of banks after respective deregulations, are mainly driven by path-breaking innovation, and are eventually channeled into economic growth.

Cornaggia et al. (2015)

This paper investigates the effect of *interstate bank branching deregulation*, as an exogenous shock to banking competition, on corporate innovation. At aggregate state level consisting of *both public and private firms*, the authors find interstate branching deregulation to be negatively associated with innovation outputs. When decomposed, the negative relation is driven by public firms, whereas private firms tend to experience an increase in innovation outputs. They argue for *channels* whereby private firms benefit from expanded bank credit after deregulation, which reduces the supply of small, innovative target firms for public firms that used to provide financing for private firms via merger and acquisitions, and thereby reduces innovation attributable to public firms.

The effect of banking competition on innovation has received wide empirical interest. Relaxation of branching restrictions has led to an increased competitive pressure on banks and a greater credit supply (Rice and Strahan 2010). This paper advances the empirical studies by further examining the real effects of banking deregulation and the determinants of innovation. In contrast to previous studies that examined the effects of the deregulatory events during the 1970s and 1980s, this paper focuses on interstate branching deregulation in the mid-1990s after the passage of the Interstate Banking and Branching Efficiency Act (IBBEA).

The authors compile patent data for both listed and unlisted firms in the US from 1976 to 2006. They construct the number of eventually granted patents and their forward citations as measures for the quantity and importance of innovation. They also construct an Rsindex following Rice and Strahan (2010) to gauge the extent of interstate branching restrictions on banking competition. Contrary to conjecture, investigation into state-level deregulatory events and innovative activities demonstrates an overall negative effect of banking competition on state-level innovation. Therefore, the paper decomposes the effect of deregulation on state-level innovation generated by public and private firms and confirms that the negative effect is mainly attributable to public corporations in the deregulatory states. Specifically, the overall patent quantity and quality decrease by 30.8% and 23.2%, respectively, and the decrease among public firms is 40.8% and 26.4%, respectively. The net effect of intrastate branching deregulation on the innovation of private firms is not significant in the baseline test.

The authors test two possible channels underlying the differential relations identified for private and public firms. Using a firm-year sample for private firms, they find a positive effect of intrastate branching deregulation on the innovation outcomes of private firms that are more dependent on external finance. They conclude that enhanced competition yields a positive effect on patent quantity and quality for external-finance-dependent private firms by relaxing financial constraints. This channel is confirmed by the finding that the positive effect is stronger for private firms that rely on out-of-state banks for financing before deregulation, because the lack of an in-state banking relationship suggests firms are unable to raise capital from nearby banks beforehand, and hence should benefit more from intrastate branching deregulation that expands their access to finance. For public firms, the authors posit a channel that helps explain the negative effect of deregulation on their innovation. Specifically, acquiring small, innovative firms is an effective way for public firms to enhance their innovation and a possible mechanism for easing the financial constraints of private firms. When intrastate branching deregulation intensifies banking competition and expands the credit available to private firms, they become less likely to consider being acquired for financing needs. Therefore, the supply of potential innovative targets for public firms reduces, thereby restricting their ability to acquire innovation capacity. Indeed, the authors find the reduction effect to be more pronounced for frequent public acquirers; and innovation output from the acquired firms reduces significantly after deregulation.

In conclusion, this paper makes use of staggered interstate branching deregulation to examine the effect of banking competition on innovation. An overall negative effect is identified based on a state-year sample, which is mainly driven by the reduction of innovation among public firms. The effect is positive for private firms that are dependent on external finance and an out-of-state bank relationship, which is consistent with the channel that interstate branching deregulation intensifies banking competition and hence enhances the credit supply for small, innovative firms. Accordingly, these small, innovative firms become less willing to be acquired to ease financial constraints, rendering fewer targets for public firms to obtain innovation capacity.

Hombert and Matray (2016)

This paper uses *intrastate branching deregulation* in the US as a negative shock to lending relations to examine the effect of relationship lending on the financing of innovation. Based on a sample of *US firms* at state-year-industry level, the authors find that the number of innovative firms decreases in the deregulated states and inventors flow out of the deregulated states after deregulation. They confirm the *channel* as disruption to existing lending relations with banks brought about by intrastate branching deregulation because the reduction of innovative firms is more pronounced among small, opaque firms, which have greater dependence on relationship lending.

This paper specifically focuses on the financing function of the financial system. It aims to explore the effect of bank relationship lending on the financing of and allocation of human capital to innovative activities. As relationship lending is a major type of bank lending organization, and human capital flows and the expansion of existing innovative firms are important aspects of the "industrial organization" of innovation, the paper extends the previous studies on the effect of banking deregulation along two important lines of market structure. However, theoretical predictions are indefinite about the effect of relationship lending on innovation. On the one hand, lenders can acquire more soft information (e.g., management competence) about borrowers through a private lending relationship, which facilitates their assessment of innovative projects that are opaque by nature (Petersen and Rajan 1994). On the other hand, a relation-based financial system may preclude the entry of external innovators by offering favorable financing terms for the incumbent over potential entrants. Therefore, the paper disentangles the competing hypotheses by examining the effect of intrastate branching deregulation on 1) the financing of innovative projects, and 2) the labor market of inventors.

Interestingly, while Chava et al. (2013) view the possibility of intrastate branching deregulation as strengthening the market power of banks and their lending relationship with firms (to finance innovation) but find no supporting evidence, this paper claims that intrastate deregulation increases banking competition and damages lending relationships, and finds evidence in support of this argument. Specifically, the authors use patent data to construct measures for innovative activities – the number of innovative firms (i.e., firms that file patents), average citations per patent, and standard deviation of the citation counts per patent. They also track inventor mobility using the Harvard Business School Inventor database. Based on a state-year-industry sample from 1968 to 1998, the authors find that both the number of innovative firms and the number of citations per patent decrease after intrastate branching deregulation; the standard deviation of citation counts also decreases, suggesting that firms tend to invest in less risky innovative projects. A negative relation is found to exhibit greater sensitivity among industries where firms are more dependent on lending relationships as proxied by the distance from the lender and the length of the relationship. In addition, using patent-pair data at inventor level, they find that young and productive investors from smaller firms in the deregulated states are more likely to switch to larger firms after deregulation; and when they switch, they are more likely to relocate to another state. In line with the findings on innovative activities, the impact of the intrastate branching deregulations on (within-state) inventor mobility is stronger for relationship-dependent industries.

In summary, this paper identifies relationship lending as a crucial determinant of innovation. It uses intrastate branching deregulations as an identification strategy, which leads to plausibly exogenous shocks to lending relationships while isolating the effect from geographical diversification via interstate banking deregulation (e.g., Amore, Schneider, and Žaldokas 2013). The paper presents a similar finding to that of Chava et al. (2013) that intrastate banking deregulation reduces the level and risk of innovation but offers a different explanation. They suggest that intrastate banking weakens the lending relationship, which is prone to the evaluation and financing of innovative projects, thereby leading to a reduction in the number of innovative firms and a relocation of innovators.

1.2 Banking Development and Innovation: Evidence from Italy

In this section, we survey two papers that use the banking deregulation in the late 1980s – 1990s in Italy to examine the effect of banking development on innovation. The deregulatory process releases province-level entry restrictions of varying degrees of stringency for banks, and thus changes the local supply of banking services across regions. Both papers reply on unique survey data ("Indagine sulle Imprese Manufatturiere") that contain detailed information on innovation and other characteristics for a large number of manufacturing firms in Italy. They also use similar empirical designs, such as instrumental variable estimation, to perform the analysis. Yet, as with other papers that study the effect of US banking deregulation, the two papers focus on different changes that the banking deregulation brought to the financial system in Italy and assess the influence on innovation via different channels.

Maria Herrera and Minetti (2007)

This paper studies the information role of financial institutions (specifically banks) in shaping innovation. Using unique data for a sample of Italian manufacturing firms and banking deregulation as exogenous shocks to the local supply of banking services, the paper identifies a positive effect of banks' information on corporate innovation via the channel of relationship lending. By further disentangling the effect, the paper shows that the increase in innovation comes from investment and the acquisition of externally-developed technologies rather than in-house research.

Theoretical literature is far from conclusive about the effect of banks' information on innovation. According to Rajan and Zingales (2001), moral hazard problems in the lending relationship between banks and firms are especially severe in the financing of new technologies because of the difficulties in understanding and verifying these technologies as well as excessive risk-taking incentives for firms. In this regard, banks' information can play a critical role in mitigating the problem, thereby increasing the credit to finance innovative projects. However, hold-up problems in bank lending (i.e., threats from banks to withhold credit and to renegotiate initial contract terms) may discourage firms from innovating as new technologies are especially susceptible to the problem. Therefore, given the ambiguous predictions regarding the effect of banks' information on innovation, this paper aims to shed light on the relation empirically.

Specifically, the authors use unique survey data that allow them to measure various dimensions of innovation and to construct proxies for banks' information. They collect data on the nature and types of innovation (e.g., product vs. process) as well as R&D expenditure, and use the duration of the bank-firm relationship (an average static measure at a point of time) as the major measure of banks' information. To address endogeneity concerns embedded in the relation between the length of the credit relationship and innovation, they construct two instrumental variables to identify exogenous shocks to the local supply of banking services. The two instruments are the number of branches created by incumbent banks and entrant banks, respectively. The instruments are arguably exogenous because they are related to the deregulation process of the banking sector in Italy in the late 1980s that removed the regional entry restrictions to varying degrees across regions. The exact direction of the association between banking deregulation and lending relation does not surrender the validity of the instruments. Based on a sample of more than 4000 manufacturing firms and using two instrumental variable estimation methods (i.e., two-stage least squares and two-stage conditional maximum likelihood estimation), the authors document a positive relation between lending relationship and innovation; and the effect is larger for product innovation than for process innovation. The finding is consistent with the argument that banks' information mitigates moral hazard problems, with an attenuated effect on process innovation given its higher secrecy and information opacity that subject it to aggravated hold-up problems at the same time. The effect is also stronger for firms with lower internal funds, confirming the major function of banks in providing capital for innovation. Moreover, the authors perform additional tests to uncover the nature of the effects on innovation. They find that the improvement of innovation is only associated with greater introduction and acquisition of new technologies instead of internal research.

