Journal of Financial Economics 139 (2021) 985–1014

Contents lists available at ScienceDirect

Journal of Financial Economics

journal homepage: www.elsevier.com/locate/jfec

Stock market liberalization and innovation☆

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ARTICLE INFO

Article history:
Received 9 April 2019
Revised 30 September 2019
Accepted 26 November 2019
Available online 23 August 2020

JEL classification:
F63
G15
O38

Keywords:
Stock market liberalization
Innovation
Equity financing
Risk sharing
Corporate governance

ABSTRACT

We investigate the effect of stock market liberalization on technological innovation. Using a sample of 20 economies that experience stock market liberalization, we find that these economies exhibit a higher level of innovation output after liberalization and that this effect is disproportionately stronger in more innovative industries. The relaxation of financial constraints, enhanced risk sharing between domestic and foreign investors, and improved corporate governance are three plausible channels that allow stock market liberalization to promote innovation. Finally, we show that technological innovation is a mechanism through which stock market liberalization affects productivity growth and therefore economic growth. Our paper provides new insights into the real effects of stock market liberalization on productivity growth and the economy.

1. Introduction

Stock market liberalization is a government decision to remove restrictions on foreign investors and allow them to participate in domestic equity markets. Over the last three decades, stock market liberalization has been shown to have a substantial impact on the world economy (e.g., Bekaert et al., 2005; Mitton, 2006; Gupta and Yuan, 2009). For example, according to Bekaert et al. (2005), stock market liberalization leads to a 1% increase in a country's annual real economic growth.[1] Nevertheless, the economic

[1] At the industry level, Gupta and Yuan (2009) show that stock market liberalization leads to a 1.9% increase in real value-added growth in the industry at the 75th percentile of external finance dependence relative to the industry at the 25th percentile. Mitton (2006) finds that an average investable firm in a country experiences a 1.9% increase in real growth in sales relative to a non-investable firm after the country liberalizes its stock market.

☆ We are grateful for the comments and suggestions from the referee (Christian Lundblad), Meghana Ayyagari, Utpal Bhattarcharya, Francesca Carrieri, Xin Chang, Kangkang Fu, Yifei Mao, R. David McLean, Hang Pham, Nagpurnanand Prabhala, Sergei Sarkissian, Bill Schwert (the editor), Yan Xu, and conference and seminar participants at the 2014 Western Finance Association annual meeting, the 2014 Northern Finance Association Conference, the 2018 China International Conference in Finance, the 2018 New Zealand Finance Meeting, and the 2018 Australasian Finance and Banking Conference. We also thank Zhengyuan Wang for his valuable contribution to the early version of this paper and Jian Huang for his excellent research assistance. Fariborz Moshirian and Bohui Zhang acknowledge the financial support of the ARC Linkage grant (LP130101050) from the Australian Research Council. Xuan Tian acknowledges financial support from the National Natural Science Foundation of China (Grant No. 71790591, 91746301, 71825002) and Beijing Outstanding Young Scientist Program (BJJWZYJH 01201910003014). We remain responsible for any remaining errors or omissions.

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https://doi.org/10.1016/j.jfineco.2020.08.018
0304-405X/

mechanisms underlying the growth effect of stock market liberalization are still not well understood.

Previous studies show that liberalization facilitates risk sharing and lowers the cost of capital, thereby inducing additional investment (e.g., Henry, 2000a; Chari and Henry, 2008; Gupta and Yuan, 2009). However, the significant growth effect of liberalization does not fully reconcile with the limited decrease in the cost of capital and the modest increase in the level of investment (e.g., Henry, 2003, 2007). In response, Bekaert et al. (2011) demonstrate that productivity and the efficiency with which the economy allocates scarce financial resources among firms are important components, with attention to the other, possibly institutional, changes liberalization could induce.[2]

Surprisingly, while technological innovation has always been considered vital for a country's productivity growth and hence the growth of its economy (Solow, 1956; Romer, 1986), no empirical research explores innovation as a mechanism underlying the productivity effect of stock market liberalization.[3] In this paper, we attempt to fill the gap between liberalization and growth by examining the impact of stock market liberalization on technological innovation.

The significant growth effect of innovation is justified by its unique features, which distinguish it from conventional investment such as capital expenditures. According to Holmstrom (1989), innovation involves long-term, risky, and idiosyncratic investment in intangible assets, requiring considerable exploration of unknown approaches, while conventional investment is simply the exploitation of well-known methods. Hence, in contrast to conventional investment, innovation entails the heavy use of a variety of intangible assets, such as human capital, knowledge, and organizational support. These distinctions result in two consequences. First, while some studies (e.g., Henry, 2000a) show that stock market liberalization leads to an increase in capital expenditures, it is unclear ex ante how stock market liberalization affects a country's innovative activities.[4] Second, the use of equity is more suitable for financing and motivating innovation than the use of debt contracted over tangible assets (Hsu et al., 2014). Therefore, innovative activities should be more sensitive to reforms in the equity markets, such as stock market liberalization, than reforms in the debt markets.[5]

Next, we examine three plausible economic channels through which stock market liberalization could affect innovation, namely, the financing channel, the risk-sharing channel, and the corporate governance channel.[6] First, we consider the most important consequence of stock market liberalization: the relaxation of financial constraints. According to the World Bank Enterprise Surveys (2006–2010), almost 40% of firms in emerging markets cite insufficient access to finance as the foremost obstacle to their operations and growth. Insufficient access to finance has an even more adverse effect on innovative firms, exhausting their internal capital and thus increasing their reliance on external finance (Brown et al., 2009, 2013). Given that stock market liberalization allows foreign investors to purchase local shares (Gupta and Yuan, 2009), we postulate that stock market liberalization affects innovation by mitigating local firms' financial constraints. We term this channel the financing channel.

Second, existing theories on corporate innovation (e.g., Holmstrom, 1989; Manso, 2011) argue that the innovation process is risky and has unforeseeable consequences involving multiple contingencies. As a result, a risk-sharing scheme that encourages firms' risk-taking activities could spur innovation. Given that foreign portfolio investment induced by stock market liberalization enhances risk sharing between domestic and foreign investors (e.g., Henry, 2000b; Chari and Henry, 2004; Bekaert et al., 2005), we also expect liberalization to spur innovation through the risk-sharing channel.[7]

Third, corporate governance is essential to firms' innovation. For example, the study of Brown et al. (2013) reveals that strong shareholder protection plays a crucial role in innovative projects, which are mainly reliant on stock market financing, because these projects are highly uncertain and suffer from a larger degree of information asymmetry.[8] To the extent that the liberalization of domestic equity markets attracts more foreign investors who are better monitors and in turn enhance domestic firms' corporate governance (e.g., Aggarwal et al., 2011), stock market liberalization could restrain managers' opportunis-

[2] Previous literature has shown the positive effects of stock market liberalization on several institutional factors that could also increase a country's capital allocative efficiency and productivity growth. See Levine and Zervos (1998), Bae, Ozoguz, Tan, and Wirjanto (2012), Bae, Bailey, and Mao (2006), Bae and Goyal, (2010), and Bekaert, Harvey, and Lundblad (2005, 2011), among others.

[3] According to Rosenberg (2004), 85% of economic growth could be attributed to technological innovation. Using an international sample of patents across 59 countries between 1980 and 2010, Chang, McLean, Zhang, and Zhang (2018) show that a one standard deviation increase in patent stock per capita portends a 0.85% increase in gross domestic product growth.

[4] An emerging body of literature shows that several economic factors affect conventional investment and innovation in substantially different ways. For instance, although traditional initial public offering (IPO) literature shows that going public allows firms to raise capital and increase their capital expenditures, Lerner, Sorensen, and Stromberg (2011) find that it is private ownership, not public ownership, that promotes innovation. A second example is that although some studies argue that financial analysts reduce information asymmetry and the cost of capital, which in turn increases ordinary capital expenditures (e.g., Derrien and Kecskes, 2013), recent studies such as those by Benner and Ranganathan (2012) and He and Tian (2013) find that financial analysts hinder innovation by imposing excessive pressure on managers to meet short-term earnings targets.

[5] In contrast to capital account openness, which allows all types of capital to flow in, stock market liberalization involves the removal of any restrictions imposed on foreigners investing in local equities.

[6] Although we test these three underlying economic channels separately, we acknowledge that these channels are not necessarily mutually exclusive and could jointly contribute to the impact of stock market liberalization on technological innovation.

[7] The financing channel and the risk-sharing channel are not entirely separate. For example, if part of the increase in innovative investment comes from the alleviated financing constraints, it could be because the relevant costs of capital have declined with larger global risk sharing after liberalization.

[8] Strong shareholder protection can impede innovation because it can increase the external pressure on managers and lead to managerial short-termism (Belloc, 2013; Lin, Liu, and Manso, 2019).

tic behaviors in innovative investment and promote domestic firms' innovation output. We call this channel the corporate governance channel.

To measure a country's innovation output, we collect global patent information from the Bureau van Dijk's Orbis patent database.[9] This data set allows us to observe the number of patents a country generates and the number of citations these patents receive post-registration. Accordingly, we are able to explore the effect of stock market liberalization on both the quantity and the quality of a country's innovation output. Moreover, the examination of the technology class distribution of patent citations allows us to better understand the fundamental nature of a country's innovative activities after stock market liberalization.[10] We collect official stock market liberalization date information from Bekaert et al. (2005). Our main sample focuses on public firms from 20 developed and emerging economies that experience stock market liberalizations during the 1981–2008 period.

Consistent with our conjectures, the country-industry-level test shows that stock market liberalization increases a country's innovation output. On average, after a country liberalizes its stock market, its patent counts, citation counts, and the number of innovative firms experience an increase of 13%, 16%, and 11%, respectively. To tackle identification challenges, we follow Acharya and Subramanian (2009) and use the country-industry-year-level panel-based fixed effects identification approach as the main specification. We find that industries with higher innovation intensity exhibit a disproportionately higher level of innovation output after a country opens its equity market. For example, for industries with innovation intensity in the top quartile compared with those with innovation intensity in the bottom quartile, stock market liberalization increases the numbers of patents, citations, and innovative firms from their mean values by 24%, 25%, and 19%, respectively. Our findings continue to hold in an extensive set of robustness checks using alternative subsamples, model specifications, and innovation measures, as well as additional tests to address the endogeneity issue.

To examine the three underlying economic channels, we explore the cross-sectional heterogeneity of our main results from the perspectives of various industry and country characteristics. First, stock market liberalization is more effective in enhancing innovation in more innovative industries of a country when the industries are more reliant on external equity finance and when the industries are less likely to pay dividends. Second, the positive effect of liberalization on innovation output in more innovative industries of a country is more pronounced when the industries have a larger difference of local beta and world beta, i.e., the benefits from diversification are greater (Chari and Henry, 2004; Bae and Goyal, 2010), and when the country has stronger creditor rights, i.e., firms' risk-taking incentives are substantially suppressed (Acharya and Subramanian, 2009). Third, the liberalization effect on innovation is significantly stronger in more innovative industries when the industries have a lower percentage of closely held blocks and when the country has a better investment profile.

Earlier literature argues that new firms, compared with existing firms, are financially more constrained, are less diversified, and have more concentrated ownership. They are thus more likely to benefit from liberalization. However, liberalization perhaps does not ease the constraints on these new firms due to entry barriers.[11] Hence, we look into the intensive versus extensive margin question by investigating whether liberalization changes some existing firms from being non-innovative to being innovative or motivates more firms that have been classified as innovative from their inception to go public. We find that liberalization leads to a significantly larger increase in the number of innovative firms for both a sample of firms listed prior to the liberalization year and a sample of firms undertaking initial public offerings (IPOs) and that the effects are stronger in more innovative industries than in less innovative industries. These results suggest that our findings hold for both the intensive and extensive margins. Overall, the results provide supportive evidence to the three underlying economic channels we propose.

Finally, we test the conjecture that technological innovation is the mechanism linking stock market liberalization with productivity growth by undertaking three sets of analyses. First, consistent with prior literature (e.g., Bekaert et al., 2005, 2011; Gupta and Yuan, 2009), liberalization, on average, promotes the growth of industry value added, the growth of industry capital stock, and the growth of industry total factor productivity (TFP). In addition, the positive effect of liberalization on the growth of industry value added and the growth of industry TFP is more pronounced in more innovative industries, while the effect on the growth of capital stock between more innovative and less innovative industries is insignificant. These findings suggest that stock market liberalization spurs productivity growth in more innovative industries mainly through promoting industry innovation output, which leads to an enhancement of economic growth in these industries.

Second, by breaking down the positive impact of stock market liberalization into temporary and permanent components, we show that liberalization has both a temporary and a permanent positive effect on industry value-added growth, industry capital stock growth, and industry TFP growth. The permanent effect on industry value-

[9] Compared with the National Bureau of Economic Research (NBER) Patent and Citation database compiled based on the United States Patent and Trademark Office (USPTO), the Orbis database has a much broader coverage. In addition to the patents filed in the US and administrated by the USPTO, the Orbis database covers patents filed in 93 non-US patent offices including national patent offices and regional and international organizations, such as the European Patent Office (EPO) and the African Intellectual Property Organization. Therefore, we are able to directly measure a country's innovation level using the Orbis database, instead of inferring it indirectly through the NBER database.

[10] These features of patent data provide a unique advantage of using innovation as the outcome variable because one cannot easily judge the change in the quality and fundamental nature of conventional investment such as capital expenditures.

[11] See Gopalan and Gormley (2008), Gupta and Yuan (2009), Foley and Greenwood (2010), and Faccio, Marchica, and Mura (2011), among others.

added growth and industry TFP growth (instead of industry capital stock growth) is mainly attributed to more innovative industries, which suggests that stock market liberalization promotes productivity growth and in turn economic growth in the long run by encouraging innovation.