In short, the paper uses the banking deregulation in Italy to identify the causal effect of banks' information, as proxied by the lending relationship with firms, on firms' innovation. The findings are consistent with the information role of banks that helps mitigate moral hazard problems in the lending relationship and fosters financing for new technologies.

Benfratello, Schiantarelli, and Sembenelli (2008)

This paper examines the effect of local banking development on the innovative activities of Italian firms in the 1990s. As a result of banking development, the probability of process innovation increases, and the effect is stronger for smaller firms and firms in high-tech industries. The cash flow sensitivity of fixed investment also reduces during the development, which promotes greater R&D investment, especially for small firms. The findings are in line with the channels that banking development promotes innovation among small, innovative firms by decreasing the cost of capital and increasing the credit supply.

While the real effect of financial development has been intensively investigated over a variety of macro aspects, such as GDP and productivity growth, little research has focused on its effect on real development at the micro level, such as firm-level innovation, which is particularly important given the crucial role of the financial system in allocating resources for efficient uses and in light of the mixed evidence of the effect that financial development has on aggregate investment. This paper, then, was among the first to advance the line of research by directly investigating the effect of banking development on firms' innovation. Since different theoretical channels have contrasting implications for the relation and ambiguous predictions can be derived through each specific channel (e.g., competition), the paper frames the question as an ultimate empirical issue and sheds particular light on smaller firms that are more dependent on local finance and hence are more likely to benefit from banking development.

This paper utilizes the varying degrees of banking development across regions to identify its effect on innovation. Specifically, it exploits the deregulatory reform in the 1990s that changed the landscape of the banking sector predetermined by the 1936 banking regulation. It measures the degree of banking development by branch density, which is the number of bank branches in a province divided by the population, and analyzes the link with different forms and aspects of innovation. By modeling the probability of introducing innovations as a function of branch density, the authors find that local banking development exerts a beneficial effect on firm-level innovation, especially for process innovation. They also find that the effect is stronger for firms operating in the high-tech sector and for small firms. To address endogeneity concerns, the authors use the measure of banking development in 1936, when the pre-deregulation banking structure was determined, as an instrument in the analysis and obtain similar qualitative results. Finally, the authors estimate the direct effect of banking development on innovation inputs such as R&D and fixed investment, which is also stronger for small firms.

In conclusion, this paper finds a significant positive effect of banking development on both input and output of firm-level innovation, with a greater effect on process innovation, small firms, and firms in high-tech sectors. The results are an advertisement for the financing role of the banking sector that eases the financial constraints of firms in engaging in innovative activities.

1.3 Banking Development and Innovation: International Evidence

In this section, we summarize two cross-country studies on the effect of banking development on innovation. The two papers differ in sample selection (developing vs. developed countries), level of analysis (firm vs. industry level), and empirical designs (association vs. identification), leading to contrasting conclusions on the effect of banking development.

Ayyagari, Demirgüç-Kunt, and Maksimovic (2011)

This paper provides evidence that access to external finance is associated with greater innovation of firms in developing countries. Specifically, access to bank credit plays a significant role in financing a variety of innovative activities, including the introduction of new products and technologies and the adoption of new production processes. While not suggesting a causal relation, the findings provide support for a beneficial effect of banking development on innovation via a financing channel.

Among the large literature on the critical conditions for promoting growth, little is known about how innovation, an important channel for promoting growth, is affected by market conditions such as access to finance, especially in developing countries. Therefore, this paper fills the gap by investigating the effect on the innovative activities of small firms in 47 emerging economies. The authors collect rich information for more than 19,000 firms from the World Bank Enterprise Surveys. They measure innovative activities in a broad sense, including both core innovation activities such as the introduction of new products and technologies and other types of activities that are conducive to innovation such as knowledge transfers via licensing and outsourcing. Using logit and ordered logit models on the sample firms from 2002 to 2004, they find a positive relation between all forms of corporate innovation and access to finance, where access to finance is proxied by the portion of investment funded by external capital. By further decomposing the funding sources, they find that bank financing is the major source that accounts for the positive effect. The findings suggest that the banking sector plays a crucial role in financing innovation when the equity market and other market-based financing systems are underdeveloped in emerging economies.

In short, this paper examines the link between finance and the innovation of relatively small firms in developing countries and provides supportive evidence that banking sector development plays a positive role in financing corporate innovation in the absence of a well-developed equity market.

Hsu, Tian, and Xu (2014)

The real effects of financial market development on the economy have long been examined. This paper contributes to the current literature by examining the respective effects of equity markets and credit markets on technological innovation, which is a vital source of economic growth, and identifies two economic channels through which the effects take place.

The paper uses a large sample of 32 developed and emerging countries from 1976 to 2006. It adopts a panel-based fixed-effects approach to identify the causal effect of financial market development on innovation. The authors obtain patent data from the USPTO and construct five innovative measures, namely Patent, Citation, Originality, Generality, and R&D, as proxies for innovation. Based on a sample at country-industry-year level, the authors find that equity market development exerts a positive influence on the innovation of industries, whereas credit market development has the opposite effect. The negative effect of the credit market is stronger for industries of greater external financial dependence and high-tech intensiveness. In other words, the credit market is not a favorable financing channel for innovative firms that rely on external capital.

The results are consistent with the arguments that: 1) a bank-based financial system lacks effective price signals (Rajan and Zingales 2001), and thus may restrict the effectiveness of bank capital allocation to profitable innovative projects (Beck and Levine, 2002); and 2) debt financing is unsuitable for innovative projects because they are risky, uncertain in terms of cash flows and outcomes, and involve intensive use of intangible assets with limited value as collateral.

In conclusion, this paper presents cross-country evidence that credit/bank market development has a negative effect on technological innovation because it restricts the credit available to finance innovative projects.

1.4 Banking Development and Innovation: Historical Evidence

In this section, we focus on one paper that examines the effect of the US banking crisis during the Great Depression on firm-level innovation. We single it out to shed greater light on the evolvement of the effect that the development of the banking sector has on innovation.

Nanda and Nicholas (2014)

This paper uses the negative shocks to the banking system during the Great Depression in the early 1930s in the US to examine the effect of bank distress on corporate innovation, which contributes to our understanding of the link between the health of the financial sector and real economic growth via technological development during an important stage in history. The authors find a negative relation between bank distress and various dimensions of firm-level innovation, which is disproportionately stronger for R&D firms that have greater external finance dependence and that are operating in severely distressed regions. The results confirm the supply-side effect of banking finance and suggest an important financing role of the banking sector in supporting R&D activities and innovation dating back to the early twentieth century.

The Great Depression from 1929 to 1933 is suitable for the research because of an unprecedented, prominent level of bank failures that severely impacted the supply of bank credit to firms during the period (e.g., Friedman and Schwartz 1963). The authors compile a set of novel microdata at firm level that combines information on R&D facilities from the surveys of industrial research laboratories by the National Research Council and records of patents and citations from the European Patent Office (EPO) PATSTAT database for both large public and small private firms from 1920 to 1938. This panel data set spans from the period before the Great Depression to the years afterwards, which is particularly helpful for identifying the change of firm-level innovation around the banking crisis. In addition, the authors exploit the cross-country variation in the severity of the bank distress to strengthen the identification. In other words, the shock to bank credit supply presumably only affects firms operating in the local regions because 1) there are restrictions on interstate banking and branching activities at that time, and 2) the stock market crashed at the beginning of the Depression, which largely cut off the funding channel for public firms via equity issuance. Therefore, the Great Depression can be viewed as an exogenous shock to the supply of banking credit for both public and private firms, which helps single out the effect of local bank financing on innovation.

The authors have constructed five measures of innovative activities to measure the quantity (the number of patents granted for a firm), quality (total number of citations of patents of a firm, average citation per patent of a firm), and novelty (originality and generality) of patenting and they use a difference-in-differences design to implement empirical tests. First, they examine the differential effect of the banking crisis on private versus public firms from before to after the crisis period. They find that private firms experience a greater decline in all five dimensions of innovation than public firms. This is consistent with the argument that private firms depend more on bank financing because they lack other financing channels, such as equity financing for public firms. However, as the results may be confounded by aggregate demand shocks that might have affected private firms more than public firms, the authors focus on public firms that presumably are faced with a similar aggregate demand from a national market, and distinguish the public firms by a) the severity of the bank distress of the county they operate in (proxied by the number of bank suspensions over the crisis period), and b) the dependence on external capital. They find that bank distress has a more pronounced adverse effect on public firms operating in severely affected counties or in more capital-intensive industries; the results are insignificant if firms operate in less capital-intensive industries. Their results, on the one hand, strengthen the negative effect of bank distress on firm-level innovation, while on the other hand they highlight the heterogeneity of the effect across counties and industries, thereby helping to reconcile the negative relation established with the overall improvement of technological development in the 1930s. Finally, they use an instrumental variable estimation to delve into the mechanism via which the severity of bank distress may vary across counties. They find that social structure, especially in more fragmented communities, is more likely to aggravate bank distress. The robustness tests confirm their earlier findings that the supply-side shock to local bank credit negatively affects the innovation of firms in severely affected countries and in capital-intensive industries.