Third, we discuss the effect of stock market liberalization on capital allocative efficiency in firms' innovative investment. Our baseline findings show that liberalization promotes firms' innovative investment particularly in industries with a higher propensity to innovate after a country opens up its stock market, suggesting that liberalization improves capital allocative efficiency in firms' innovative investment. Moreover, our earlier channel tests indicate that liberalization not only facilitates cross-industry capital allocative efficiency by enhancing the innovation output of firms in industries with a higher innovation propensity while facing financial constraints, lack of risk sharing, and weak governance, but also facilitates within-industry capital allocative efficiency by encouraging existing firms to innovate more in industries with a higher innovation propensity and by attracting more new firms with innovation needs to go public.

Our paper contributes to two streams of literature. First, it adds to the literature on financial openness and economic growth and joins the debate on the growth effects of stock market liberalization. On the one hand, Rodrik (1998) and Edison et al. (2004) find that the effects of stock market liberalization are weak. In a survey paper, Kose et al. (2009) find mixed collective evidence regarding the effect of financial liberalization on economic growth.[12] On the other hand, Bekaert et al. (2005), Gupta and Yuan (2009), and Mitton (2006) find strong growth effects at country, industry, and firm levels. However, it is puzzling that the growth effect of liberalization cannot be fully justified by the small risk-sharing benefit of liberalization in reducing the cost of capital (Henry, 2003, 2007). Our findings help explain this puzzle by showing that technological innovation substantiates a permanent effect of stock market liberalization on economic growth. Moreover, previous literature (e.g., Levine, 2001; Bonfiglioli, 2008; Gupta and Yuan, 2009; Bekaert et al., 2011) finds that stock market liberalization increases productivity growth. The positive effect of liberalization on productivity growth could result from several mechanisms, such as the increase in stock liquidity (Levine and Zervos, 1998), the improvement in information efficiency (Bae et al., 2012) or, more generally, information environments (Bae et al., 2006), and the enhancement of corporate governance (Bae and Goyal, 2010) and legal institutions (Bekaert et al., 2005, 2011). Different from these studies, our paper identifies technological innovation as an alternative economic mechanism through which stock market liberalization enhances productivity growth.

Second, our paper contributes to the literature on finance and innovation in a cross-country setting. Broadly speaking, existing studies (e.g., Acharya and Subramanian, 2009; Brown et al., 2013; Hsu et al., 2014; Luong et al., 2017; Bhattacharya et al., 2017) explore how country-specific characteristics such as bankruptcy codes, legal institutions, equity market development, foreign institutional ownership, and policy uncertainty affect research and development (R&D) investment and innovation output.[13] Unlike these studies, we explore how an important policy change — stock market liberalization — affects a country's innovation output, as well as the underlying economic channels through which this effect occurs. Our paper is distinct from Hsu et al. (2014). Using a sample of 32 emerging and developed economies, they find that equity market development is beneficial to innovation. We develop this line of inquiry by showing that stock market liberalization exhibits a positive effect on innovation even after controlling for a country's equity market development. We identify and test, based on economic theory, three plausible alternative channels (i.e., the financing, risk-sharing, and corporate governance channels) through which stock market liberalization promotes innovation. Our evidence suggests that the effect of stock market liberalization on innovation is beyond what equity market development can capture.[14]

The rest of the paper is organized as follows. Section 2 describes our sample selection and reports summary statistics. Section 3 presents our main empirical findings and a variety of robustness checks. Section 4 explores plausible underlying economic channels through which stock market liberalization affects innovation. Section 5 reports additional results. Section 6 concludes.

2. Data, sample, and variables

2.1. Data and sample

To construct our innovation variables, we use Bureau van Dijk's Orbis patent database, which is sourced from the

[12] Another large body of literature linking finance and growth goes back to Goldsmith (1969) and Shaw (1973). More recent research has shown that the size and depth of a country's financial system positively affects its future growth per capita, real income, employment, entrepreneurship, and output (e.g., King and Levine, 1993; Jayaratne and Strahan, 1996; Rajan and Zingales, 1998; Beck and Levine, 2002; Black and Strahan, 2002).

[13] Other studies that explore finance and innovation include Acharya, Baghai, and Subramanian (2013), Aghion, van Reenen, and Zingales (2013), Brav, Jiang, Ma, and Tian (2018), Bradley, Kim, and Tian (2017), Chemmanur, Loutskina, and Tian (2014), Cornaggia, Mao, Tian, and Wolfe (2015), Lerner, Sorensen, and Stromberg (2011), Levine, Lin, and Wei (2017), Lin, Liu, and Manso (2019), Manso (2011), Seru (2014), and Tian and Wang (2014). See He and Tian (2018, 2020) for surveys of this literature.

[14] Fang, Tian, and Tice (2014) find that an increase in stock liquidity of US firms leads to a reduction in these firms' innovation output. He and Tian (2013) use a sample of US firms to show that financial analysts impede firm innovation by imposing too much pressure on short-term earnings targets. At first blush, these results appear inconsistent with our findings because stock liberalization is positively related to stock liquidity and analyst coverage (Levine and Zervos, 1998; Bae, Bailey, and Mao, 2006). We believe that their findings are built on the existence of a fully liberalized equity market, such as that of the US. In other words, the negative effects of stock liquidity and analyst coverage on innovation in US firms along the intensive margin perhaps do not exist to the same extent along the extensive margin in other countries whose equity markets are less liberalized and developed. Therefore, the effect of stock market liberalization on innovation through its effect on stock liquidity and analyst coverage could be very different in our setting in which both developed economies (excluding the US) and emerging economies are examined.

Worldwide Patent Statistical Database (PATSTAT), maintained by the European Patent Office (EPO). The Orbis patent database offers a comprehensive coverage of more than 36 million patents granted worldwide from 1850 to 2013. These patents are filed by both publicly traded and privately held firms throughout 94 regional, national, and international patent offices.

The Orbis patent database has a much wider coverage than the National Bureau of Economic Research (NBER) Patent and Citation database, which is based solely on patent filings to the United States Patent and Trademark Office (USPTO). Although the NBER database has been widely used in the innovation literature (e.g., Hall et al., 2005; Aghion et al., 2013), it has limitations in cross-country studies as it covers patents filed only in the US and granted by the USPTO. Hence, the NBER database could result in biases (most likely underestimation) in judging the innovative performance of non-US firms that do not file patent applications to the USPTO.[15] Another important feature of the Orbis database is the ease of identifying patent assignees (owners). The Orbis database lists the majority of patent owners using its unique firm identifiers, with which we are able to determine patent owners' domicile, industry classification, and listing status.[16]

We collect data on the official stock market liberalization date of each country from Bekaert et al. (2005). Furthermore, we extract industry-level data from the United Nations Industrial Development Organization (UNIDO) Industrial Statistics database and country-level data, such as gross domestic product (GDP) per capita, human capital index, imports and exports as a fraction of GDP, and government consumption as a fraction of GDP from the Penn World Table (PWT) version 8.0.

Our initial sample consists of firms in industries from 87 countries that are jointly covered by the UNIDO and the PWT databases.[17] We then merge the initial sample with the Orbis database and further filter the sample according to the following five criteria. First, we remove non-public firms because stock market liberalization has a relatively more direct impact on publicly traded firms (Chari and Henry, 2008).[18] Second, we focus solely on manufacturing industries [Standard Industrial Classification (SIC) codes 20–39] not only because the UNIDO database is limited to these industries, but also because manufacturing industries are the most innovative and hence the most relevant industries. According to the 2008 Business R&D and Innovation Survey (BRDIS) by the National Science Foundation (available at http://www.nsf.gov/statistics/infbrief/nsf11300), 22% of manufacturing firms introduce product innovation, compared with 8% of nonmanufacturing firms in the period from 2006 to 2008.[19]

Third, following previous studies (e.g., Hirshleifer et al., 2012), we exclude countries where public firms do not produce a single patent during the entire sample period. Nevertheless, our main findings are robust to the inclusion of these countries. Fourth, we remove US firms from our sample but use them to control for industrial patenting activities or innovation opportunities over time (e.g., Acharya and Subramanian, 2009; Hsu et al., 2014). Fifth, to explore the time variation in corporate innovation before and after liberalization, we restrict our analysis to a sample of countries that experience stock market liberalization during the sample period by removing 18 countries that liberalized their stock market prior to the beginning of the sample period and 12 countries that did not liberalize their stock market during the period.[20] Our final sample consists of 20 industries in 20 countries that were liberalizing their equity markets between 1981 and 2008.[21]

2.2. Measures of innovation

Following previous studies (e.g., Aghion et al., 2013; Seru, 2014), we construct the first innovation measure as the number of successful patent applications by public firms in each two-digit SIC industry for each country each year (*Pat*). We use the patent application date instead of the grant date in the analysis because the former is closer to the actual invention date, according to Hall et al. (2001). Patent count captures innovation output based on the premise that manufacturing firms materialize inventions in the form of patents. However, simply adding up firms' patents applied at different patent offices could lead to overestimation because inventors can obtain multiple patents in different countries to protect the same invention. To solve this issue, we count one patent per innovation. For example, if a Japanese firm patents an innovation in Japan, the US, and China, then we would count this as a single Japanese patent. Moreover, a patent application on the same invention can be filed with different patent offices on different dates. To determine the actual date of innovation for these cases, we choose the earliest application date (priority date) for an innovation.

One concern for a simple patent count is that it could reflect only the quantity as opposed to the quality of a firm's inventions. Given that a more significant patent is

[15] Chang et al. (2018) show that firms in many countries, especially those in emerging markets, do not file patent applications to the USPTO and that this proportion varies across countries over time.

[16] We provide a detailed comparison of the Orbis database with the NBER Patent and Citation database in Section A of the Online Appendix.

[17] The Orbis database uses the US Standard Industrial Classification (SIC), and the UNIDO database employs the International Standard Industrial Classification (ISIC). Thus, we match the two-digit US SIC codes with the two-digit ISIC codes using the concordance table provided by the European Commission.

[18] We examine the effect of stock market liberalization on innovation in more innovative industries for a sample of large private firms in countries experiencing liberalization during our sample period and find an insignificant effect. We describe this test in Section 5.1.

[19] Patenting innovation is more important to manufacturing industries because these industries rely heavily on patents as a means of appropriating new technologies (Cohen, 1995).

[20] In one of the robustness tests in the Online Appendix, we show that our results are insensitive to the inclusion of the liberalized sample and the non-liberalized sample.

[21] We start our sample from 1981 because we are able to identify a firm's listing status from Orbis only since 1980 and use one year lagged industry innovation intensity in the regression analysis. We end our sample in 2008 because the UNIDO data are incomplete after 2008. On average, a two- to three-year lag exists between the patent application date and the patent grant date according to Hall et al. (2001). Because our sample period ends in 2008, the impact of this lag on our study is minimal.

expected to be cited more frequently by other patents subsequent to it, a patent's forward citations reflect the quality of an invention and thus better capture the technological or economic significance of the firm's inventions (Hall et al., 2005). This is particularly true for patents created by emerging economies because the technological development in these countries is relatively slow and their patents are less likely to be cited. An increase in the number of patent citations in emerging markets indicates that their technology level has reached a certain threshold, a trend widely acknowledged by the scientific community. Hence, our second innovation measure is the number of citations received by all firms' patents in each two-digit SIC industry for each country in each year. One potential concern for this variable, as pointed out by Hall et al. (2005), is that patents in certain technology classes and years tend to receive more citations. To address this issue, we adjust raw citations using time–technology class fixed effects as recommended by prior literature, e.g., Atanassov (2013) and Hirshleifer et al. (2012). The citation counts, adjusted for time–technology class fixed effects, are defined as raw citation counts scaled by the average citations in the same year and in the same technology class (*Tcite*).[22]

Our third measure of innovation is the number of innovative firms, as suggested by Acharya and Subramanian (2009), which is defined as the number of public firms that have successful patent applications in each two-digit SIC industry for each country and year (*Nfirm*).

Although the above measures are widely accepted and used in the innovation literature to capture firms' technological advances and innovation output (Acharya and Subramanian, 2009; Acharya et al., 2013; Hsu et al., 2014), we fully acknowledge the limitations of using these measures as the proxy for innovation. For example, firms do not always patent all their innovations either because some innovations do not satisfy patentability criteria or because firms tend to keep the details of their technology secret for strategic reasons.

2.3. Control variables

We control for several industry and country characteristics that could be correlated with stock market liberalization and innovation. First, to account for comparative advantages (Acharya and Subramanian, 2009) and heterogeneous developments of different industries in a country (Hsu et al., 2014), we include the share of value added in a two-digit SIC industry to the total value added for each country each year (*VA*) as a control. Second, we consider a country's macroeconomic conditions. We include the logarithm of real gross domestic product per capita (*GDP*) and the standard deviation of annual GDP per capita growth in the past five years (*VGDP*) as proxies for the level of economic development and macroeconomic risk, respectively. Previous literature shows that wealthier countries could innovate more (Acharya and Subramanian, 2009; Acharya et al., 2013) and more macroeconomic uncertainty can be beneficial for long-run innovation as uncertainty increases the upside from innovative new products (Bloom, 2014).

Third, we control for the logarithm of human capital index (*HumCap*) from PWT 8.0, because Benhabib and Spiegel (2005) show that human capital plays a positive role as an engine for innovation by providing essential intellectual support. Fourth, free trade can encourage firms to patent their innovations to protect domestic sales and secure foreign sales (Acharya and Subramanian, 2009), while government spending crowds out innovative investment in the private sector (Dissanayake et al., 2018). In addition, as a result of domestic macro reforms, the liberalization of stock markets in a country could be coupled with its trade openness and the contraction of government intervention (Bekaert et al., 2005; Bumann et al., 2013). We thus include the share of imports and exports in a country's GDP (*Trade*) and the share of government consumption in a country's GDP (*Gov*) to capture the country's trade openness and government size, respectively.

Fifth, we control for the time trend of industry-level patenting activities, as Hall et al. (2001) show that the patenting propensity in different industries varies over time.[23] Following Acharya and Subramanian (2009), we include the logarithm of one plus the average number of patents applied by US firms in each two-digit SIC industry and year as a proxy for the industrial patenting propensity (*Intensity*).[24] We choose the US as the benchmark to adjust for the time trend, because the US has the fullest patent data across different technology classes over time, the most developed financial market for funding technological development, and the most favorable research environment in the world. Moreover, Cohen et al. (2000) point out that the propensity for patenting in an industry in the US reflects the technological characteristics of the industry. Apart from the above reasons, our measure of innovation intensity exhibits time series variation, indicating that industry technological innovation evolves over time (Hall et al., 2001). This is consistent with Kortum and Lerner (1999), that the development of industry technological innovation is mainly due to industry technological shocks. All these arguments make US firms' patents a natural choice as a proxy for the global industrial patenting propensity.

We are aware of the possibility that industry-level innovation intensity in the US can be a noisy proxy for global industry innovativeness. For example, the industry innovation intensity could capture global industry growth opportunities instead of the inherent technological industry difference, as shown in Fisman and Love (2007), or reflect the allocation of industries for a modern supply chain. Al-

[22] In the Orbis database, technological classes are defined using the International Patent Classification (IPC) system, and we adjust the raw citation counts using the one-digit IPC code.

[23] See Hall et al. (2001) and Cohen et al. (2000) for a detailed discussion of this pattern.

[24] Using the median number of patents applied by US firms in each two-digit SIC industry each year as the measure of innovation intensity does not change our results. Moreover, in an untabulated test, we follow Acharya and Subramanian (2009) and create the industry innovation intensity using Japanese firms' patents and exclude Japan from the analysis. The results show that our main findings remain intact.

though we follow previous literature (e.g., Bekaert et al., 2005; Acharya and Subramanian, 2009) to control for global industry growth opportunities and comparative advantages, we cannot completely purge the noise in this measure, especially given the complexity of the modern global supply chain.[25] We suggest interpreting these results in light of these considerations.

2.4. Descriptive statistics

Table 1, Panel A, presents the sample distribution by country. Our sample covers 20 countries with a mixture of both developed and developing economies.[26] Columns 1 and 2 of Panel A report the official liberalization year and the number of observations for each country. Columns 3–5 report the aggregate innovation measures, i.e., patent counts, citation counts, and the number of innovative firms across industries in each country.

In our sample, Japan has the largest number of patents (521,571), the largest number of citations (1,060,234), and the largest number of innovative firm-years (16,286), and Indonesia has the lowest number of patents (five), Malaysia has the lowest number of citations (two), and Chile has the lowest number of innovative firms (two). The large cross-country variation in innovation performance reflects not only different phases of technological development but also other related factors, such as the capacity of the market (i.e., the number of public firms in each country), the protection of intellectual property, and firms' incentives to keep their innovation secret.[27]

Although the general trends of the three innovation output measures are similar, some cross-country differences emerge. For example, although the number of patents in Turkey (966) is twice as many as that in Spain (417), the number of citations in Spain (1,541) is similar in magnitude to that in Turkey (1,936). These results indicate that patents created by Spanish firms have a larger impact in terms of citations than those by Turkish firms, highlighting the importance of using different innovation measures to capture innovation output.

Panel B of Table 1 shows the sample distribution of innovation output average values, the share of industry value added, and the innovation intensity across 20 industries over all country-years. Columns 2 to 4 indicate that patents, patent citations, and the number of innovative firms vary significantly across different industries. The industry of electronic and other electrical equipment and components, except computer equipment (SIC 36), has the largest number of patent counts, citation counts, and innovative firms. The leather and leather products industry (SIC 31) has the lowest number of patents, citations, and innovative firms.[28]

As observed in Column 5, industries that contribute the largest portions of industry value added are food and kindred products (SIC 20) and chemicals and allied products (SIC 28), which account for approximately 16% and 11% of the total industry value added, respectively, in an average country. Industries that contribute the smallest portions are measuring, analyzing, and controlling instruments; photographic, medical, and optical goods; watches and clocks (SIC 38); and non-furniture lumber and wood products (SIC 24), which account for only 1% and 2% of the total industry value added, respectively. Column 6 shows that, despite some slight differences, innovation intensity defined using the US data follows a similar pattern as that of innovation output.

In Table 2, we report the descriptive statistics of the sample. The means of *Pat*, *Tcite*, and *Nfirm* are 81.5, 155.4, and 2.6, respectively, and these variables have sizable standard deviations. Given that innovation measures are highly skewed, we use the logarithm of one plus these variables [i.e., *Ln*(1+*Pat*), *Ln*(1+*Tcite*), and *Ln*(1+*Nfirm*)] in the regression analyses. For country-level variables, the means of *GDP*, *VGDP*, *HumCap*, *Trade*, and *Gov* are 3.18, 0.03, 0.90, 0.42, and 0.16, respectively. With respect to industry-level variables, the means of *VA* and *Intensity* are 5.02% and 2.53, respectively.

3. Main findings

3.1. Univariate analysis

To investigate the relation between stock market liberalization and innovation, we start with a univariate analysis by examining the average changes in innovation output around liberalization for all sample industries and comparing the differences in changes between more innovative and less innovative industries, which are classified according to the median industry innovation intensity in each year. We define the liberalization year as event year 0 and compute the average changes in *Ln*(1+*Pat*), *Ln*(1+*Tcite*), and *Ln*(1+*Nfirm*) from two years before liberalization (i.e., event year −2) to one year before liberalization (i.e., event year −1) and from two years before liberalization to t years (t = 1, 3, and 5) after liberalization.[29]

[25] To mitigate the concern that our measure of industry innovation intensity captures global industry growth opportunities, we include the global industry price-to-earnings (PE) ratio from Datastream (Bekaert et al., 2007) and its interactions with *Lib* and other control variables in the regressions, similar to Fisman and Love (2007). Untabulated results show that the coefficient estimates of *Lib*×*Intensity* are still positive and significant after the inclusion of the global industry PE ratio and the associated interactions. Moreover, in our baseline model, we include the ratio of the value added in each industry over the total value added in a country as a proxy for the comparative advantage of the country, which, to a large extent, alleviates the concern that our results capture only the effect of industry allocation across countries.

[26] Panel A of Table 1 also shows that stock market liberalization occurred across geographically diverse countries in our sample over the sample period, which is another noticeable feature of the liberalizing group.

[27] Firms face a trade-off between patenting their innovation and keeping it secret. While patenting innovation can protect innovators' intellectual property, the information disclosure through patenting could enable competitors to obtain certain technological knowledge (Saidi and Zaldokas, 2019).

[28] The tobacco products industry (SIC 21) has the second lowest number of 0.07 innovative firms on average.

[29] In an untabulated analysis, we exclude Japan to mitigate the concern that Japan has the largest numbers of industry patents, industry patent citations, and industry innovative firms in our sample, which could bias the statistical comparisons of the average values of changes in innovation output. We find that our results do not alter.

Table 1
Sample distribution.
The sample contains public firms of manufacturing industries in countries and economies experiencing stock market liberalization, which are jointly covered by Bureau van Dijk's Orbis patent database, United Nations Industrial Development Organization (UNIDO) Industrial Statistics database, and Penn World Table (PWT) version 8.0 database from 1981 to 2008. In Panel A, stock market liberalization years are from Bekaert et al. (2005). *N* denotes the number of industry-year observations. *Pat, Tcite*, and *Nfirm* are the total number of patents, the total number of citations adjusted for time–technology class fixed effects, and the total number of innovative firms in a country across all industries and years, respectively. In Panel B, *N* denotes the number of country-year observations. *Pat, Tcite*, and *Nfirm* are the average number of patents, the average number of citations adjusted for time–technology class fixed effects, and the average number of innovative firms in an industry, respectively. *VA* is the average ratio of the value added in a two-digit Standard Industrial Classification (SIC) industry over the total value added for each country each year. *Intensity* is the average number of patents held by a US firm in a two-digit SIC industry in each year.

Panel A: Sample distribution by country and economy

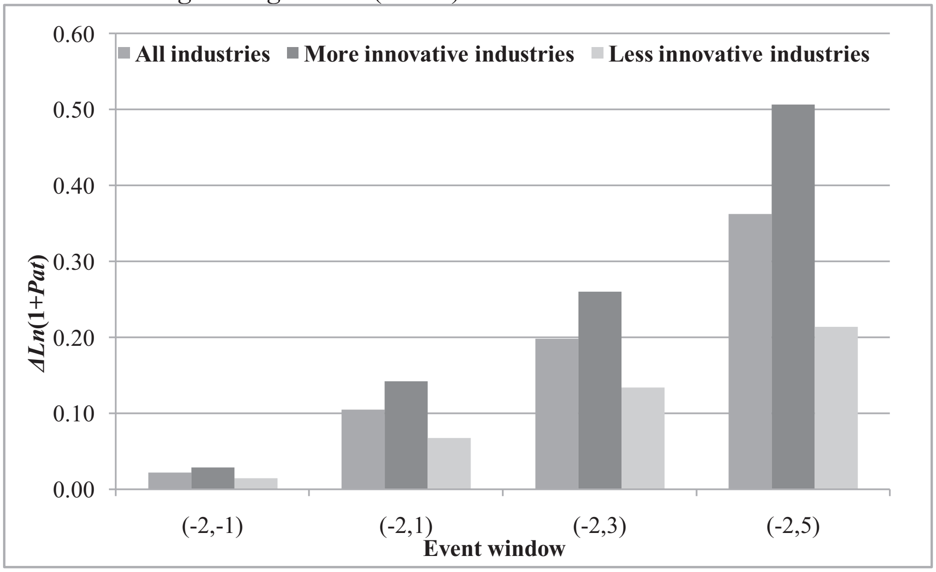
Country and economy	Liberalization year (1)	*N* (2)	*Pat* (3)	*Tcite* (4)	*Nfirm* (5)
Argentina	1989	380	7	7	3
Brazil	1991	348	60	158	22
Chile	1992	387	7	12	2
Greece	1987	400	26	87	15
India	1992	560	2,325	4,113	373
Indonesia	1989	360	5	3	4
Israel	1993	546	1,315	2,393	185
Japan	1983	555	521,571	1,060,234	16,286
South Korea	1992	558	132,616	199,936	3,157
Malaysia	1988	560	12	2	11
Mexico	1989	480	29	41	14
New Zealand	1987	396	112	309	39
Philippines	1991	557	11	7	7
Portugal	1986	400	30	90	17
Saudi Arabia	1999	280	214	535	8
South Africa	1996	544	156	331	26
Spain	1985	560	417	1,541	166
Taiwan, China	1991	400	79,571	137,517	3,220
Thailand	1987	400	31	78	13
Turkey	1989	400	966	1,936	98

Panel B: Sample distribution by industry

SIC	SIC description	*N* (1)	*Pat* (2)	*Tcite* (3)	*Nfirm* (4)	*VA* (5)	*Intensity* (6)
20	Food and kindred products	459	16.32	29.28	2.45	0.16	2.22
21	Tobacco products	389	3.21	5.17	0.07	0.02	0.18
22	Textile mill products	459	7.26	14.75	0.94	0.05	1.99
23	Apparel and other finished products made from fabrics and similar materials	459	1.53	4.31	0.31	0.03	1.68
24	Lumber and wood products, except furniture	459	1.19	2.33	0.25	0.02	2.47
25	Furniture and fixtures	453	0.85	1.67	0.25	0.02	1.79
26	Paper and allied products	459	9.91	21.23	0.82	0.03	2.85
27	Printing, publishing, and allied industries	459	7.81	13.97	0.36	0.03	1.35
28	Chemicals and allied products	458	240.25	405.72	9.78	0.11	3.89
29	Petroleum refining and related industries	459	2.16	4.81	0.37	0.06	3.17
30	Rubber and miscellaneous plastics products	459	32.67	85.16	1.79	0.04	2.95
31	Leather and leather products	459	0.26	0.06	0.07	0.03	1.26
32	Stone, clay, glass, and concrete products	459	27.88	62.01	1.54	0.05	3.83
33	Primary metal industries	459	72.30	113.19	2.90	0.07	2.47
34	Fabricated metal products, except machinery and transportation equipment	458	11.53	21.77	1.49	0.05	2.16
35	Industrial and commercial machinery and computer equipment	458	311.64	584.71	9.14	0.05	3.67
36	Electronic and other electrical equipment and components, except computer equipment	459	543.19	994.24	11.65	0.07	3.77
37	Transportation equipment	459	187.00	393.21	4.03	0.05	3.57
38	Measuring, analyzing, and controlling instruments; photographic, medical, and optical goods; watches and clocks	435	126.69	293.38	2.61	0.01	2.94
39	Miscellaneous manufacturing industries	453	15.98	38.31	0.94	0.02	2.06

Panel A of Fig. 1 plots average changes in the number of patents [$\Delta Ln(1+Pat)$] for the event windows (−2, −1), (−2, 1), (−2, 3), and (−2, 5). The average change in the number of patents from event year −2 to −1 is not significantly different from zero (p-value = 0.25) for all sample industries, and the difference in changes between more innovative and less innovative industries is also insignificant (p-value = 0.36). When we expand the event window to (−2, 1), our sample industries start to exhibit an increase in the number of patents, which is significantly