In summary, the paper has identified a negative relation between bank distress and corporate innovation via a supply-side shock to the credit supply, which implies that the health of the banking sector and banking development on average should have a beneficial effect on innovation.

2. BANKING DEVELOPMENT AND INNOVATION: REASSESSMENT AND EXTENSION

In this section, we build on the existing studies on banking deregulation and innovation, and extend their analysis in three ways. First, we focus on the effect of the US intrastate branching deregulation on the innovation of public firms. This research question is not worth a single paper given the many studies that have already examined (a) the effect of intrastate branching deregulation on private firms (Chava et al. 2013), (b) the effect of intrastate branching deregulation on the aggregate innovation of both public and private firms (Hombert and Matray 2016), (c) the effect of interstate banking deregulation on public (Amore, Schneider, and Žaldokas 2013) and private (Chava et al. 2013) firms, and (d) the effect of interstate branching deregulation on the innovation of the aggregate number of public and private firms and the number for the respective public and private firm (Cornaggia et al. 2015). However, it is the only piece that remains unanswered in providing a complete picture of banking deregulation and innovation, that is, singling out the effect on public firms in the US.[2] Second, we extend the dimensions of innovative activities beyond simple measures of quantity (i.e., patent count) and quality (i.e., citation and citation per patent). Besides more granular measures of innovation based on the distribution of citations (e.g., generality and originality), we also distinguish innovations by their technological classes (new class vs. known class) and the action of knowledge discovery (exploitive vs. explorative), and we additionally incorporate the market value of patents and market reaction to new product announcement. Third, we focus on Asian economies and investigate the effect of the credit market and banking development on the rate and quality of innovation.

2.1 Intrastate Branching Deregulation and Innovation: Evidence from the US

2.1.1 Sample and Variables

We start from the universe of public firms in the US as contained in the Compustat database from 1976 to 2006, which is the period for which our patent data are available from the NBER patent database. Then, we merge firm-level financial information with patent records to form a firm-year panel of 19,304 firms. We do not restrict this to firms with patent filing records in order to preserve the complete universe of public firms to examine the overall effect of intrastate branching deregulation on innovation at both

[2] The banking deregulation in Italy mainly liberates inter-province banking restrictions. The two papers we surveyed (Maria Herrera and Minetti 2007; Ayyagari, Demirgüç-Kunt, and Maksimovic 2011) have analyzed the effect on both public and private manufacturing firms in Italy.

intensive and extensive margins. For firms with patent filing records, we focus on the patents that are eventually granted by the USPTO to ensure comparability of the quality of patents across firms. We also follow the standard practice in the literature to date the invention by the year the eventually granted patent is filed (i.e., the application year) to avoid any anomalies arising from the discrepancy between the timing of an application and its eventual granting (Hall, Jaffe, and Trajtenberg 2001). Besides patent-based innovation measures, we also obtain information from financial statements, the stock market, and other corporate disclosures. We categorize the measures into six groups with the detailed construction illustrated below.

(1) R&D Input

We first use R&D expenditure to measure innovation input. We define *R&D/At* as R&D expenditure scaled by total assets to capture the amount of innovation input.

(2) Traditional Patent-based Measures of Innovation

Then, we use patent records to construct three traditional measures of innovation. We define *Patent* as the number of eventually granted patents filed by a firm in a year. This measure gauges the quantity of innovation using patenting outcomes. We define *Citation* as the total number of forward citations received by the eventually granted patents filed by a firm in a year, adjusted for truncation bias. We further define *Citation/Patent* as the total number of truncation-adjusted citations divided by the total number of eventually granted patents. *Citation* measures the overall quality of innovation in terms of usefulness and *Citation/Patent* measures the productivity of patents on average.

(3) More Granular Intensity Measures

The traditional measure of the quantity of innovation (i.e., *Patent*) does not differentiate among patents with distinct characteristics, and hence is less informative about the exact types of patents that are affected by banking deregulation. Therefore, we divide patents based on more granular dimensions and then calculate patenting intensity within each specific type. Following Balsmeier, Fleming, and Manso (2017), we first divide patents according to the knowledge domain they draw reference from, which is indicated by the technological classes that the patent belongs to. Specifically, if a patent is filed in a technological class that was previously unknown to the firm (i.e., the firm does not have any previous patents filed in this technological class), we classify the patent as a new-class patent, whereas if the patent is filed in a technological class that the firm has already known, the patent is considered a known-class patent. Correspondingly, we count the number of patents within each group. *New_class* is the number of new-class patents and *Known_class* is the number of known-class patents.

Second, we further divide patents according to the action of knowledge discovery; that is, whether the inventions are mainly developed by exploiting existing knowledge or by exploring new frontiers. We construct two measures to gauge the intensity of exploitive and explorative innovation, respectively. We define a collection of variables, *Exploitive_patent_X*, as the number of patents where more than X% of their citations refer to existing knowledge of a firm that is based on all the technological classes previously known to the firm. Similarly, we define another collection of variables, *Explorative_patent_X*, as the number of patents with more than X% of citations not referring to the existing knowledge set of the firm. We use three cutoffs, 70%, 80%, and 90%, respectively, to determine whether the major development is via exploitive action or explorative action.

(4) More granular quality measures

To supplement traditional measures of innovation quality using total or average citation counts, we construct two more measures based on the distribution of citations made or received by a patent across different technological classes and one measure based on the distribution of technological classes of patents filed by a firm in the current year relative to the previous year. We use *Generality* and *Originality* to measure the extent to which the patent is generally applicable and highly original based on the citation distributions. *Generality* is defined as the average value of one minus the Herfindahl Index of the technological class distribution of patents citing each patent filed by a firm in a year. A higher generality score indicates that the patents on average are cited by other patents from more diverse technological classes, and hence more generally applicable. *Originality* is defined as the average value of one minus the Herfindahl Index of the technological class distribution of patents that are cited by each patent filed by a firm in a year. A higher originality score suggests greater originality of the patent as it does not refer to existing knowledge from a single technological class.

We also follow Jaffe (1989) to construct a measure of the technological proximity of patents filed in the current year with those in the previous year (*Tech_prox*). Specifically, we use the following equation, where $f_{i,k,t}$ denotes the fraction of firm i's patents filed in technological class *k* in year *t* and $f_{i,k,t-1}$ denotes the fraction of all firm i's patents belonging to technological class *k* as of year *t-1*.

$$Tech\_prox_{i,t} = \frac{\sum_{k=1}^{K} f_{i,k,t} f_{i,k,t-1}}{(\sum_{k=1}^{K} f_{i,k,t}^2 \sum_{k=1}^{K} f_{i,k,t-1}^2)^{\frac{1}{2}}}$$

The technological proximity measure ranges from 0 to 1, with 1 indicating the highest proximity in the distribution of technological classes between the patents filed in the current year and that of the previous patent stock.

(a) Patent value

We then incorporate information beyond patent-related attributes to enrich the measure of innovation quality. We follow Kogan et al. (2017) and use stock market reaction to patent releases to measure the market value of patents. We define *Patent_value* as the total market value of eventually granted patents filed by a firm in a year scaled by the asset book value.

(b) Product introduction

Finally, we use new product data from Mukherjee, Singh, and Žaldokas (2017). They provide two measures of market reaction to new product announcements collected from news reports. The first measure is *New_product_announce*, which is defined as the summation of all positive cumulative returns over the year of product announcements. The second measure is *New_product_announce_75*, which is defined as the number of product announcements of a firm in a year that has cumulative abnormal returns above the 75^{th} percentile. Based on the announcement data, we construct an additional variable to capture the action of new product introduction, *New_product*, as an indicator equal to one if a firm introduces a new product in a year.

Summary statistics of the variables are presented in Table 1.

Table 1: Summary Statistics

Variable	N	Mean	S.D.
RD/At	85,949	0.14	3.407
Patent	180,451	1.14	10.173
Citation	180,451	1.145	10.263
Citation/Patent	180,451	1.114	6.453
New_class	180,451	0.316	1.353
Known_class	180,451	3.357	41.17
Exploitive_patent_70	180,451	2.011	28.729
Exploitive_patent_80	180,451	1.613	23.343
Exploitive_patent_90	180,451	1.263	17.61
Explorative_patent_70	180,451	0.66	6.192
Explorative_patent_80	180,451	0.558	5.655
Explorative_patent_90	180,451	0.524	5.537
Generality	25,943	0.568	0.245
Originality	27,938	0.542	0.256
Tech_prox	23,291	0.582	0.326
Patent_value	29,523	0.060	0.170
New_product	112,685	0.04	0.195
New_product_announce	4,457	0.127	0.276
New_product_announce_75	4,457	1.505	3.496
Size	180,451	4.168	2.277
MB	180,451	2.621	8.451
LEV	180,451	0.284	0.434
ROA	180,451	-0.031	0.655
Age	180,451	11.704	7.953
Log(GDP per capita)	180,451	10.354	0.183
GDP_growth	180,451	0.016	0.029
Log(population)	180,451	16.049	0.842

This table summarizes the distribution statistics of all the variables used in our analysis. Our sample consists of 19,304 firms from 1976 to 2006. A detailed definition of variables is presented in Panel A of Appendix 2.

2.1.2 Empirical Design

We use a similar *difference-in-differences* empirical design to the previous studies on banking deregulation and innovation. Specifically, as our identification rests on the staggered deregulation of intrastate branching restrictions across states, we define an indicator variable *Dereg* for each state-year, which is set equal to one in the years after a state has deregulated branching restrictions and zero otherwise. We use the following specification throughout our analysis:

$$Innovation_{i,s,t} = \alpha + \beta Dereg_{s,t} + \gamma X_{i,s,t} + \delta_i + \delta_t + \varepsilon_{i,s,t} \quad \textbf{(1),}$$

where $Innovation_{i,s,t}$ is the measure of innovation for firm *i* operating in state *s* in year *t*. $X_{i,s,t}$ includes all the control variables at firm and state levels, including firm size (*Size*) measured in the natural logarithm of total market capitalization, market-to-book ratio equity (*MB*), book leverage (*LEV*), return on asset (*ROA*) measured as operating income before depreciation scaled by total assets, age of a firm (*Age*), state-level economic growth (*Log(GDP per capita)* and *GDP_growth*) and state population (*Log(population)*). Detailed construction and summary statistics of control variables are presented in Panel A of Appendix 2 and Table 1, respectively. We include firm fixed effects (δ_i) and year fixed effects (δ_t) in the regression to control for all the time-invariant firm characteristics and to condition out contemporaneous events occurring in the same year as the deregulation. We cluster standard errors at operating state level as observations can be correlated in the operating states where deregulation takes effect. We are interested in the coefficient of $Dereg_{s,t}$, which gives the estimate of the treatment effect of intrastate branching restrictions on innovation by exploiting within-firm variation.

2.1.3 Baseline Results

We first examine the effect of the intrastate branching deregulation on traditional measures of innovation. We apply a regression specification (1) to R&D expenditure, total patent count, total citation, and citation per patent. The results are shown in Table 2. The deregulation does not have any significant effect on innovation input, which is R&D expenditure, but has a negative effect on the level of patent count and citation count. The dependent variable in column (2), *Log(Patent)*, is defined as the natural logarithm of one plus the total number of patents. Hence, the coefficient of –0.026 indicates an approximately 2.6% decrease in patent count after a state deregulates the branching restrictions within the state. Similarly, total citation and citation per patent decrease by 2.4% and 2.2%, respectively. The results indicate that intrastate branching deregulation on average is associated with an overall reduction in the output quantity and quality of innovation.

Table 2: Banking Deregulation and Corporate Innovation

	(1) **RD/At**	**(2)** **Log(Patent)**	**(3)** **Log(Citation)**	**(4)** **Log(Citation/Patent)**
Dereg	–0.004	–0.026*	–0.024**	–0.022**
	(0.01)	(0.01)	(0.01)	(0.01)
Size	0.049	0.031***	0.027***	0.031***
	(0.03)	(0.00)	(0.00)	(0.00)
MB	0.002	–0.000**	–0.000	–0.000
	(0.00)	(0.00)	(0.00)	(0.00)
LEV	0.320	0.005**	0.003	0.004
	(0.22)	(0.00)	(0.00)	(0.00)
ROA	–0.538***	–0.006***	–0.008***	–0.008***
	(0.15)	(0.00)	(0.00)	(0.00)
Age	0.036	0.072***	0.082***	0.089***
	(0.02)	(0.01)	(0.01)	(0.01)
Log(GDP per capita)	–0.188	–0.006	–0.032	–0.025
	(0.23)	(0.11)	(0.09)	(0.10)
GDP_growth	0.132	0.114**	0.133***	0.137***
	(0.28)	(0.06)	(0.04)	(0.05)
Log(population)	0.045	0.169***	0.195***	0.198***
	(0.09)	(0.06)	(0.05)	(0.05)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	85,949	180,451	180,451	180,451
adj. R-sq	0.257	0.806	0.754	0.722

This table presents the effect of intrastate branching deregulation on R&D investment (column 1), patent count (column 2), citation (column 3), and citation per patent (column 4). A detailed definition of variables is presented in Panel A of Appendix 2. The regressions include firm and year fixed effects. Standard errors are clustered at operating state level and presented in parentheses. *, **, and *** denote significance level at 10%, 5%, and 1%, respectively.

Next, we disentangle patents by their technological classes. Specifically, we use the number of patents separately calculated for those filed in new classes versus those filed in known classes. As stated above, these two measures distinguish the patents that are featured with new knowledge from those relying on an existing knowledge set. We find that, after the intrastate branching deregulation, the number of patents filed in new technological classes decreases while that in the existing classes remains largely unchanged. The results are presented in Table 3.

We further distinguish patents by their main way of acquiring knowledge, that is, whether these patents are developed by mainly exploiting or by exploring new technological fields. As shown in Table 4, the number of explorative patents on average decreases by 2% after intrastate branching deregulation, whereas the effect is insignificant on the number of exploitive patents. Taking Table 3 and Table 4 together, the results suggest that, while intrastate branching deregulation decreases the number of patents, the effect is mainly driven by the most innovative ones that are more likely to lead to path-breaching technological progress. The results are consistent with the argument in Chava et al. (2013) that both the level and risk of innovation decrease following intrastate branching deregulation.

Table 3: Intrastate Branching Deregulation and New-Class vs. Known-Class Patents

	(1) Log(New_class)	(2) Log(Known_class)
Dereg	–0.017**	–0.035
	(0.01)	(0.02)
Controls	Yes	Yes
Firm FE	Yes	Yes
Year FE	Yes	Yes
N	180,451	180,451
adj. R-sq	0.464	0.786

This table presents the effect of intrastate branching deregulation on the extensive and intensive margin of innovation, respectively proxied by the number of patents filed in new technological classes (column 1) and the number of patents filed in existing patent classes (column 2). A detailed definition of variables is presented in Panel A of Appendix 2. The regressions include firm and year fixed effects. Standard errors are clustered at operating state level and presented in parentheses. *, **, and *** denote significance level at 10%, 5%, and 1%, respectively.

Table 4: Intrastate Branching Deregulation and Exploitive vs. Explorative Patents

	(1) Log(Exploitive _patent_70)	(2) Log(Exploitive _patent_80)	(3) Log(Exploitive _patent_90)	(4) Log(Explorative _patent_70)	(5) Log(Explorative _patent_80)	(6) Log(Explorative _patent_90)
Dereg	–0.033	–0.033	–0.032	–0.020**	–0.020**	–0.022**
	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	180,451	180,451	180,451	180,451	180,451	180,451
adj. R-sq	0.743	0.736	0.732	0.723	0.703	0.691

This table presents the effect of intrastate branching deregulation on conventional vs. path-breaking innovation respectively as proxied by the number of exploitive (columns 1–3) and explorative (columns 4–6) patents. A detailed definition of variables is presented in Panel A of Appendix 2. The regressions include firm and year fixed effects. Standard errors are clustered at operating state level and presented in parentheses. *, **, and *** denote significance level at 10%, 5%, and 1%, respectively.

We then examine the effect on the novelty of innovation, as measured by the generality, originality, and technological proximity of patents filed by the firms. The results in Table 5 show that none of these novelty measures are significantly affected by intrastate branching deregulation. The effect on technological proximity is insignificant both statistically and economically. In other words, intrastate branching deregulation does not affect the distribution of citations made to or from the patents, or the overlap of the distribution of technological classes between patents filed in the current year and the patent stock as of the previous year.

Table 5: Intrastate Branching Deregulation and Generality, Originality, and Technology Proximity

	(1) Generality	(2) Originality	(3) Tech_prox
Dereg	–0.002	0.005	–0.000
	(0.01)	(0.01)	(0.01)
Controls	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	25,943	27,938	23,291
adj. R-sq	0.317	0.295	0.440

This table presents the effect of intrastate branching deregulation on the novelty of patents, including generality (column 1), originality (column 2), and technological proximity between the newly filed patents in a year to the existing patent portfolio of a firm as of the previous year (column 3). A detailed definition of variables is presented in Panel A of Appendix 2. The regressions include firm and year fixed effects. Standard errors are clustered at operating state level and presented in parentheses. *, **, and *** denote significance level at 10%, 5%, and 1%, respectively.

We also examine the effect of intrastate branching deregulation on the market value of patents. According to Kogan et al. (2017), the market value of patents captures the private economic value of innovation rather than its scientific value as proxied by citation. Therefore, we can see how banking deregulation can affect the economic value, that is, the monopoly rents that patent owners can extract from innovation. We use aggregate market value measures for patents as dependent variables in the regressions of Table 6. The results suggest that the deregulation of intrastate branching restrictions has a negative effect on the economic value of patents. For every $1 million US dollars of total assets, the reduction in the market value associated with patents amounts to $14,000 in a year. The cumulative effect can be even larger if it lasts for more than one year. Collectively, our evidence shows that the deregulation of intrastate branching restrictions negatively affects both the scientific and economic value of innovation.

In the last baseline test, we extend the analysis to new product announcement, which is an important measure of innovation outcomes beyond patents. We use three variables to capture three dimensions associated with new product introduction: the likelihood, the market response, and the intensity. We present the results in Table 7. While intrastate branching deregulation does not change the likelihood of new product introduction, it decreases the aggregate positive stock market responses to new product introduction, and the number of product announcements with substantial positive reactions from the market. The results are consistent with our previous analysis using patent-based measures for innovation and add new insight into the effect of intrastate branching deregulation on a broader spectrum of innovation activities.