Panel A: Average changes in Ln(1+Pat) around liberalization



Panel B: Average changes in Ln(1+Tcite) around liberalization

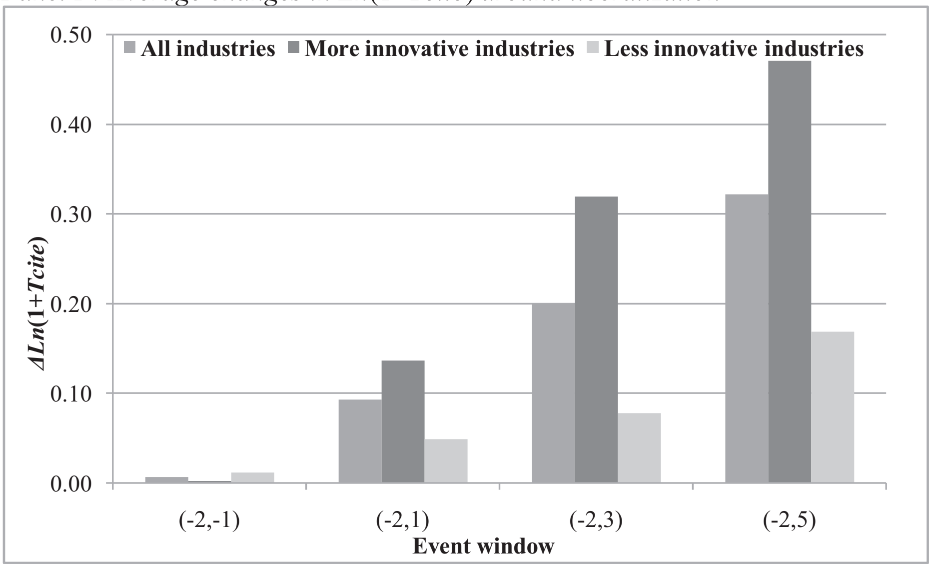


Fig. 1. Average changes in innovation output around liberalization. The sample contains public firms of manufacturing industries in countries experiencing stock market liberalization, which are jointly covered by Bureau van Dijk's Orbis patent database, United Nations Industrial Development Organization (UNIDO) Industrial Statistics database, and Penn World Table (PWT) version 8.0 database from 1981 to 2008. *Pat, Tcite*, and *Nfirm* are the total number of patents, the total number of citations adjusted for time–technology class fixed effects, and the total number of innovative firms in an industry for each country each year, respectively. More (less) innovative industries are defined as industries of which the industry innovation intensity is above (below) the sample median. The changes in $Ln(1+Pat)$, $Ln(1+Tcite)$, and $Ln(1+Nfirm)$ are computed from two years before liberalization (i.e., year -2) to one year before liberalization (i.e., year -1) and to t years (t = 1, 3, and 5) after liberalization.

different from zero (p-value < 0.01). The difference in the change in the number of patents between more innovative and less innovative industries is marginally significant (p-value = 0.10), although more innovative industries experience a slightly higher increase in the number of patents. Further extending the event window to (-2, 3) and (-2, 5), we find even larger increases in the number of patents, which are significantly different from zero at the 1% level (p-value < 0.01), and the increase is particularly large in more innovative industries relative to less innovative industries (p-values = 0.07 and 0.01, respectively).

Panels B and C of Fig. 1 plot average changes in the number of patent citations [$\Delta Ln(1+Tcite)$] and the number of innovative firms [$\Delta Ln(1+Nfirm)$], respectively. Similar to the pattern of the number of patents, our sample industries, on average, experience a significant increase in the number of patent citations [p-values = 0.02, $<$ 0.01, and $<$ 0.01 for event windows (-2, 1), (-2, 3) and (-2, 5), respec-

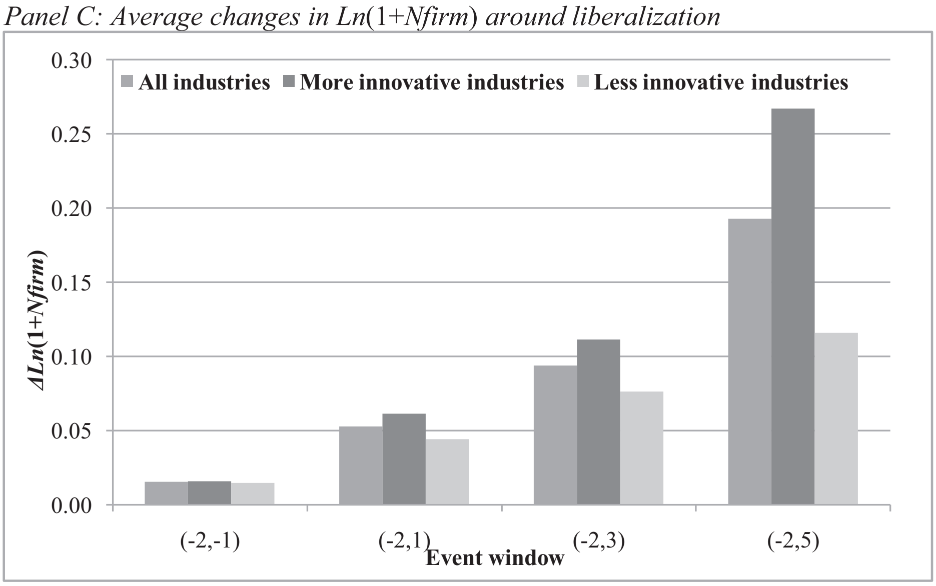


Fig. 1. Continued

Table 2
Summary statistics.

The sample contains public firms of manufacturing industries in countries experiencing stock market liberalization, which are jointly covered by Bureau van Dijk's Orbis patent database, United Nations Industrial Development Organization (UNIDO) Industrial Statistics database, and Penn World Table (PWT) version 8.0 database from 1981 to 2008. *Pat, Tcite*, and *Nfirm* are the total number of patents, the total number of citations adjusted for time–technology class fixed effects, and the total number of innovative firms in an industry for each country each year, respectively. *VA* is the percentage of the value added in a two-digit Standard Industrial Classification (SIC) industry over the total value added for each country each year, measured in year *t*-1. *GDP* is the logarithm of gross domestic product (GDP) per capita for each country each year. *VGDP* is the sample standard deviation of the annual GDP per capita growth estimated using a five-year moving window for each country each year, measured in year *t*. *HumCap* is the logarithm of human capital index from PWT 8.0, measured in year *t*-1. *Trade* is a country's exports and imports as a fraction of GDP, measured in year *t*-1. *Gov* is a country's government spending as a fraction of GDP, measured in year *t*-1. *Intensity* is the logarithm of one plus the average number of patents held by a US firm in a two-digit SIC industry each year. Variables in dollars are computed in real terms at constant national prices in 2005 US dollars.

Variable	Mean (1)	Standard deviation (2)	Minimum (3)	Q1 (4)	Median (5)	Q3 (6)	Maximum (7)
Pat	81.52	505.46	0.00	0.00	0.00	0.00	4,428.00
Ln(1+*Pat*)	0.61	1.65	0.00	0.00	0.00	0.00	8.40
Tcite	155.37	952.96	0.00	0.00	0.00	0.00	8,081.36
Ln(1+*Tcite*)	0.62	1.81	0.00	0.00	0.00	0.00	9.00
Nfirm	2.61	13.52	0.00	0.00	0.00	0.00	230.00
Ln(1+*Nfirm*)	0.32	0.86	0.00	0.00	0.00	0.00	4.71
VA	5.02%	4.55%	0.13%	2.10%	3.72%	6.42%	27.19%
GDP	3.18	0.80	1.08	2.73	3.32	3.83	4.37
VGDP	0.03	0.02	0.00	0.01	0.02	0.03	0.10
HumCap	0.90	0.19	0.31	0.77	0.94	1.05	1.25
Trade	0.42	0.26	0.06	0.24	0.37	0.55	1.47
Gov	0.16	0.06	0.06	0.12	0.15	0.18	0.38
Intensity	2.53	1.12	0.00	1.79	2.51	3.36	5.09

tively] and in the number of innovative firms [p-values < 0.01 for event windows $(-2, 1)$, $(-2, 3)$ and $(-2, 5)$, respectively] after liberalization. Moreover, the differences in the changes in the number of patent citations and the number of innovative firms between more innovative and less innovative industries for the event windows $(-2, 3)$ and $(-2, 5)$ are statistically significant (p-values $= 0.01$ and 0.01 for the number of patent citations and p-values $= 0.17$ and < 0.01 for the number of innovative firms, respectively).

Overall, the patterns in Fig. 1 suggest that our sample industries are likely to exhibit an increase in innovation output post-liberalization and that this effect is disproportionately stronger for firms in more innovative industries than for those in less innovative industries. Given an insignificant change in innovation output and an insignificant difference between firms in more innovative and less innovative industries before liberalization, the univariate results are consistent with our conjecture that stock market liberalization promotes innovation, which is particularly the case in more innovative industries.

3.2. The effect of stock market liberalization on innovation

We first examine the general effect of stock market liberalization on firms' innovation output in a country by estimating the regression model in Eq. (1):

$$Innovation_{i,j,t} = \alpha + \beta Lib_{i,t-3} + \gamma' X_{i,j,t-1} + Industry_j \times Country_i + Year_t + \varepsilon_{i,j,t}, \quad (1)$$

where *Innovation* represents the three innovation output measures, i.e., *Ln*(1+*Pat*), *Ln*(1+*Tcite*), or *Ln*(1+*Nfirm*), in industry *j* for country *i* in year *t*. *Lib*, our key explanatory variable, is defined as a binary variable that equals one if the observation is in the year after country *i*'s official liberalization and zero otherwise, measured in year *t*-3.[30] *X* represents the share of value added (*VA*) in industry *j* for country *i* in year *t*-1, GDP per capita (*GDP*), the standard deviation of annual GDP growth (*VGDP*), the logarithm of human capital index (*HumCap*), the share of exports and imports in GDP (*Trade*), the share of government consumption in GDP (*Gov*) in country *i* and year *t*-1, and the industrial patenting propensity (*Intensity*) in industry *j* and year *t*-1. We also control for time-invariant industry characteristics in each country and business cycle by including country-industry fixed effects and year fixed effects. We cluster standard errors by country-industry. Our key variable of interest is *Lib*, and its coefficient estimate, β, captures the general effect of stock market liberalization on innovation.

We present the results estimating Eq. (1) in Table 3. The results show that the coefficient estimates of *Lib* are positive and significant in all three columns, suggesting that firms' innovation output in a country increases after the country liberalizes its stock market. This positive effect is not only statistically significant but also economically sizable. For example, in countries that experience stock market liberalization during our sample period, patent counts, citation counts, and the number of innovative firms, on average, experience an increase of 13%, 16%, and 11%, respectively, after they liberalize their stock markets.

The coefficient estimates of control variables have signs that are generally consistent with previous evidence. For example, *GDP* has a significant and positive effect on innovation at the 1% level in all regressions. *Trade* has a significant and negative effect on innovation, which can be driven by imports because most of our sample countries are less technologically developed. Thus, the results could indicate that a country is more likely to rely on foreign products if its technologies are not sufficiently innovative.

[30] For stock market liberalization to have an impact on innovation output in a country, a series of events need to happen: (1) the country deregulates its stock market, (2) capital flows into the country, (3) firms issue new equity, (4) firms undertake new innovative activities, (5) firms create something new, and (6) firms apply for patents. The time length is undoubtedly long. We hence assume that the stock market liberalization takes effect from three years after the official announcement year. In an untabulated robustness check, we conduct the analysis by assuming that stock market liberalization takes effect from one to five years after the liberalization year and find that the coefficients are still highly significant.

Table 3
The effect of stock market liberalization on innovation.
The sample contains public firms of manufacturing industries in countries experiencing stock market liberalization, which are jointly covered by Bureau van Dijk's Orbis patent database, United Nations Industrial Development Organization (UNIDO) Industrial Statistics database, and Penn World Table (PWT) version 8.0 database from 1981 to 2008. *Pat, Tcite*, and *Nfirm* are the total number of patents, the total number of citations adjusted for time–technology class fixed effects, and the total number of innovative firms in each two-digit Standard Industrial Classification (SIC) industry for each country each year, respectively, which are measured in year *t*. *Lib* is a binary variable that takes the value of one if the observation is in the year since a country's official liberalization and zero otherwise, measured in year *t*-3. *VA* is the ratio of the value added in a two-digit SIC industry over the total value added for each country each year, measured in year *t*-1. *GDP* is the logarithm of gross domestic product (GDP) per capita for each country each year, measured in year *t*-1. *VGDP* is the sample standard deviation of the annual GDP per capita growth estimated using a five-year moving window for each country each year, measured in year *t*. *HumCap* is the logarithm of human capital index from PWT 8.0, measured in year *t*-1. *Trade* is a country's exports and imports as a fraction of GDP, measured in year *t*-1. *Gov* is a country's government spending as a fraction of GDP, measured in year *t*-1. *Intensity* is the logarithm of one plus the average number of patents held by a US firm in a two-digit SIC industry each year, measured in year *t*-1. Variables in dollars are computed in real terms at constant national prices in 2005 US dollars. Robust standard errors in parentheses are clustered by country-industry. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Variable	*Ln*(1+*Pat*) (1)	*Ln*(1+*Tcite*) (2)	*Ln*(1+*Nfirm*) (3)
Lib	0.125***	0.156***	0.076***
	(0.05)	(0.05)	(0.02)
VA	2.484*	2.847*	1.409*
	(1.33)	(1.47)	(0.72)
GDP	1.421***	1.425***	0.827***
	(0.18)	(0.20)	(0.10)
VGDP	1.261*	0.172	0.802**
	(0.74)	(0.76)	(0.36)
HumCap	0.609	0.923	0.399
	(0.54)	(0.59)	(0.27)
Trade	−1.515***	−1.387***	−0.841***
	(0.22)	(0.25)	(0.13)
Gov	−0.145	−0.774	0.073
	(0.44)	(0.51)	(0.21)
Intensity	−0.011	0.002	−0.009
	(0.02)	(0.02)	(0.01)
Year fixed effects	Yes	Yes	Yes
Country-industry fixed effects	Yes	Yes	Yes
Number of observations	9,071	9,071	9,071
R-squared	0.23	0.15	0.27

Taken together, the findings in Table 3 suggest that stock market liberalization has a positive effect on firms' innovation output in a country.