Table 6: Intrastate Branching Deregulation and the Value of Patents

	(1) Patent_value
Dereg	–0.014**
	(0.01)
Controls	Yes
Firm FE	Yes
Year FE	Yes
N	29,523
adj. R-sq	0.405

This table presents the effect of intrastate branching deregulation on the value of patents. Patent_value is the aggregate market value of all the eventually granted patents filed by a firm in a year scaled by the book value of assets. A detailed definition of the variable is presented in Panel A of Appendix 2. The regressions include firm and year fixed effects. Standard errors are clustered at operating state level and presented in parentheses. *, **, and *** denote significance level at 10%, 5%, and 1%, respectively.

Table 7: Intrastate Branching Deregulation and New Product Introduction

	(1) New_product	(2) New_product_announce	(3) New_product_announce_75
Dereg	0.004	–0.106**	–1.465**
	(0.01)	(0.05)	(0.59)
Controls	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	112,685	4,457	4,457
adj. R-sq	0.408	0.471	0.511

This table presents the effect of intrastate branching deregulation on new product introduction. New_product is an indicator variable set to one if a firm launches a new product in a year. New_product_announcement is the summation of all the positive cumulative abnormal returns over the year of new product announcements of a firm. New_product_announce_75 is the number of new product announcements of a firm with cumulative abnormal returns above the 75th percentile in the sample. A detailed definition of variables is presented in Panel A of Appendix 2. The regressions include firm and year fixed effects. Standard errors are clustered at operating state level and presented in parentheses. *, **, and *** denote significance level at 10%, 5%, and 1%, respectively.

2.1.4 Dynamic Effect

Besides quantifying the baseline effect, we also conduct a dynamic regression analysis to trace the effect of deregulation on innovation activities over subsequent years following the approach in Beck, Levine, and Levkov (2010). We augment the baseline specification in the following way:

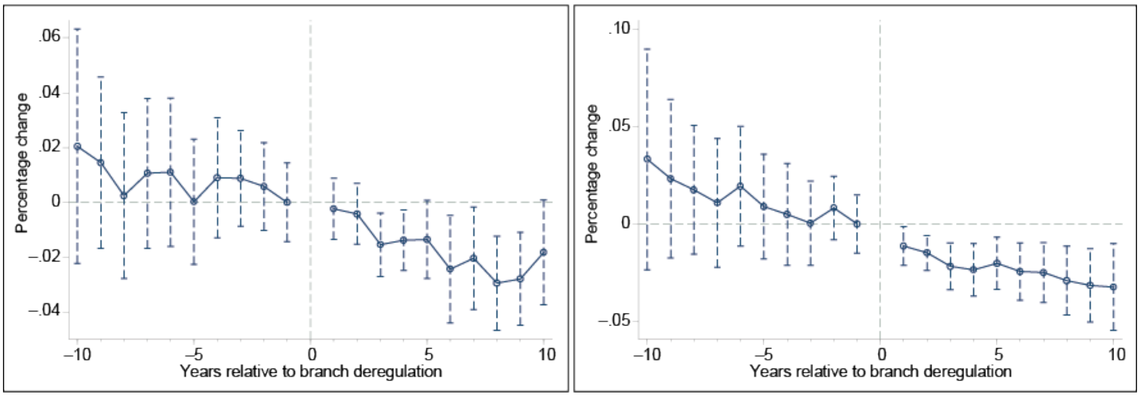
$$Innovation_{i,s,t} = \alpha + \beta^{-10}D_{s,t}^{-10} + \beta^{-9}D_{s,t}^{-9} + \cdots + \beta^{-1}D_{s,t}^{-1} + \beta^{+1}D_{s,t}^{+1} + \beta^{+2}D_{s,t}^{+2} + \cdots + \beta^{+10}D_{s,t}^{+10} + \gamma X_{i,s,t} + \delta_i + \delta_t + \varepsilon_{i,s,t} \quad (2)$$

Specifically, we use 20 time dummies to indicate each year in the pre- and post-deregulation periods. For example, $D_{s,t}^{-1}$ is set equal to one for a state in the year prior to the deregulation and zero otherwise. For the two dummies at the two ends of the 20-year period, they capture all the years beyond the end points. That is, $D_{s,t}^{-10}$ is set equal to one for a state ten or more years before the deregulation and $D_{s,t}^{+10}$ is set equal to one for a state ten or more years after the deregulation. The year of deregulation is used as the benchmark year for our estimates. As with the baseline regressions, we include an assortment of control variables and firm and year fixed effects, and we cluster the standard error at operating state level.

After obtaining the estimated coefficients of each time dummy, we plot the estimated effect against the relative year to the deregulation in Figure 1. We focus on two measures of explorative innovation for illustration. In Panel A, we present the dynamic effect of the intrastate branching deregulation on the number of patents filed in new technological classes. In Panel B, we present that on the number of explorative patents with more than 80% of citations coming from new knowledge to the firm. The two figures depict two key facts. First, there are no significant effects on these innovative activities prior to the deregulation, which suggests that the deregulation can be regarded as a largely exogenous shock to innovation. Second, these innovative measures start to decrease after the deregulation and the magnitude of the decrease is getter larger as time elapses. Overall, the figures confirm our baseline findings that the intrastate branching deregulation has a prolonged negative effect on the quantity and quality of innovation, and the effect is mainly driven by high-quality, path-breaking innovation. The results are also consistent with the findings in Chava et al. (2013) and Hombert and Matray (2016).

Figure 1: Dynamic Effect of Intrastate Branching Deregulation and Explorative Innovation

A. Log(New_class) **B. Log(Explorative_patent_80)**



The figures plot the dynamic effect of intrastate branching deregulation on explorative innovation. We present the effect on the number of patents in new technological classes in Panel A and the effect on the number of explorative patents with more than 80% new knowledge in Panel B. A detailed definition of variables is presented in Panel A of Appendix 2. The dots represent the estimated coefficients and the surrounding dotted lines represent the 95% confidence interval. The vertical axis is the percentage change (in decimal points) of the innovation measure and the horizontal axis is the number of years relative to the year of intrastate branch deregulation.

2.2 Banking Development and Innovation in Asian Economies

In this section, we first provide an overview of the development of credit markets and banking industries in Asian economies over a maximum period of nearly four decades from 1975 to 2013. We then assess the effect of banking development on the rate and quality of innovation against the effect from stock market development in these economies.

2.2.1 Sample and Variables

We start with all the Asian economies with a stock exchange as recorded in Bhattacharya and Daouk (2002) and with patent records in the European Patent Office (EPO) Worldwide Patent Statistics Database (PATSTAT) before 2014. Following Levine, Lin, and Wei (2017), we focus on the first granted patent filed by an entity for an invention in the EPO or one of the patent offices in the member countries of the Organisation for Economic Co-operation and Development (OECD). We date the patent by the year of application to approximate the year of invention. We construct six patent-based measures of innovation at industry-country-year level. *Patent Count* is the natural logarithm of one plus the total number of eventually granted patents in an industry-country-year, where the industry is first defined in International Patent Classification (IPC) subclasses and then converted to two-digit Standard Industrial Classification (SIC) based on the concordance scheme in Lybbert and Zolas (2012). *Patent Entities* is the natural logarithm of the total number of patenting entities (with eventually granted patents) in an industry-country-year. *Citation* is the natural logarithm of the truncation-adjusted forward citation counts of all the eventually granted patents filed in an industry-country-year. *Citation* is a common measure for the quality of innovation. *PC Top 25%* is the natural logarithm of one plus the highly cited patents in an industry-country-year, where a patent is regarded as highly cited if its citation count falls within the top 25 percentiles of all the patents in the same industry and year. This measure gauges the intensity of impactful innovation. *Originality* and *Generality* are defined as the natural logarithm of one plus the originality and generality index aggregated across all the eventually granted patents in an industry-country-year. The construction and economic meaning of the two indices at individual patent level were presented in Section 2.1.1. A detailed construction of the variables is contained in Panel B of Appendix 2.

Then, we merge the patent information in these economies with the World Development Indicators (WDI) database from the World Bank to obtain the measures of capital market development and exclude those where information is unavailable for either stock market or credit market development. Specifically, Taipei,China and Uzbekistan are removed from this step and we end up with 26 Asian economies in the sample for a period from 1975 to 2013. We further obtain granular indicators of credit market and banking development from the Global Financial Development Database (GFDD), which was constructed by Cihak et al. (2012) and has been maintained by the World Bank.

2.2.2 Overall Development of the Credit Market and Banking Sector in Asia

We present the average value of stock market and credit market development indicators for each of the 26 Asian economies in our sample in Table 8. *Stock/GDP* is the indicator of stock market development, which is defined as the ratio of market capitalization of all the listed domestic firms in a country over its GDP in a year. *Credit/GDP* is defined as the ratio of domestic credit provided by the financial sector over GDP, which gauges the overall development of the credit market. *Private Credit/GDP* is domestic credit to the private sector as a percentage of GDP. *Bank Private Credit/GDP* is the ratio of domestic credit to the private sector that is provided by banks over GDP, which specifically measures the depth of banking industry development. All four indicators are obtained from the World Bank WDI database. We also provide the average raw value of the six patent-based measures of innovation respectively for each country over the sample period. As shown in the table, there is a wide dispersion across these economies in terms of market development and innovation prospects, which provide an adequate degree of variation for our subsequent regression analysis.

We also plot the time series evolvement of the four financial market indicators in Figure 2. Panel A presents the average level of each of the four market indicators across the 26 Asian economies over our sample period. Panel B shows that of the United States, which most existing studies focus on. Several facts arise from the figure. First, the credit market in Asia exhibited steady growth over the sample period. Second, among the credit provided to the economy, most of it goes to the private sector; and among the credit to the private sector, almost all is contributed by banks. Third, the stock market size wobbled in the first three decades and started to rise in the 2000s, but the overall size is comparable to that of the credit market.[3] The conditions are different in the United States. First, although the credit market had a substantial growth in depth in the 1990s, it has far exceeded the size of the stock market since the start of the sample period. In other words, the credit market in the United States has been sustaining a relatively mature stage for many decades. However, only a small fraction of the credit to the private sector comes from the banking sector. Moreover, the stock market in the United States experienced a dramatic boom in the 1990s and early 2000s, and it outweighed the banking sector significantly over most of the sample period. Given the clear divergence in the development status of financial markets between Asian economies and the United States, we tend to conjecture a different relation between banking development and innovation.

Table 8: Overview of Financial Market Development and Innovation by Economies

	Market Cap	**Credit** (% of GDP)		
Country	(% of GDP)	**All Credit**	**Private Credit**	**Private Credit by Bank**
Australia	76.18	84.83	70.67	70.61
Bahrain	92.39	31.81	46.68	46.68
Bangladesh	11.70	30.62	19.66	19.57
People's Republic of China (PRC)	49.83	99.65	92.06	101.63
Hong Kong, China	365.67	150.22	156.40	156.40
India	75.29	50.52	29.31	29.31
Indonesia	31.78	36.52	30.91	29.88
Iran	14.63	49.70	29.12	29.12
Israel	48.95	104.34	65.51	65.51
Japan	66.07	264.04	175.68	137.11
Jordan	130.10	85.18	63.51	63.37
Kazakhstan	18.61	29.98	27.96	27.79
Republic of Korea	43.03	78.33	73.34	72.17
Kuwait	80.47	67.16	52.30	52.30
Lebanon	20.58	142.52	72.15	69.87
Malaysia	133.78	113.50	96.09	95.22
Mongolia	5.81	23.11	22.80	22.69
New Zealand	38.74	79.11	73.75	72.77
Oman	34.87	25.35	28.19	28.18
Pakistan	21.98	47.97	24.10	23.69
Philippines	52.49	44.46	29.98	29.97
Singapore	160.52	66.18	87.42	87.41
Sri Lanka	19.33	40.53	23.87	23.80
Tanzania	2.63	17.10	8.96	8.76
Thailand	57.13	106.77	89.34	84.91
Turkey	26.74	39.86	23.56	23.20

continued on next page

[3] The effective *Stock/GDP* ratio should be much lower than the value shown in the figure in the early years because most Asian economies started to develop their stock markets in the 1990s or later. However, credit markets have a much longer history in these economies.

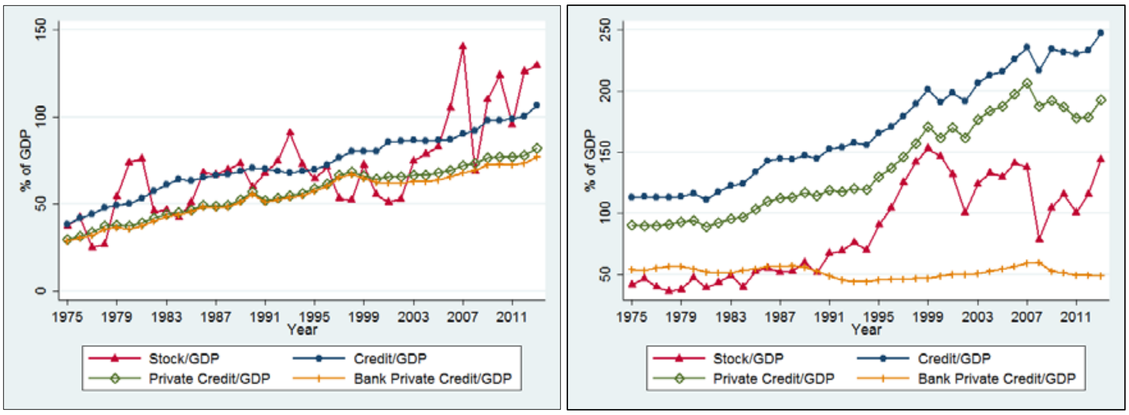
Table 8 *continued*

	Patent-based Innovation					
Country	**Patent Count**	**Patent Entities**	**Citation**	**PC Top 25%**	**Originality**	**Generality**
Australia	453.61	549.85	12,274.76	141.69	98.94	83.20
Bahrain	0.74	0.95	15.97	0.14	0.13	0.09
Bangladesh	0.18	0.23	3.58	0.05	0.02	0.03
People's Republic of China (PRC)	677.04	590.00	19,992.79	154.49	159.70	54.87
Hong Kong, China	132.74	143.67	2,741.81	37.79	28.80	20.33
India	257.69	233.31	8,849.88	44.17	52.22	19.13
Indonesia	3.10	4.03	39.93	0.59	0.65	0.37
Iran	5.28	6.51	65.02	0.92	0.87	0.52
Israel	536.77	605.28	26,632.48	184.37	131.16	100.15
Japan	21,001.81	12,339.74	495,395.70	7,643.18	4,786.15	4,511.32
Jordan	1.82	1.74	18.72	0.28	0.32	0.19
Kazakhstan	0.49	0.69	3.00	0.03	0.08	0.01
Republic of Korea	19,743.07	9,374.72	117,774.40	1,527.49	1,422.29	692.62
Kuwait	7.44	7.74	94.84	1.32	1.98	0.56
Lebanon	2.05	2.31	28.19	0.41	0.29	0.24
Malaysia	32.56	34.90	699.93	6.83	8.20	3.25
Mongolia	0.10	0.10	0.66	0.05	0.01	0.03
New Zealand	58.00	75.59	1,504.20	16.23	12.10	9.90
Oman	0.38	0.36	5.37	0.03	0.12	0.05
Pakistan	1.51	1.72	29.35	0.10	0.28	0.14
Philippines	6.46	7.28	152.70	1.48	1.34	0.74
Singapore	176.59	149.54	6,349.87	54.19	42.57	25.75
Sri Lanka	0.69	0.90	12.80	0.15	0.15	0.10
Tanzania	0.08	0.10	0.33	0.03	0.02	0.01
Thailand	11.26	12.08	301.80	2.99	2.46	1.22
Turkey	44.36	41.26	465.37	3.39	5.22	1.50

This table presents the average value of the development indicators of financial markets and the average raw value of patent-based measures of innovation in a year for each of the 26 Asian economies in our sample. Stock market development is measured by *Stock/GDP*, which is defined as the total market capitalization of listed firms in a country as a percentage of GDP. Credit market development is gauged by three indicators, *Credit/GDP*, *Private Credit/GDP*, and *Bank Private Credit/GDP*. The intensity and quality of innovation are measured by six patent-based measures. All the variables are defined in Panel B of Appendix 2.

Figure 2: Time series Evolvement of Financial Market Indicators

A. Asian Economies **B. United States**



This figure plots the level of four financial market indicators, namely Stock/GDP, Credit/GDP, Private Credit/GDP, and Bank Private Credit/GDP, against the years in our sample period. Panel A focuses on the 26 Asian economies in our sample and shows the average value over time. Panel B focuses on the United States.

2.2.3 Results on Banking Development and Innovation

In this section, we aim to establish a causal relation between banking development and innovation. We follow the identification strategies in Rajan and Zingales (1998) and Hsu, Tian, and Xu (2014). Specifically, we work on industry-country-year panel data and examine whether industries that are more dependent on external finance or naturally more innovative respond more to banking development. We adopt the following regression specification to implement the strategy:

$$Innovation_{j,c,t} = \alpha + \beta_1 Stock/GDP_{c,t} \times Industry_j + \beta_2 Credit/GDP_{s,t} \times Industry_j + \delta_{c,t} + \delta_{i,t} + \varepsilon_{j,c,t} \quad (3),$$

Innovation is evaluated as one of the patent-based measures of innovation in a natural logarithm. *Stock/GDP* and *Credit/GDP* (or *Private Credit/GDP* and *Bank Private Credit/GDP*) are indicators of stock market and credit market (or banking sector) development, respectively. *Industry* is the External Financial Dependence (EFD) of an industry or the natural rate of innovation in an industry proxied by the growth rate of R&D expenditure. Both measures are constructed in a similar spirit to Rajan and Zingales (1998), where we use the US economy as the benchmark. We further define two indicator variables, *EFD* and *High Tech*, based on these two measures, which are set to one if the corresponding value exceeds the sample median and zero otherwise. We include country-by-year and industry-by-year fixed effects in the regression to condition the effect of country-specific and industry-specific trends, as well as contemporaneous events that may confound our results. Standard errors are two-way clustered by country and year to adjust for the correlation of observations within the same country or year.

The baseline results are presented in Table 9. We find that credit market development in general and the banking sector in particular have exerted a positive effect on the intensity and quality of innovation in industries that are more dependent on external finance or are naturally more innovative. The finding is consistent with a beneficial role of the credit market and banking sector in promoting innovation. That is, if credit market and banking development helps promote innovation, the effect should be disproportionately larger for industries whose innovation is most constrained by the lack of financing. On the other hand, we do not find a significant effect of stock market development on innovation in most specifications. This suggests that Asian economies on average rely more on bank credit to finance innovative activities than the stock market, which is in line with the important role of indirect financing in these regions.

We also explore the role of more granular indicators of banking sector development. We obtain the following measures on the banking sector structure from the GFDD. *Bank Penetration* is defined as the number of commercial bank branches per 100,000 adults in an economy. *Bank Concentration* is defined as the assets of the three largest commercial banks as a share of total commercial banking assets. It is an inverse measure for banking industry competition. *Bank Deposits/GDP* is the ratio of the total bank deposit value in a country over its GDP. *Offshore Loans/GDP* is the ratio of loans taken from banks located outside of the country to its GDP. *% Foreign Banks (Bank Asset)* is the number (total assets) of foreign banks as a percentage of the total number (assets) of banks in the economy. These measures become available from different years in our sample, which restricts the regression period under different specifications.