3.3. The effect of stock market liberalization on innovation across industries

Following Acharya and Subramanian (2009), we examine how stock market liberalization affects innovation output differently across industries with different degrees of innovativeness by undertaking a difference-in-differences approach as in Eq. (2):

$$Innovation_{i,j,t} = \alpha + \beta Lib_{i,t-3} \times Intensity_{j,t-1} + \theta Lib_{i,t-3} + \gamma' X_{i,j,t-1} + Industry_j \times Country_i + Year_t + \varepsilon_{i,j,t}, \quad (2)$$

Table 4
The effect of stock market liberalization on innovation across different industries.
The sample contains public firms of manufacturing industries in countries experiencing stock market liberalization, which are jointly covered by Bureau van Dijk's Orbis patent database, United Nations Industrial Development Organization (UNIDO) Industrial Statistics database, and Penn World Table (PWT) version 8.0 database from 1981 to 2008. *Pat, Tcite*, and *Nfirm* are the total number of patents, the total number of citations adjusted for time–technology class fixed effects, and the total number of innovative firms in each industry for each country each year, respectively, which are measured in year *t*. *Lib* is a binary variable that takes the value of one if the observation is in the year since a country's official liberalization and zero otherwise, measured in year *t*-3. The definitions of other variables are in Table 3. Robust standard errors in parentheses are clustered by country-industry. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Variable	*Ln*(1+*Pat*) (1)	*Ln*(1+*Tcite*) (2)	*Ln*(1+*Nfirm*) (3)	*Ln*(1+*Pat*) (4)	*Ln*(1+*Tcite*) (5)	*Ln*(1+*Nfirm*) (6)
Lib × *Intensity*	0.150***	0.161***	0.087***	0.118***	0.135***	0.070***
	(0.03)	(0.04)	(0.02)	(0.03)	(0.03)	(0.02)
Lib	−0.249***	−0.247***	−0.141***	−0.171**	−0.179**	−0.098**
	(0.08)	(0.09)	(0.04)	(0.08)	(0.09)	(0.04)
VA	2.124*	2.459*	1.199*	0.803	−0.190	0.139
	(1.25)	(1.37)	(0.67)	(1.44)	(1.61)	(0.78)
GDP	1.429***	1.433***	0.832***	1.264***	1.246***	0.708***
	(0.18)	(0.20)	(0.10)	(0.16)	(0.17)	(0.09)
VGDP	1.247*	0.157	0.794**	2.953**	1.476	1.417**
	(0.73)	(0.75)	(0.36)	(1.39)	(1.30)	(0.70)
HumCap	0.634	0.950*	0.413	0.383	0.879	0.273
	(0.52)	(0.57)	(0.26)	(0.51)	(0.54)	(0.26)
Trade	−1.506***	−1.377***	−0.836***	−1.309***	−1.212***	−0.715***
	(0.22)	(0.24)	(0.12)	(0.30)	(0.30)	(0.15)
Gov	−0.113	−0.739	0.092	0.855	0.380	0.218
	(0.43)	(0.50)	(0.21)	(0.78)	(0.83)	(0.29)
Intensity	−0.093***	−0.086***	−0.056***	−0.295*	−0.277	−0.243***
	(0.03)	(0.03)	(0.01)	(0.17)	(0.18)	(0.09)
VA × *Intensity*				0.450	0.932	0.381
				(0.64)	(0.70)	(0.35)
GDP × *Intensity*				0.065*	0.071*	0.048**
				(0.03)	(0.04)	(0.02)
VGDP × *Intensity*				−0.714	−0.549	−0.272
				(0.61)	(0.59)	(0.31)
HumCap × *Intensity*				0.121	0.057	0.070
				(0.13)	(0.13)	(0.06)
Trade × *Intensity*				−0.081	−0.070	−0.050
				(0.09)	(0.09)	(0.05)
Gov × *Intensity*				−0.396	−0.447	−0.058
				(0.34)	(0.39)	(0.12)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country-industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	9,071	9,071	9,071	9,071	9,071	9,071
R-squared	0.24	0.16	0.29	0.25	0.17	0.30

where we include the interaction term of the stock market liberalization indicator and industry innovation intensity (*Lib* × *Intensity*). All other variables are defined as in Eq. (1). Our key variable of interest is the coefficient estimate of *Lib* × *Intensity*, β, which captures the change in innovation output before and after liberalization between more innovative and less innovative industries. If the liberalization effect is more pronounced for more innovative industries, we expect β to be positive and significant.

We present the results from estimating Eq. (2) in Columns 1–3 of Table 4. In Columns 4–6, we present our baseline results by further including interaction terms of control variables and industry innovation intensity to account for potential correlations between industry and country characteristics and stock market liberalization across industries with different levels of industrial patenting propensity, as pointed out by Acharya and Subramanian (2009). The coefficient estimates of *Lib* × *Intensity* remain positive and significant at the 1% level in all regressions. This finding suggests that, compared with that of less innovative industries, the innovation output of more innovative industries increases more substantially after the country opens its stock market to foreign investors. Our results are economically sizable. In Columns 1–3, an increase in *Intensity* from the 25th percentile (1.79) to the 75th percentile (3.36) is associated with an increase in the number of patents, the number of citations, and the number of innovative firms from their mean values by 24%, 25%, and 19%, respectively, after stock market liberalization.[31] These results indicate that the more innovative industries drive the results, suggesting that stock market liberalization pro-

[31] For example, because $d[Ln(1+Pat)]/d[Intensity] = 0.150\times Lib\text{–}0.093$ in Column 1 of Table 4, $dPat = (0.150\times Lib\text{–}0.093)\times(1+Pat)\times d[Intensity]$. When quantifying the effect of the change in *Lib* on the difference in the change of *Pat* between more innovative and less innovative industries ($\Delta dPat$), we increase *Lib* from zero to one. So, $\Delta dPat/Pat = 0.150\times(1+Pat)\times d[Intensity]/Pat$. Hence, the difference in the increase of the number of patents from its mean value (81.52) after liberalization between more innovative industries with *Intensity* at the 75th percentile (3.36) and less innovative industries with *Intensity* at the 25th percentile (1.79) is equal to $0.150\times(1 + 81.52)\times(3.36\text{-}1.79)/81.52 = 24\%$.

motes innovation by enhancing it in more innovative industries.

3.4. Robustness checks

We conduct an array of additional tests to check the robustness of our baseline results. For brevity, we report the results of the following seven sets of robustness checks in Tables OA1 to OA9 of the Online Appendix. All regressions include interaction terms of control variables and industrial patenting intensity.

First, dating stock market liberalization is challenging because multiple factors can cloud the importance of official liberalization.[32] Several studies (e.g., Bekaert et al., 2002, 2003) thus estimate de facto liberalization dates using US equity portfolio holdings. De facto liberalization dates are identified as structural breaks in foreign ownership when foreign presence significantly increases. We extract these dates from Bekaert et al. (2003), replace our official liberalization dates used in the main analysis with these dates, and reestimate the regressions.[33] Apart from using the de facto liberalization dates, we conduct additional robustness tests using several alternative de jure liberalization dates as in Bekaert et al. (2005), such as the first American Depositary Receipt (ADR) dates, the first country fund dates, and the first sign dates defined as the year associated with the earliest of the three dates: official liberalization, first ADR announcement, and first country fund launch. Our results remain robust to alternative identification of liberalization dates.

Second, we test the robustness of our main results to several additional sampling criteria. Given that Japan has the largest number of patents, patent citations, and innovative firms among all the countries in our sample, our inferences from the main analysis plausibly are driven by Japan. We thus exclude Japan from the sample. Moreover, because firms cross-listed on foreign stock exchanges can be affected by both the liberalization of domestic stock markets and the conditions of foreign stock markets, we exclude firms cross-listed in the US, the largest capital market in the world, to mitigate the impact of cross-listing. Finally, as industrial patenting activities increase over time in response to strengthened patent rights and national policies that encourage patenting activities (Lerner and Seru, 2017), our results could merely reflect such an upward time trend in certain countries. We hence include both the liberalized sample and the non-liberalized sample to control for the trend.[34] The results show that imposing the above sample criteria does not alter our main findings.

Third, following Hsu et al. (2014), we conduct an analysis at the technology-class level. We aggregate all variables at the three-digit International Patent Classification (IPC) class and reestimate the baseline regressions. Our results do not change qualitatively.

Fourth, to further mitigate the concern regarding the presence of residual correlation in both country and year dimensions, we employ a two-way clustering of standard errors at both country-industry and year, following the suggestion of Petersen (2009). Our baseline results are robust to the two-way clustering.

Fifth, similar to Acharya and Subramanian (2009), we replace dependent variables with the number of patents and the number of patent citations of an average (median) firm as proxies for the innovation output of a typical firm in an industry. The results remain intact.[35]

Sixth, to further capture the long-term nature of the innovation process (Manso, 2011), we construct the liberalization indicator in year *t*-5 (*Lib_lag5*) instead of year *t*-3 in the baseline model. Hence, we are estimating the effect of stock market liberalization on a country's five-year-ahead innovation output. The results are robust to this model specification that takes into account the delayed effect of stock market liberalization on innovation output.

Seventh, we design three tests to further mitigate the concern that the frequent observations of zero in the dependent variables could drive our results. First, we follow Acharya and Subramanian (2009) and remove countries with the total number of patents of fewer than one hundred. Second, we follow Levine et al. (2017) and remove industries with no patent at all during the entire sample period. Third, we focus on industries in the US with the number of patents granted above the sample median.[36] We reestimate the baseline regressions based on the three sample filtering criteria and find our main findings are unaffected.

3.5. Further tests on identification

To ensure that the effect of stock market liberalization is causal, we conduct three additional tests.

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[32] In addition to the simultaneity of macroeconomic, political, and financial reforms, which can confound the examination of the effect of liberalization, factors such as nonbinding investment restrictions prior to the reform and the gradual implementation of regulatory changes that permit foreign investment also make the dating of liberalization difficult (Bekaert et al., 2003; Bumann et al., 2013).

[33] The de facto liberalization dates in Bekaert et al. (2003) are estimated based on the method in Bekaert et al. (2002). Compared with the dates in Bekaert et al. (2002), those in Bekaert et al. (2003) are more appropriate for our setting because the shifts are particularly related to foreign portfolio investment, not equity market integration in general.

[34] An alternative approach to alleviate the concern that our results are driven by an improvement in patent rights, which can be correlated with stock market liberalization, is to examine how the innovation effect of liberalization varies depending on the intellectual property protection of a country. In an untabulated test, we find that the liberalization-innovation effect does not change according to a country's intellectual property protection index compiled by Park (2008), suggesting that improving patent rights is unlikely to be an explanation to our findings.

[35] To further mitigate the concern that our findings can be driven by factors affecting firms' patenting incentives, we compare the differential effects of liberalization on two additional measures of patents' scientific value between more innovative and less innovative industries in a supplementary test (untabulated). We follow previous literature (e.g., Chava et al., 2013; Chang et al., 2018) and use the number of average citations per patent and the number of citation-weighted patents to proxy for the scientific importance of innovation. We find a significant increase in the number of citations per patent and the number of citation-weighted patents in more innovative industries of a country after the country liberalizes its stock market.

[36] We follow Levine et al. (2017) and calculate the time series average of the total number of patents granted in each industry in the US. We then rank the observations in our sample according to this measure and keep industries that rank above the median.

3.5.1. Controlling for potential omitted variables

We first directly include a few variables omitted from the baseline regressions. Financial market development can be related to both stock market liberalization and innovation. Hsu et al. (2014) show that equity (credit) market development is positively (negatively) associated with innovation in industries that are more dependent on external finance. Given the possibility that stock market liberalization coincides with local financial market development, we include the ratio of total market capitalization of all public firms in a country to its GDP (*Equity*) as a proxy for equity market development and the ratio of domestic credit provided by the banking sector over GDP (*Credit*) as a proxy for credit market development in the regressions.

The second variable relates to foreign direct investment (FDI). Previous literature shows that, through inflows of FDI, foreign acquirers encourage local firms to innovate by facilitating technology transfer to local markets (Guadalupe et al., 2012) and allowing these firms to hire and use high-quality employees (Javorcik, 2015) who are essential to innovative firms. If stock market liberalization, which attracts equity inflows, is correlated with a country's pro-FDI policies, then the positive correlation between stock market liberalization and innovation could be spurious. We hence include the ratio of FDI inflows over GDP (*FDI*) into the regressions.

Last, we add a set of institutional characteristics into the baseline regressions. These characteristics are the quality of institutions (*Institution*) as in Bekaert et al. (2005, 2011), intellectual property protection index (*IPProtect*) created by Park (2008), the Quinn and Toyoda (2008) capital account openness index (*CAOpen*), and an indicator denoting the enforcement of insider trading laws in a country (*InsideTrade*) compiled by Bhattacharya and Daouk (2002) to account for the possibility that a country's stock market liberalization coincides with the change in its legal and regulatory environments.[37]

We control for all these variables and their interactions with *Intensity* in the regression model in Eq. (2) and present the results in Columns 1–3 of Table 5, Panel A. The coefficient estimates of $Lib \times Intensity$ keep positive and significant at the 5% or 1% level in all three columns.

We further include country-year and industry-year fixed effects to account for the potential effects of time-varying country and industry characteristics and present the results in Columns 4–6. The coefficient estimates of $Lib \times Intensity$ are all positive and significant at the 5% level, suggesting that the positive effect of stock market liberalization on the innovation output of more innovative industries continues to hold after controlling for these important variables omitted from the baseline regressions. Also, these additional control variables exhibit signs that are generally consistent with previous findings.

Overall, the evidence in this section suggests that our baseline results are not likely to be driven by these potential omitted variables.

3.5.2. Test on reverse causality

To further address the reverse causality concern, we conduct a test to examine the dynamics of innovation output surrounding stock market liberalization. If the reverse causality drives the results, i.e., a country liberalizes its equity market to facilitate innovative firms' financing needs, an increase in innovation output should be evident even prior to the liberalization year. To rule out this possibility, we follow Bertrand and Mullainathan (2003) and create eight indicators, i.e., Lib_{t-3}, Lib_{t-2}, Lib_{t-1}, Lib_t, Lib_{t+1}, Lib_{t+2}, Lib_{t+3}, and $Lib_{\geq t+4}$, which denote relative years around liberalization with t referring to the liberalization years. Lib_{t-3} (Lib_{t-2}, Lib_{t-1}) equals one if the observation is three years (two years, one year) before the liberalization year and zero otherwise. Lib_t equals one if the observation is in the liberalization year and zero otherwise. Lib_{t+1} (Lib_{t+2}, Lib_{t+3}) equals one if the observation is one year (two years, three years) after the liberalization year and zero otherwise. $Lib_{\geq t+4}$ equals one if the observation is four years after the liberalization year and onward and zero otherwise. We then reestimate the baseline regressions by replacing $Lib \times Intensity$ with the interactions of *Intensity* and these eight indicators and replacing *Lib* with these eight indicators.

We present the results in Table 5, Panel B. The coefficient estimates of $Lib_{t-3} \times Intensity$, $Lib_{t-2} \times Intensity$, and $Lib_{t-1} \times Intensity$ are statistically insignificant, suggesting no significant increase in innovation output prior to stock market liberalization. More important, the coefficient estimate of $Lib_{t+1} \times Intensity$ starts to become marginally significant and those of $Lib_{t+2} \times Intensity$, $Lib_{t+3} \times Intensity$, and $Lib_{\geq t+4} \times Intensity$ are positive and significant at the 5% or 1% level.[38] This result suggests that firms' innovation output increases from the liberalization year onward. The magnitudes of the coefficient estimates of $Lib_{t+1} \times Intensity$, $Lib_{t+2} \times Intensity$, $Lib_{t+3} \times Intensity$, and $Lib_{\geq t+4} \times Intensity$ increase monotonically, suggesting that the impact of stock market liberalization on the innovation output of more innovative industries is long lasting and increasing over time. The result is also consistent with the patterns observed in Fig. 1.

Overall, the analysis suggests that the opening of a country's equity market leads to an enhancement of innovation output in the country, not vice versa.

[37] The quality of institutions is defined as the sum of the three components of the composite political risk rating in the International Country Risk Guide (ICRG), namely, "law and order," "bureaucratic quality," and "corruption." The intellectual property protection index is on a scale of 1 to 5, with 5 representing the strongest intellectual property protection. The Quinn and Toyoda (2008) capital account openness index is created based on the text from the International Monetary Fund (IMF) *Exchange Arrangements and Exchange Restrictions*. The openness measure has a scale of 0 to 1, with 1 representing a full open economy. Our results are also robust to the Chinn and Ito (2006) capital account openness index. The insider trading enforcement indicator takes the value of one in the year of a country's first insider trading enforcement case and thereafter and zero in years before the enforcement. See Bekaert et al. (2005, 2011), Park (2008), Quinn and Toyoda (2008), Chinn and Ito (2006), and Bhattacharya and Daouk (2002) for more details on variable constructions.

[38] The coefficient estimate of $Lib_t \times Intensity$ is significant at the 5% and 10% level when the dependent variable is $Ln(1+Tcite)$ and $Ln(1+Nfirm)$, respectively. The coefficient estimate of $Lib_{t+1} \times Intensity$ is insignificant when the dependent variable is $Ln(1+Nfirm)$.

Table 5
Test on endogeneity.

The sample contains public firms of manufacturing industries in countries experiencing stock market liberalization, which are jointly covered by Bureau van Dijk's Orbis patent database, United Nations Industrial Development Organization (UNIDO) Industrial Statistics database, and Penn World Table (PWT) version 8.0 database from 1981 to 2008. *Pat*, *Tcite*, and *Nfirm* are the total number of patents, the total number of citations adjusted for time–technology class fixed effects, and the total number of innovative firms in each industry for each country each year, respectively, which are measured in year *t*. *Lib* is a binary variable that takes the value of one if the observation is in the year since a country's official liberalization and zero otherwise, measured in year *t*-3. In Panel A, *Equity* is the ratio of stock market capitalization over gross domestic product (GDP), measured in year *t*-1. *Credit* is the ratio of domestic credit provided by the banking sector over GDP, measured in year *t*-1. *FDI* is a country's inward foreign direct investment over GDP, measured in year *t*-1. *Institution* is the quality of institutions, which includes three components of the composite political risk rating in the International Country Risk Guide (ICRG), namely, "law and order," "bureaucratic quality," and "corruption," measured in year *t*-1. *IPProtect* is the intellectual property protection index of a country from Park (2008), measured in year *t*-1. *CAOpen* is the capital account openness in Quinn and Toyoda (2008), measured in year *t*. *InsideTrade* is a dummy variable that takes the value of one in the year after a country's first insider trading enforcement case and thereafter and zero in years before the enforcement from Denis and Xu (2013), measured in year *t*. In Panel B, Lib_{t-3} (Lib_{t-2}, Lib_{t-1}) is a binary variable that takes the value of one if a country liberalizes its equity market three years (two years, one year) ago and zero otherwise. Lib_{t+1} (Lib_{t+2}, Lib_{t+3}) is a binary variable that takes the value of one if a country liberalizes its equity market in one year (two years, three years) and zero otherwise. $Lib_{\geq t+4}$ is a binary variable that takes the value of one if a country liberalizes its equity market in four years and thereafter and zero otherwise. In Panel C, the event window in Columns 1–3 (Columns 4–6) is seven (11) years with three (five) years before and three (five) years after the liberalization effect starting year, which is three years since a country liberalizes its equity market. The definitions of other variables are in Table 3. Robust standard errors in parentheses are clustered by country-industry. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Panel A: Controlling for omitted variables

Variable	*Ln*(1+*Pat*) (1)	*Ln*(1+*Tcite*) (2)	*Ln*(1+*Nfirm*) (3)	*Ln*(1+*Pat*) (4)	*Ln*(1+*Tcite*) (5)	*Ln*(1+*Nfirm*) (6)
Lib × *Intensity*	0.069**	0.114***	0.037***	0.102**	0.126**	0.036**
	(0.03)	(0.03)	(0.01)	(0.05)	(0.06)	(0.01)
Lib	−0.131	−0.211**	−0.058*			
	(0.09)	(0.09)	(0.03)			
Intensity	−0.053	−0.014	−0.105*			
	(0.11)	(0.13)	(0.06)			
Equity	−0.109	−0.204	−0.037			
	(0.11)	(0.13)	(0.03)			
Credit	0.275***	0.380***	0.106***			
	(0.10)	(0.12)	(0.03)			
FDI	−0.372	0.675	−0.422			
	(1.06)	(1.16)	(0.49)			
Institution	0.014	−0.001	0.016**			
	(0.01)	(0.01)	(0.01)			
IPProtect	−0.044	−0.057	−0.043**			
	(0.05)	(0.05)	(0.02)			
CAOpen	−0.243	0.184	−0.153			
	(0.21)	(0.23)	(0.10)			
InsideTrade	−0.123	−0.146	−0.102**			
	(0.08)	(0.09)	(0.04)			
Equity × *Intensity*	0.040	0.084*	0.016	0.061	0.110*	0.022
	(0.04)	(0.04)	(0.01)	(0.05)	(0.06)	(0.01)
Credit × *Intensity*	−0.109***	−0.166***	−0.032**	−0.129***	−0.171***	−0.036**
	(0.04)	(0.04)	(0.01)	(0.04)	(0.04)	(0.01)
FDI × *Intensity*	0.020	−0.939*	0.032	−0.336	−1.130*	−0.045
	(0.51)	(0.53)	(0.24)	(0.56)	(0.61)	(0.23)
Institution × *Intensity*	0.010**	0.013**	0.002	0.017***	0.022***	0.007**
	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)
IPProtect × *Intensity*	0.023	0.021	0.019**	0.012	−0.008	−0.000
	(0.02)	(0.02)	(0.01)	(0.03)	(0.03)	(0.01)
CAOpen × *Intensity*	−0.166**	−0.230***	−0.060*	−0.143*	−0.237***	−0.064*
	(0.08)	(0.08)	(0.03)	(0.07)	(0.09)	(0.04)
InsideTrade × *Intensity*	0.038	0.015	0.021*	0.054*	0.012	0.015
	(0.03)	(0.03)	(0.01)	(0.03)	(0.03)	(0.02)
Controls and interactions	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	No	No	No
Country-industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country-year fixed effects	No	No	No	Yes	Yes	Yes
Industry-year fixed effects	No	No	No	Yes	Yes	Yes
Number of observations	7,555	7,555	7,555	7,555	7,555	7,555
R-squared	0.15	0.10	0.19	0.95	0.92	0.95

continued on next page

Table 5
Continued.

Panel B: Test on reverse causality

Variable	$Ln(1+Pat)$ (1)	$Ln(1+Tcite)$ (2)	$Ln(1+Nfirm)$ (3)
$Lib_{t-3} \times Intensity$	0.036	0.042	0.014
	(0.04)	(0.04)	(0.02)
$Lib_{t-2} \times Intensity$	0.058	0.075	0.024
	(0.04)	(0.05)	(0.02)
$Lib_{t-1} \times Intensity$	0.049	0.055	0.022
	(0.04)	(0.05)	(0.02)
$Lib_{t} \times Intensity$	0.070	0.106**	0.031*
	(0.04)	(0.05)	(0.02)
$Lib_{t+1} \times Intensity$	0.076*	0.098*	0.030
	(0.05)	(0.05)	(0.02)
$Lib_{t+2} \times Intensity$	0.095**	0.130**	0.043**
	(0.05)	(0.05)	(0.02)
$Lib_{t+3} \times Intensity$	0.125***	0.178***	0.046**
	(0.05)	(0.06)	(0.02)
$Lib_{\geq t+4} \times Intensity$	0.172***	0.202***	0.097***
	(0.05)	(0.05)	(0.02)
Lib_{t-3}	−0.121	−0.058	−0.061
	(0.09)	(0.10)	(0.04)
Lib_{t-2}	−0.218**	−0.173	−0.097**
	(0.10)	(0.11)	(0.05)
Lib_{t-1}	−0.238**	−0.178*	−0.111**
	(0.10)	(0.11)	(0.05)
Lib_{t}	−0.256**	−0.235*	−0.118**
	(0.11)	(0.12)	(0.05)
Lib_{t+1}	−0.195*	−0.155	−0.072
	(0.12)	(0.13)	(0.06)
Lib_{t+2}	−0.213*	−0.206	−0.092
	(0.12)	(0.13)	(0.06)
Lib_{t+3}	−0.257**	−0.275*	−0.080
	(0.13)	(0.15)	(0.06)
$Lib_{\geq t+4}$	−0.320**	−0.261*	−0.167***
	(0.13)	(0.13)	(0.06)
Intensity	−0.322**	−0.318*	−0.250***
	(0.16)	(0.17)	(0.09)
Controls and interactions	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Country-industry fixed effects	Yes	Yes	Yes
Number of observations	9,071	9,071	9,071
R-squared	0.25	0.17	0.30

Panel C: Event study

Event window	Window (−3 yr, +3 yr)			Window (−5 yr, +5 yr)		
Variable	$Ln(1+Pat)$ (1)	$Ln(1+Tcite)$ (2)	$Ln(1+Nfirm)$ (3)	$Ln(1+Pat)$ (4)	$Ln(1+Tcite)$ (5)	$Ln(1+Nfirm)$ (6)
$Lib \times Intensity$	0.063***	0.072***	0.031***	0.083***	0.099***	0.041***
	(0.02)	(0.02)	(0.01)	(0.03)	(0.03)	(0.01)
Lib	−0.165***	−0.131**	−0.073***	−0.168**	−0.200***	−0.087***
	(0.05)	(0.06)	(0.02)	(0.07)	(0.07)	(0.03)
VA	−0.026	−0.125	−0.172	−1.053	−1.859	−0.843
	(1.23)	(1.28)	(0.59)	(1.64)	(1.73)	(0.68)
GDP	0.597***	0.567**	0.280***	0.911***	0.927***	0.512***
	(0.19)	(0.22)	(0.08)	(0.21)	(0.24)	(0.10)
VGDP	−0.206	1.210	−0.386	−0.229	1.041	−0.188
	(1.03)	(0.97)	(0.54)	(1.37)	(1.42)	(0.68)
HumCap	3.227**	3.346*	1.896**	2.653***	3.444***	1.583***
	(1.64)	(1.90)	(0.76)	(0.87)	(1.11)	(0.44)
Trade	−1.163**	−1.302**	−0.579**	−1.645***	−1.849***	−0.845***
	(0.53)	(0.62)	(0.25)	(0.36)	(0.47)	(0.17)
Gov	−1.731***	−1.168*	−1.010***	−1.511**	−1.545**	−0.939***
	(0.61)	(0.68)	(0.31)	(0.63)	(0.75)	(0.33)

Table 5
Continued.

Panel C: Event study						
Event window	Window (−3 yr, ±3 yr)			Window (−5 yr, ±5 yr)		
Variable	*Ln*(1+*Pat*) (1)	*Ln*(1+*Tcite*) (2)	*Ln*(1+*Nfirm*) (3)	*Ln*(1+*Pat*) (4)	*Ln*(1+*Tcite*) (5)	*Ln*(1+*Nfirm*) (6)
						continued on next page
Intensity	0.123	0.296	0.008	−0.096	−0.005	−0.130*
	(0.18)	(0.27)	(0.06)	(0.16)	(0.25)	(0.07)
VA × *Intensity*	−0.017	−0.147	0.036	0.849	1.290	0.565
	(0.63)	(0.70)	(0.29)	(0.85)	(0.93)	(0.36)
GDP × *Intensity*	−0.042	−0.110*	−0.002	−0.021	−0.074	0.010
	(0.04)	(0.06)	(0.01)	(0.04)	(0.05)	(0.02)
VGDP × *Intensity*	−0.936*	−1.260**	−0.199	−0.855	−1.142	−0.253
	(0.52)	(0.51)	(0.26)	(0.70)	(0.79)	(0.31)
HumCap × *Intensity*	0.058	0.106	−0.007	0.188	0.200	0.094
	(0.17)	(0.21)	(0.06)	(0.17)	(0.22)	(0.07)
Trade × *Intensity*	0.006	0.067	0.003	−0.014	0.064	−0.034
	(0.09)	(0.11)	(0.04)	(0.10)	(0.13)	(0.05)
Gov × *Intensity*	−0.275	−0.333	−0.072	−0.244	−0.079	−0.031
	(0.24)	(0.32)	(0.12)	(0.27)	(0.34)	(0.13)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country-industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	2,596	2,596	2,596	3,902	3,902	3,902
R-squared	0.17	0.09	0.18	0.19	0.12	0.22

3.5.3. Event study

While the baseline analysis shows that innovation output in more innovative industries becomes higher after a country opens up its stock market to foreign investors, this analysis does not focus directly on the changes in innovation output around the liberalization events. In this section, we conduct an analysis by examining the change in average levels of innovation output surrounding liberalization using short event windows. This approach also alleviates the concern that our results capture the upward time trend in industrial innovation output.