Table 9: Financial Market Development and Innovation in Asian Economies

Panel A

Dependent Variable	Patent Count (1)	Patent Entities (2)	Citation (3)	PC Top 10% (4)	Generality (5)	Originality (6)
Stock/GDP × EFD	0.0058	0.0139	0.0307	–0.0075	–0.0101	–0.0052
	(0.36)	(0.86)	(1.17)	(–0.66)	(–1.10)	(–0.44)
Credit/GDP × EFD	0.1825***	0.1302***	0.1863***	0.1849***	0.1821***	0.1989***
	(5.02)	(4.54)	(4.11)	(4.54)	(4.58)	(5.03)
Observation	23,514	23,514	23,514	23,514	23,514	23,514
Adj. R-squared	0.862	0.868	0.876	0.799	0.775	0.781
Stock/GDP × EFD	–0.0173	–0.0031	0.0049	–0.0282**	–0.0318**	–0.0287**
	(–1.39)	(–0.25)	(0.28)	(–2.21)	(–2.50)	(–2.18)
Private Credit/GDP × EFD	0.2852***	0.2068***	0.3109***	0.2720***	0.2740***	0.3009***
	(4.92)	(5.18)	(5.40)	(3.81)	(3.81)	(4.26)
Observation	24,172	24,172	24,172	24,172	24,172	24,172
Adj. R-squared	0.861	0.868	0.875	0.798	0.775	0.780
Stock/GDP × EFD	–0.0208	–0.0061	–0.0008	–0.0291*	–0.0333*	–0.0311*
	(–1.41)	(–0.49)	(–0.04)	(–1.86)	(–2.06)	(–1.87)
Bank Private Credit/GDP × EFD	0.3003***	0.2210***	0.3389***	0.2713***	0.2766***	0.3088***
	(3.83)	(4.43)	(4.34)	(3.05)	(3.01)	(3.35)
Observation	24,172	24,172	24,172	24,172	24,172	24,172
Adj. R-squared	0.861	0.868	0.875	0.797	0.774	0.780
Country-by-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-by-year FE	Yes	Yes	Yes	Yes	Yes	Yes

Panel B

Dependent Variable	Patent Count (1)	Patent Entities (2)	Citation (3)	PC Top 10% (4)	Generality (5)	Originality (6)
Stock/GDP × High Tech	–0.0011	0.0083	0.0811	–0.0258	–0.0371	–0.0291
	(–0.03)	(0.28)	(1.60)	(–0.94)	(–1.65)	(–1.07)
Credit/GDP × High Tech	0.5020***	0.4291***	0.5044***	0.5162***	–0.0371	0.5267***
	(4.13)	(4.58)	(4.55)	(4.21)	(–1.65)	(4.42)
Observation	22,555	22,555	22,555	22,555	22,555	22,555
Adj. R-squared	0.871	0.877	0.882	0.816	0.797	0.803
Stock/GDP × High Tech	–0.0645*	–0.0461	0.0104	–0.0851**	–0.0943**	–0.0902**
	(–1.75)	(–1.59)	(0.29)	(–2.17)	(–2.40)	(–2.25)
Private Credit/GDP × High Tech	0.7910***	0.6786***	0.8547***	0.7706***	0.7294***	0.7912***
	(4.25)	(4.93)	(6.32)	(3.63)	(3.34)	(3.76)
Observation	23,185	23,185	23,185	23,185	23,185	23,185
Adj. R-squared	0.871	0.877	0.882	0.816	0.798	0.803
Stock/GDP × High Tech	–0.0696	–0.0511	–0.0033	–0.0874*	–0.0968*	–0.0938*
	(–1.51)	(–1.44)	(–0.08)	(–1.79)	(–1.95)	(–1.87)
Bank Private Credit/GDP × High Tech	0.8040***	0.6932***	0.9203***	0.7667***	0.7273**	0.7946***
	(3.32)	(3.94)	(4.75)	(2.90)	(2.63)	(2.97)
Observation	23,185	23,185	23,185	23,185	23,185	23,185
Adj. R-squared	0.869	0.875	0.881	0.811	0.792	0.798
Country-by-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-by-year FE	Yes	Yes	Yes	Yes	Yes	Yes

This table shows the differential effect of stock market and credit market development on the innovation of industries with different extents of external financial dependence or different natural rates of innovation. We follow the specification in equation (3). *Innovation* is evaluated as one of the patent-based measures of innovation in natural logarithm. *Stock/GDP*, *Credit/GDP*, *Private Credit/GDP*, and *Bank Private Credit/GDP* are indicators of stock market and credit market development, respectively. *Industry* is *EFD* in Panel A and *High Tech* in Panel B, which is an indicator variable set to one if the value of the corresponding industry measure is greater than the sample median. A detailed definition of variables is presented in Panel B of Appendix 2. The regressions include country-by-year and industry-by-year fixed effects. Standard errors are two-way clustered at country and year levels. *, **, and *** denote significance level at 10%, 5%, and 1%, respectively.

Table 10: Banking Development and Innovation: Granular Indicators

Panel A

	Patent Count					
Dependent Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Stock/GDP × EFD	–0.0187	–0.0172	–0.0217	–0.0200	–0.0051	0.0131
	(–1.27)	(–1.07)	(–0.81)	(–1.33)	(–0.36)	(0.83)
Bank Private Credit/GDP × EFD	0.3628***	0.3173***	0.2983***	0.2606***	0.3369***	0.3321***
	(4.22)	(3.66)	(3.28)	(2.85)	(4.23)	(3.86)
Bank Penetration × EFD	–0.0025					
	(–0.67)					
Bank Concentration × EFD		–0.0584				
		(–0.26)				
Bank Deposits/GDP × EFD			0.0054			
			(0.05)			
Offshore Loans/GDP × EFD				–2.3775***		
				(–3.67)		
% Foreign Banks × EFD					–0.2298	
					(–1.45)	
% Foreign Bank Assets × EFD						–0.4097**
						(–2.90)
Observations	9,191	15,598	24,043	19,251	17,983	8,367
Adjusted R-squared	0.868	0.854	0.861	0.867	0.861	0.870
Period	2004 to 2013	1996 to 2013	1975 to 2013	1975 to 2013	1995 to 2013	2004 to 2013
Country-by-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-by-year FE	Yes	Yes	Yes	Yes	Yes	Yes

Panel B

	Patent Count					
Dependent Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Stock/GDP × High Tech	–0.0548	–0.0527	–0.0768	–0.0656	–0.0101	0.0190
	(–1.46)	(–1.33)	(–0.91)	(–1.43)	(–0.33)	(0.68)
Bank Private Credit/GDP × High Tech	0.8839***	0.7847***	0.7698***	0.7308**	0.8812***	0.8496***
	(4.06)	(3.65)	(3.17)	(2.73)	(4.38)	(4.44)
Bank Penetration × High Tech	–0.0031					
	(–0.38)					
Bank Concentration × High Tech		–0.1388				
		(–0.29)				
Bank Deposits/GDP × High Tech			0.0508			
			(0.14)			
Offshore Loans/GDP × High Tech				–5.3141***		
				(–3.49)		
% Foreign Banks × High Tech					–0.8243**	
					(–2.18)	
% Foreign Bank Assets × High Tech						–0.9507***
						(–3.69)
Observations	8,815	14,966	23,060	18,442	17,258	8,024
Adjusted R-squared	0.874	0.862	0.869	0.874	0.871	0.879
Period	2004 to 2013	1996 to 2013	1975 to 2013	1975 to 2013	1995 to 2013	2004 to 2013
Country-by-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-by-year FE	Yes	Yes	Yes	Yes	Yes	Yes

This table presents the marginal effect of other banking sector indicators on innovation, conditional on the overall effect of bank credit provided to the private sector. The dependent variable is *Patent Count* for illustration purposes. *Stock/GDP*, *Credit/GDP*, *Private Credit/GDP*, and *Bank Private Credit/GDP* are indicators of stock market and credit market development, respectively. *Industry* is *EFD* in Panel A and *High Tech* in Panel B, which is an indicator variable set to one if the value of the corresponding industry measure is greater than the sample median. A detailed definition of variables is presented in Panel B of Appendix 2. The regressions include country-by-year and industry-by-year fixed effects. Standard errors are two-way clustered at country and year levels. *, **, and *** denote significance level at 10%, 5%, and 1%, respectively.

We augment regression equation (3) by adding an interaction between these additional indicators and the *Industry* dummy. In this way, we can assess the marginal effect of these other advances in the banking sector on top of its overall development. The results are shown in Table 10. We only tabulate the results of *Patent Count* to conserve space, yet the results hold if we use the other five measures of innovation. As can be seen from the table, most of the other banking sector measures have an insignificant load in the regressions. The presence of foreign loans and foreign banks has a negative effect on the rate of innovation, which is consistent with the argument that foreign banks are less able to monitor firms due to greater physical and cultural distance. Taken together, the findings indicate that the predominant effect of the banking sector on innovation comes from the overall depth and size of the domestic market. Other dimensions of banking sector development are less of a concern.

3. CONCLUSION

In conclusion, among the papers we have surveyed, while theoretical implications are generally indefinite about the effect of banking development on innovation, empirical findings are less ambiguous given their distinct focus of sample firms and the underlying channels investigated. Moreover, the development conditions of financial markets matter in drawing implications for the effect of financial institutions on innovation. Specifically, when the stock market is relatively less developed, as in most Asian economies, banks play a significant role in financing and promoting innovation. Therefore, it seems plausible for policymakers in these regions to strengthen the development of the banking sector and to improve the depth of the credit market.