We perform a regression analysis for a seven-year event window, i.e., three years before and three years after the liberalization events, and an 11-year event window, i.e., five years before and five years after the liberalization events. Table 5, Panel C, presents the event study results. The coefficient estimates of *Lib* × *Intensity* are positive and significant at the 1% level across all columns. The results of the event analysis lend further support to our conjecture that more innovative industries are more likely to experience an increase in innovation output after a country liberalizes its stock market.

4. Economic channels

In this section, we explore three plausible underlying economic channels through which stock market liberalization affects innovation output. These economic channels are built upon existing theories of how stock market liberalization could benefit local firms, paying special attention to financing, risk sharing, and corporate governance as important factors that could promote innovation (Holmstrom, 1989; Manso, 2011). We examine the three plausible economic channels by employing a triple interaction approach. We include the three-way interaction of the liberalization indicator, industry innovativeness, and the partitioning variable together with two-way interactions of each pair of the three variables and each individual variable in the regressions. For brevity, we tabulate only the key variables of interest.

4.1. The financing channel

Innovation is a long-term investment process that tends to exhaust internal capital. Its special features, such as high uncertainty and high failure risk, hinder effective communication between firms and outside investors (Bhattacharya and Ritter, 1983), which significantly increases the financing cost of innovative activities. As a result, innovative firms suffer more severely from limited external finance. Given that stock market liberalization allows foreign investors to purchase shares of public firms listed on domestic stock exchanges and thus attracts more foreign capital inflows (Gupta and Yuan, 2009), stock market liberalization could promote corporate innovation by better satisfying innovative firms' financing needs. As such, we expect the effect of stock market liberalization on the innovation output of more innovative industries to be stronger in industries with greater financing needs, such as those with higher external equity finance dependence and those that are less likely to pay dividends.[39]

To examine this conjecture, we explore how industry external equity finance dependence and the percentage of non-dividend-paying firms in an industry alter our baseline results. We follow Rajan and Zingales (1998) and construct

[39] Previous literature shows that better access to equity finance relaxes financial constraints of innovative firms because higher risk and information asymmetry lead to a greater reliance of these firms on equity financing (Brown et al., 2009; 2013) and that firms that do not pay dividends are more likely subject to financial constraints (Lang and Stulz, 1994; Chari and Henry, 2008).

the industry-level equity finance dependence (*EquityDep*) as the industry median equity finance dependence of all US public firms from 1981 to 2008, with firm-level equity finance dependence defined as the ratio of net amount of equity issues to capital expenditures.[40] To smooth temporal fluctuations and reduce the effects of outliers, we aggregate firms' equity issues during the 1981–2008 period and then divide it by the sum of capital expenditures over the same period. In addition, similar to previous literature (e.g., Mitton, 2006; Bae and Goyal, 2010), we define the percentage of firms not paying dividends of an industry as one minus the percentage of firms paying nonzero dividends of an industry in a country (1-*DivPay*). We then employ *EquityDep* and 1-*DivPay*, respectively, as the partitioning variable in the triple interaction approach.

We present the results of the two tests in Panels A and B of Table 6. The coefficient estimates of *Lib* × *Intensity* × *EquityDep* and *Lib* × *Intensity* × (1-*DivPay*) are positive and significant at the 5% level, suggesting that stock market liberalization promotes innovation in more innovative industries by better satisfying the financing needs of the industries. The results support the view that stock market liberalization encourages innovation through the financing channel.

4.2. The risk-sharing channel

Earlier literature (e.g., Henry, 2000b; Chari and Henry, 2004; Bekaert et al., 2005) shows that foreign portfolio holdings induced by stock market liberalization enhance risk sharing between domestic and foreign investors. Moreover, recent studies find that foreign investors can better achieve diversification through their international portfolio investment, which encourages the risk taking of firms they hold (Faccio et al., 2011; Boubakri et al., 2013). To the extent that stock market liberalization lifts the restrictions on foreign investors purchasing shares of domestic listed firms, these firms are better able to tolerate potential failures involved in innovative activities and, hence, should undertake more innovative projects after liberalization.

To test the risk-sharing channel, we consider two proxies related to firms' risk-sharing needs. First, previous studies (e.g., Chari and Henry, 2004; Bae and Goyal, 2010) show that when the market of a country is accessible to foreign investors, risks associated with the investment in the country are largely diversifiable due to these investors' large portfolios. Moreover, the larger the benefits of diversification are, the less the local industry's returns are correlated with the global market portfolio. Second,

Table 6
Testing the financing channel.
The sample contains public firms of manufacturing industries in countries experiencing stock market liberalization, which are jointly covered by Bureau van Dijk's Orbis patent database, United Nations Industrial Development Organization (UNIDO) Industrial Statistics database, and Penn World Table (PWT) version 8.0 database from 1981 to 2008. *Pat, Tcite*, and *Nfirm* are the total number of patents, the total number of citations adjusted for time–technology class fixed effects, and the total number of innovative firms in each industry for each country each year, respectively, which are measured in year *t*. *Lib* is a binary variable that takes the value of one if the observation is in the year since a country's official liberalization and zero otherwise, measured in year *t*-3. In Panel A, *EquityDep* is industry equity finance dependence measure based on US data following Rajan and Zingales (1998). In Panel B, *DivPay* is the percentage of firms paying dividends in each industry for each country each year, measured in year *t*-1. The definitions of other variables are in Table 3. Control variables and their interactions with industry innovation intensity are included in all regressions but are not tabulated. Robust standard errors in parentheses are clustered by country-industry. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Variable	*Ln*(1+*Pat*) (1)	*Ln*(1+*Tcite*) (2)	*Ln*(1+*Nfirm*) (3)
Panel A: Equity dependence (*N* = 9,071)			
Lib × *Intensity* × *EquityDep*	0.363**	0.467**	0.230***
	(0.17)	(0.20)	(0.09)
Lib × *Intensity*	0.033	0.031	0.021
	(0.03)	(0.04)	(0.02)
Lib × *EquityDep*	−0.555	−0.799	−0.419*
	(0.44)	(0.49)	(0.22)
Intensity × *EquityDep*	−0.335	−0.335	−0.127
	(0.27)	(0.29)	(0.13)
Lib	−0.055	−0.031	−0.025
	(0.08)	(0.09)	(0.04)
Intensity	−0.238	−0.218	−0.219**
	(0.16)	(0.17)	(0.09)
R-squared	0.26	0.18	0.31
Panel B: One minus the percentage of firms paying dividends (*N* = 5,849)			
Lib × *Intensity* × (1-*DivPay*)	0.275***	0.278**	0.115**
	(0.10)	(0.12)	(0.04)
Lib × *Intensity*	−0.006	−0.005	0.020
	(0.05)	(0.06)	(0.03)
Lib × (1-*DivPay*)	−0.454**	−0.497*	−0.214**
	(0.23)	(0.25)	(0.10)
Intensity × (1-*DivPay*)	−0.184**	−0.188*	−0.064*
	(0.09)	(0.10)	(0.04)
Lib	0.099	0.161	0.032
	(0.15)	(0.16)	(0.07)
1-*DivPay*	0.129	0.206	0.038
	(0.21)	(0.22)	(0.09)
Intensity	−0.127	−0.036	−0.173*
	(0.18)	(0.21)	(0.10)
R-squared	0.23	0.13	0.28

Acharya and Subramanian (2009) show that a creditor-friendly bankruptcy code impedes innovation by exacerbating intolerance for failure and discouraging risk taking in innovation as a result of potential deadweight costs arising from liquidation. Therefore, we expect the effect of stock market liberalization on the innovation output of more innovative industries to be more pronounced in industries with a larger difference between local beta and world beta and in economies with a creditor-friendly bankruptcy code where firms are more risk averse.

We examine how the innovation effect of liberalization varies according to the correlation between the returns of local industries with those of the global market portfolio and the bankruptcy code of a country. We follow pre-

[40] As pointed out by Rajan and Zingales (1998), there are different levels of dependence on external finance across industries. Because the US equity market has a long history and is open to global investors, US data are better able to reflect these fundamental industry attributes. More important, using US data helps alleviate the concern that a country's industry characteristics are driven by its stock market liberalization or innovative activities and hence resolves the reverse causality concern that innovative activities lead to stock market liberalization. This method has been widely used in the cross-country innovation studies, e.g., Brown et al. (2013) and Hsu et al. (2014).

vious literature (e.g., Stulz, 1999; Chari and Henry, 2004; Bae and Goyal, 2010) and use the difference between local beta and world beta (*DiffBeta*) to capture the benefits of risk sharing after a country allows foreign portfolio investment. World (local) beta is calculated as the covariance of the monthly stock return with the global (local) market index return over the past five years divided by the global (local) market index return variance, with the local market index return orthogonalized to the global market index return. We use the median of firm-level beta difference in each industry each year as the partitioning variable. Furthermore, we use the creditor rights index (*CR*) created by Djankov et al. (2007) to measure the strength of the bankruptcy code in a country. A higher value of the creditor rights index indicates a more creditor-friendly bankruptcy code. We then estimate the regressions using the triple interaction approach with the difference of local beta and world beta and the creditor rights index as the partitioning variable. We report the results in Panels A and B of Table 7.

The coefficient estimates of *Lib* × *Intensity* × *DiffBeta* and *Lib* × *Intensity* × *CR* are both positive and statistically significant, suggesting that our main result is more pronounced in industries and economies with more potential benefits from risk sharing. Hence, risk sharing appears to be an underlying economic channel through which stock market liberalization affects innovation.

4.3. The corporate governance channel

Previous studies (e.g., Mitton, 2006; Bekaert et al., 2005, 2011) argue that the liberalization of stock markets attracts more foreign investors who require better corporate governance, which effectively disciplines managers' opportunistic behaviors and promotes firms' investment efficiency (Ferreira and Matos, 2008; Aggarwal et al., 2011). Furthermore, recent literature highlights the important role of good corporate governance in innovation. In a cross-country setting, Brown et al. (2013) find that strong shareholder protection promotes innovation because innovative projects, compared with conventional investment, are highly risky and have greater information asymmetry. Atanassov (2013) points out the moral hazard problems in innovative projects by showing that firms' innovation output declines after the states where these firms are incorporated pass antitakeover laws, which leads to a weakened disciplinary effect of the takeover market on managers. More important, previous studies (e.g., Stulz, 2005; Wei, 2018; Boubakri et al., 2013) find that foreign investors are more likely to exert efforts to improve domestic firms' governance and promote these firms' risk taking in countries where corporate insiders cannot easily expropriate outside investors for private benefits and where the government's rent-seeking activities due to poor institutions are not prevalent. The reason is that these foreign investors are likely to gain benefits from doing so in the situations.

We consider two variables related to firms' governance and institutional environments. First, prior literature (e.g., Faccio and Lang, 2002; Doidge et al., 2009) shows that insider blockholders are more likely to extract private benefits from control and cause agency issues. In response, foreign investors invest less in firms with more shares closely held by insiders as a result of limited gains (Leuz et al., 2009). The second variable is the investment profile of a country, which captures the risk of expropriation and thus the attractiveness of the country to foreign direct and portfolio investors. Several studies (e.g., Bekaert et al., 2005, 2011; Bekaert et al., 2007) show that foreign investors' abilities to discipline managers and to promote firms' investment efficiency are more effective when a country has better protection of foreign investors. As such, if improving

Table 7
Testing the risk-sharing channel.
The sample contains public firms of manufacturing industries in countries experiencing stock market liberalization, which are jointly covered by Bureau van Dijk's Orbis patent database, United Nations Industrial Development Organization (UNIDO) Industrial Statistics database, and Penn World Table (PWT) version 8.0 database from 1981 to 2008. *Pat*, *Tcite*, and *Nfirm* are the total number of patents, the total number of citations adjusted for time–technology class fixed effects, and the total number of innovative firms in each industry for each country each year, respectively, which are measured in year *t*. *Lib* is a binary variable that takes the value of one if the observation is in the year since a country's official liberalization and zero otherwise, measured in year *t*-3. In Panel A, *DiffBeta* is the median of the difference between the sensitivity of a local firm's returns to the local market returns (local beta) and the sensitivity of the local firm's returns to the world market returns (world beta) in each industry for each country each year, measured in year *t*-1. In Panel B, *CR* is the creditor rights index compiled by Djankov et al. (2007), which is measured in year *t*-1. The definitions of other variables are in Table 3. Control variables and their interactions with industry innovation intensity are included in all regressions but are not tabulated. Robust standard errors in parentheses are clustered by country-industry. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Variable	*Ln*(1+*Pat*) (1)	*Ln*(1+*Tcite*) (2)	*Ln*(1+*Nfirm*) (3)
Panel A: The difference of local beta and world beta (N = 5,524)			
Lib × *Intensity* × *DiffBeta*	0.121**	0.107*	0.056**
	(0.06)	(0.06)	(0.03)
Lib × *Intensity*	0.011	0.025	0.028
	(0.05)	(0.05)	(0.02)
Lib × *DiffBeta*	−0.160	−0.181	−0.088
	(0.12)	(0.12)	(0.06)
Intensity × *DiffBeta*	−0.162***	−0.142**	−0.080***
	(0.06)	(0.06)	(0.03)
Lib	0.105	0.164	0.036
	(0.15)	(0.16)	(0.07)
DiffBeta	0.280**	0.265**	0.154***
	(0.12)	(0.12)	(0.06)
Intensity	−0.205	−0.114	−0.203*
	(0.18)	(0.20)	(0.11)
R-squared	0.21	0.11	0.26
Panel B: Creditor rights (N = 9,071)			
Lib × *Intensity* × *CR*	0.049**	0.044*	0.027**
	(0.02)	(0.03)	(0.01)
Lib × *Intensity*	0.005	0.029	0.007
	(0.05)	(0.05)	(0.03)
Lib × *CR*	−0.120**	−0.108**	−0.059**
	(0.05)	(0.05)	(0.03)
Intensity × *CR*	−0.044	−0.052*	−0.025*
	(0.03)	(0.03)	(0.01)
Lib	0.113	0.086	0.044
	(0.12)	(0.11)	(0.06)
CR	0.267***	0.219***	0.149***
	(0.08)	(0.08)	(0.04)
Intensity	−0.210	−0.186	−0.195**
	(0.16)	(0.18)	(0.09)
R-squared	0.25	0.17	0.30

corporate governance is an underlying economic channel that allows stock market liberalization to promote innovation, we expect the positive effect of stock market liberalization on the innovation output of more innovative industries to be stronger in industries with a lower percentage of closely held blocks and in countries with a better investment profile.[41]

Following previous studies, e.g., McConnell and Servaes (1990), Li et al. (2006), and Faccio et al. (2011), we define the percentage of closely held blocks of an industry (*Block*) as the percentage of firms with a block holding of 5% or more in the industry. For easy interpretation of results, we use one minus *Block* in the regression analysis. Moreover, we use the investment profile rating (*InvProf*) from the International Country Risk Guide (ICRG) as a proxy for foreign investor protection, which is a subcategory from the ICRG composite political risk ratings, including the assessment of contract viability, profit repatriation, and payment delays.