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APPENDIX 1: SUMMARY OF EMPIRICAL STUDIES ON BANKING AND INNOVATION

Paper	Sample	Key Findings	Major Channels Identified
Amore, Schneider, and Žaldokas (2013)	Public manufacturing firms in US (1976–1995)	Banking development via *interstate banking* deregulation promotes corporate innovation.	Banks are more able to diversify risk geographically, which enhances their ability to lend to firms to engage in risky innovative projects.
Chava et al. (2013)	Young, private firms in the US (1975–2005)	The nature of banking development matters for the effect on innovation: *intrastate (interstate) banking* deregulation has a negative (positive) effect on innovation.	Intrastate (interstate) deregulation increases (decreases) market power of banks, hence reduces (increase) credit to innovative firms.
Cornaggia et al. (2015)	Public and private firms in the US (1976–2006)	Banking development via *interstate branching* has a positive (negative) effect on the innovation by private (public) firms.	Bank deregulation increases credit for private firms, but reduces the supply of small, innovative targets for public firms.
Hombert and Matray (2016)	Public and private firms in the US (state level and inventor level) (1968–1998)	Banking development via *intrastate branching* deregulation decreases aggregate innovation and leads to an outflow of productive inventors.	Intrastate branching weakens existing bank lending relation with firms, hence negatively affects credit provision for their innovation.
Maria Herrera and Minetti (2007)	Italian manufacturing firms (1998–2000)	Bank information has a positive effect on innovation.	Banking deregulation shifts local supply of banking services and affects innovation via relationship lending.
Benfratello, Schiantarelli, and Sembenelli (2008)	Italian manufacturing firms (1991–2000)	Local banking development increases innovation.	Local banking development decreases cost of capital and increases credit supply for innovative firms.
Ayyagari, Demirgüç-Kunt, Maksimovic (2011)	47 emerging economies (2002–2004)	Bank financing is associated with greater innovation of firms in emerging economics.	Banks play a key role to provide credit for innovative activities when market-based financing channels are absent.
Hsu, Tian, and Xu (2014)	32 economics (1976–2006)	Credit market development has a negative effect on industries' innovation.	Bank financing lacks effective price signal to channel credit to innovative projects and is not incentive-compatible for the financing of risky projects.
Nanda and Nicholas (2014)	Public and private firms in the US (1920–1938)	Banking distress during the Great Depression has negatively affected corporate innovation.	Bank distress reduces credit supply for innovative activities.

This table presents a brief summary of the sample composition, key findings, and major channels identified in each paper surveyed.

APPENDIX 2: VARIABLE DEFINITIONS

Panel A. Intrastate Banking Deregulation and Innovation

Variable	Definition
Dereg	A dummy set to one for states in the years after bank branch deregulation within the states
RD/At	R&D expenditures scaled by total assets; Source: Compustat
Patent	Firm's total number of eventually granted patents filed in a given year; Source: NBER database
Citation	Total number of citations received on the firm's patents filed (and eventually granted) in a given year; Source: NBER database
Citation/Patent	Total number of citations received on the firm's patents filed (and eventually granted) scaled by total number of patents in a given year; Source: NBER database
New_class	Firm's total number of patents filed in a new technological class over total number of patents filed in a given year; Source: NBER database
Known_class	Firm's total number of patents filed in a known technological class over total number of patents filed in a given year; Source: NBER database
Exploitive_patent_70	Firm's total number of exploitive patents filed in a given year. Exploitive patents are defined as such if at least 70% of their citations refer to existing knowledge, which includes all the patents that the firm produced and all the patents that were cited by the firm's patents filed over the past five years; Source: NBER database
Exploitive_patent_80	Firm's total number of exploitive patents filed in a given year. Exploitive patents are defined as such if at least 80% of their citations refer to existing knowledge, which includes all the patents that the firm produced and all the patents that were cited by the firm's patents filed over the past five years; Source: NBER database
Exploitive_patent_90	Firm's total number of exploitive patents filed in a given year. Exploitive patents are defined as such if at least 90% of their citations refer to existing knowledge, which includes all the patents that the firm produced and all the patents that were cited by the firm's patents filed over the past five years; Source: NBER database
Explorative_patent_70	Firm's total number of explorative patents filed in a given year. Explorative patents are defined as such if at least 70% of their citations do not refer to existing knowledge, which includes all the patents that the firm produced and all the patents that were cited by the firm's patents filed over the past five years; Source: NBER database
Explorative_patent_80	Firm's total number of explorative patents filed in a given year. Explorative patents are defined as such if at least 80% of their citations do not refer to existing knowledge, which includes all the patents that the firm produced and all the patents that were cited by the firm's patents filed over the past five years; Source: NBER database
Explorative_patent_90	Firm's total number of explorative patents filed in a given year. Explorative patents are defined as such if at least 90% of their citations do not refer to existing knowledge, which includes all the patents that the firm produced and all the patents that were cited by the firm's patents filed over the past five years; Source: NBER database
Generality	The generality score of each patent is defined as one minus the Herfindahl Index of the technological class of patents citing it; the higher the generality score, the more generally applicable the patents are for other types of innovations; Source: NBER database
Originality	The generality score of each patent is defined as one minus the Herfindahl Index of the technological class of patents that it cites; the higher the originality score, the wider the range of technologies it draws upon; Source: NBER database
Tech_prox	The technological proximity between the patents filed in year t to the existing patent portfolio held by the same firm up to year t-1, and is calculated according to Jaffe (1989); Source: NBER database
Patent_value	The market value of eventually granted patents filed in a given year scaled by book value of assets; Source: NBER database & Kogan et al. (2017)
New_product	A dummy set to one if the firm launches a new product in a year; Source: Mukherjee, Singh, and Žaldokas (2017)
New_product_announce	The sum of all positive cumulative abnormal announcement returns over the year; Source: Mukherjee, Singh, and Žaldokas (2017)
New_product_announce_75	The count of the number of announcements with cumulative abnormal returns above the 75th percentile; Mukherjee, Singh, and Žaldokas (2017)
Size	Log of firm's market value; Source: Compustat
MB	Market value of equity divided by book value of equity; Source: Compustat
LEV	Firm's book leverage; Source: Compustat
ROA	The operating income before depreciation scaled by the total assets of a firm in a fiscal year; Source: Compustat
Age	Firm's age; Source: Compustat
Log(GDP per capita)	Log value of GDP per capita in a state; Source: BEA
GDP_growth	The growth rate of GDP per capita in a state; Source: BEA
Log(population)	Log value of total population in a state; Source: BEA

Panel B. Banking Development and Innovation in Asian Countries

Variable	Definition
Patent Count	The natural logarithm of one plus the total number of eventually granted patents in an industry-country-year, where the industry was first defined in the subclasses of the International Patent Classification (IPC) and then converted to the two-digit Standard Industrial Classification (SIC) based on the concordance scheme in Lybbert and Zolas (2012); Source: PATSTAT
Patent Entities	The natural logarithm of the total number of patenting entities (with eventually granted patents) in an industry, country, year; Source: PATSTAT
Citation	The natural logarithm of the truncation-adjusted forward citation counts to all the eventually granted patents filed in an industry, country, year. Citation is a common measure for the quality of innovation; Source: PATSTAT
PC Top 15%	The natural logarithm of one plus the highly cited patents in an industry, country, year, where a patent is regarded as highly cited if its citation count falls within the top 25 percentiles of all the patents in the same industry and year; Source: PATSTAT
Generality	The natural logarithm of one plus the originality and generality index aggregated across all the eventually granted patents in an industry, country, year; Source: PATSTAT
Originality	The natural logarithm of one plus the originality index aggregated across all the eventually granted patents in an industry, country, year; Source: PATSTAT
Stock/GDP	The ratio of market capitalization of all the listed domestic firms in a country over GDP; Source: WDI
Credit/GDP	The ratio of domestic credit provided by the financial sector over GDP; Source: WDI
Private Credit/GDP	The ratio of domestic credit to the private sector over GDP; Source: WDI
Bank Private Credit/GDP	The ratio of domestic credit to the private sector that is provided by banks over GDP; Source: WDI
EFD	An indicator equal to one if industry external financial dependence (EFD) is greater than the sample median and zero otherwise; industry EFD measure is constructed following Rajan and Zingales (1998) and benchmarked to the US; Source: Compustat
High Tech	An indicator equal to one if the average growth rate of R&D expenditure in an industry is greater than the sample median and zero otherwise; industry measure of R&D growth is benchmarked to the US; Source: Compustat
Bank Penetration	The number of commercial bank branches per 100,000 adults in an economy; Source: GRDD
Bank Concentration	The assets of the three largest commercial banks as a share of total commercial banking assets; Source: GRDD
Bank Deposits/GDP	The ratio of total bank deposit value in a country over its GDP; Source: GRDD
Offshore Loans/GDP	The ratio of loans taken from banks located outside of the country to its GDP; Source: GRDD
% Foreign Banks	The number of foreign banks as a percentage of the total number of banks in the economy; Source: GRDD
% Foreign Bank Assets	The total assets of foreign banks as a percentage of the total assets of all the banks in the economy; Source: GRDD

This table contains definitions and data sources of all the variables used in our analysis. Panel A contains the variables used in Section 2.2 on intrastate banking deregulation and innovation. Panel B contains the variables used in Section 2.3 on banking and innovation in Asian economies.