We present the results estimated using the triple interaction approach with one minus the percentage of closely held blocks in an industry and the investment profile rating of a country as the partitioning variable in Panels A and B of Table 8, respectively. The coefficient estimates of *Lib* × *Intensity* × (1-*Block*) and *Lib* × *Intensity* × *InvProf* are both positive and significant, suggesting that our baseline result is more pronounced in industries with fewer shares closely held by insiders and in countries with a better investment profile where foreign investors have stronger incentives to participate in the governance of domestic firms.

Overall, these findings support the enhancement of local firms' corporate governance as a channel through which stock market liberalization affects innovation output in more innovative industries. Our results also complement the previous findings (e.g., Bekaert et al., 2005, 2011; Kose et al., 2009; Leuz et al., 2009; Popov, 2011) that the benefits of liberalization in terms of economic growth are greater in countries with better investment and institutional environments.

4.4. The liberalization effect on existing firms versus new firms

Previous studies (e.g., Gopalan and Gormley, 2008; Faccio et al., 2011; Foley and Greenwood, 2010) argue that new firms, compared with existing firms, are financially more constrained, less diversified, and have more concentrated ownership. Therefore, new firms are more likely to achieve greater benefits from the liberalization of a country's stock market. Some literature (e.g., Gupta and Yuan, 2009) shows that these new firms hardly benefit from liberalization due to entry barriers. As such, we investigate whether liberalization enhances the intensive margin of firms' innovation by turning non-innovative firms into innovative firms for a sample of existing firms or promotes the extensive margin of corporate innovation by attracting more new firms already engaged in innovative activities to go public. The answer can help explain the dynamic changes in existing firms' and new entrants' innovative activities after a country liberalizes its stock market as well as the three channels we propose.

Following Foley and Greewood (2010), we use the base date in Datastream to identify a firm's first listing date. We

Table 8
Testing the corporate governance channel.
The sample contains public firms of manufacturing industries in countries experiencing stock market liberalization, which are jointly covered by Bureau van Dijk's Orbis patent database, United Nations Industrial Development Organization (UNIDO) Industrial Statistics database, and Penn World Table (PWT) version 8.0 database from 1981 to 2008. *Pat, Tcite*, and *Nfirm* are the total number of patents, the total number of citations adjusted for time–technology class fixed effects, and the total number of innovative firms in each industry for each country each year, respectively, which are measured in year *t*. *Lib* is a binary variable that takes the value of one if the observation is in the year since a country's official liberalization and zero otherwise, measured in year *t*-3. In Panel A, *Block* is the percentage of firms with closely held blocks of 5% or more in each industry for each country each year, measured in year *t*-1. In Panel B, *InvProf* is the investment profile component of the composite political risk rating in the International Country Risk Guide (ICRG), measured in year *t*-1. The definitions of other variables are in Table 3. Control variables and their interactions with industry innovation intensity are included in all regressions but are not tabulated. Robust standard errors in parentheses are clustered by country-industry. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Variable	*Ln*(1+*Pat*) (1)	*Ln*(1+*Tcite*) (2)	*Ln*(1+*Nfirm*) (3)
Panel A: One minus the percentage of firms with closely held blocks (N = 6,089)			
Lib × *Intensity* × (1-*Block*)	0.281**	0.371**	0.163**
	(0.14)	(0.16)	(0.07)
Lib × *Intensity*	0.048	0.031	0.034
	(0.05)	(0.06)	(0.03)
Lib × (1-*Block*)	−0.501	−0.577*	−0.245
	(0.32)	(0.34)	(0.15)
Intensity × (1-*Block*)	−0.125	−0.190	−0.059
	(0.13)	(0.14)	(0.06)
Lib	0.015	0.046	−0.021
	(0.15)	(0.16)	(0.07)
1-*Block*	0.585*	0.547*	0.278*
	(0.33)	(0.32)	(0.15)
Intensity	−0.180	−0.095	−0.195*
	(0.18)	(0.21)	(0.10)
R-squared	0.23	0.14	0.29
Panel B: Investment profile (N = 8,435)			
Lib × *Intensity* × *InvProf*	0.027*	0.028*	0.020**
	(0.01)	(0.02)	(0.01)
Lib × *Intensity*	−0.078	−0.065	−0.078
	(0.09)	(0.11)	(0.05)
Lib × *InvProf*	0.024	−0.005	−0.001
	(0.03)	(0.03)	(0.02)
Intensity × *InvProf*	−0.013	−0.015	−0.011**
	(0.01)	(0.01)	(0.01)
Lib	−0.293	−0.106	−0.063
	(0.19)	(0.20)	(0.10)
InvProf	−0.027	−0.015	−0.009
	(0.02)	(0.03)	(0.01)
Intensity	−0.143	−0.106	−0.148*
	(0.15)	(0.17)	(0.08)
R-squared	0.19	0.12	0.24

[41] In an untabulated test, we employ industry competition as an alternative corporate governance variable and examine the impact of industry competitive pressure on the liberalization-innovation relation. We use one minus the Herfindahl-Hirschman Index (*HHI*), constructed using US public firms in Compustat, as a proxy for the competitive pressure in an industry. The coefficient estimates of *Lib*×*Intensity*×(1-*HHI*) are positive and significant, suggesting that the innovation effect of liberalization is likely driven by firms in industries facing more competitive threat.

Table 9
The effects of liberalization on existing firms and new firms.
The sample contains public firms of manufacturing industries in countries experiencing stock market liberalization, which are jointly covered by Bureau van Dijk's Orbis patent database, United Nations Industrial Development Organization (UNIDO) Industrial Statistics database, and Penn World Table (PWT) version 8.0 database from 1981 to 2008. *Nfirm_exi* and *Nfirm_IPO* are the total number of innovative firms for a sample of existing firms prior to liberalization and the total number of innovative initial public offering (IPO) firms in each industry for each country each year, respectively, which are measured in year *t*. *Lib* is a binary variable that takes the value of one if the observation is in the year since a country's official liberalization and zero otherwise, measured in year *t*-3. The definitions of other variables are in Table 3. Robust standard errors in parentheses are clustered by country-industry. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Variable	*Ln*(1+*Nfirm_exi*) (1)	*Ln*(1+*Nfirm_IPO*) (2)	*Ln*(1+*Nfirm_exi*) (3)	*Ln*(1+*Nfirm_IPO*) (4)
Lib × *Intensity*			0.038***	0.033***
			(0.01)	(0.01)
Lib	0.038***	0.080***	−0.058**	−0.001
	(0.01)	(0.02)	(0.02)	(0.02)
VA	0.362	0.796***	−0.085	−0.253
	(0.39)	(0.30)	(0.49)	(0.40)
GDP	0.436***	0.227***	0.348***	0.171***
	(0.07)	(0.05)	(0.05)	(0.04)
VGDP	−0.325	0.394***	0.048	0.126
	(0.26)	(0.15)	(0.45)	(0.30)
HumCap	0.466***	0.094	0.474***	0.117
	(0.15)	(0.10)	(0.14)	(0.11)
Trade	−0.480***	−0.190***	−0.295***	−0.107
	(0.08)	(0.05)	(0.09)	(0.07)
Gov	−0.396***	−0.201**	−0.170	−0.202
	(0.13)	(0.09)	(0.21)	(0.12)
Intensity	−0.009	0.003	−0.105**	−0.090**
	(0.01)	(0.00)	(0.05)	(0.04)
VA × *Intensity*			0.124	0.358*
			(0.16)	(0.20)
GDP × *Intensity*			0.036***	0.021***
			(0.01)	(0.01)
VGDP × *Intensity*			−0.165	0.102
			(0.21)	(0.12)
HumCap × *Intensity*			0.005	0.001
			(0.04)	(0.03)
Trade × *Intensity*			−0.072**	−0.033
			(0.03)	(0.02)
Gov × *Intensity*			−0.092	0.004
			(0.09)	(0.05)
Year fixed effects	Yes	Yes	Yes	Yes
Country-industry fixed effects	Yes	Yes	Yes	Yes
Number of observations	9,071	9,071	9,071	9,071
R-squared	0.16	0.06	0.18	0.07

define a firm as an existing firm if the firm's listing year is prior to the country's liberalization year, and we define a firm as an innovative IPO firm if the firm has patents before its IPO year. We then construct two measures, namely, the number of innovative firms for a sample of existing firms (*Nfirm_exi*) and the number of innovative IPO firms (*Nfirm_IPO*) by aggregating existing firms with successful patent applications and IPO firms with successful patent applications prior to their IPOs in each industry for each country each year, respectively. We reestimate Eq. (1) with the dependent variable replaced with the logarithm of one plus the two measures separately and present the results in Columns 1 and 2 of Table 9. In addition, we compare the differential effects of liberalization between more innovative and less innovative industries by reestimating the baseline model with the logarithm of one plus the above two measures as the dependent variable, respectively. The results are presented in Columns 3 and 4 of Table 9.

In Columns 1 and 2, the coefficient estimates of *Lib* are positive and significant, suggesting that liberalization leads to a significant increase in the number of firms that are reclassified as more innovative and a significant increase in the number of innovative firms that are going public. Moreover, in Columns 3 and 4, the positive and significant coefficient estimates of *Lib* × *Intensity* suggest that the above liberalization effects are stronger in more innovative industries. Collectively, these results suggest that our main findings hold on both the intensive and the extensive margins and, thus, complement our findings in the channel tests by showing that liberalization benefits both existing firms and new firms by relaxing financing constraints, enhancing risk sharing, and improving the governance of these firms.

5. Further analysis

5.1. The liberalization effect on innovation for a sample of private firms

Previous studies (e.g., Chari and Henry, 2004, 2008) show that stock market liberalization has a more direct impact on publicly traded firms because these firms become investible to foreign investors after liberalization. However, it does not preclude the spillover of the innovation effect of liberalization to private firms for a number of reasons. First, the competitive environment within an industry could encourage both public firms and private firms to engage in innovative activities. Second, the changes in the broader institutional environment brought about by liberalization could induce any firms to face an altered incentive to engage in innovation regardless of their listing status. Third, stock market liberalization in a country is often coupled with pro-FDI policies (Henry, 2000a), which generally exhibit friendliness to private equity or venture capital and strategic alliances or joint ventures (Conklin and Lecraw, 1997). The presence of these funds in the industry could also fundamentally transform firms' propensity to engage in innovation irrespective of their listing status.[42]

To examine this spillover effect, we conduct a test by reestimating the baseline model using a sample of large private firms. Given that Orbis classifies all public firms as large firms and classifies private firms into either large firms or small firms according to several criteria, we focus on large private firms to make the sample of public firms and the sample of private firms comparable.[43] The results are presented in Panel A of Table 10. We find that large private firms in more innovative industries and those in less innovative industries exhibit a similar increase in innovation output after a country opens up its stock market to foreign investors. It appears that there is not a spillover effect of liberalization on innovation for large private firms.

These results capture only the average effect of stock market liberalization on the difference in private firms' innovation output between more innovative and less innovative industries. A better understanding of the spillover effect requires a more refined analysis of how the liberalization-innovation relation varies with the degree of competitiveness of an industry, the broader institutional environment of a country, and the general friendliness to private equity or venture capital and strategic alliances or joint ventures in an industry.

Similar to the tests in Section 4, we examine these conditional effects using the triple interaction approach (see Panel B of Table 10). We use one minus the Herfindahl-Hirschman Index (*HHI*), constructed using US public firms in Compustat, as a proxy for competitive pressures in an industry. We find positive and significant coefficient estimates of *Lib* × *Intensity* × (1-*HHI*), suggesting that the effect of liberalization on the innovation output of private firms in more innovative industries is likely to manifest when firms in these industries face more competitive pressures. We follow previous literature (e.g., Bekaert et al., 2005, 2011) and use the quality of institutions (*Institution*) as defined in Section 3.5.1 to proxy for the broader institutional environment of a country. The coefficient estimates of *Lib* × *Intensity* × *Institution* are positive and significant across all three columns, suggesting that an improvement in the institutional environment is more likely to strengthen the liberalization effect on private firms' innovation output in more innovative industries.

We also create two binary variables to measure the presence of private equity or venture capital (*PE*) and the presence of strategic alliances or joint ventures (*SA*), respectively. Specifically, *PE* equals one if an industry has private equity or venture capital investment according to the SDC VentureXpert database and zero otherwise. *SA* equals one if an industry has activities of joint ventures or strategic alliances according to the SDC Joint Ventures & Strategic Alliances database and zero otherwise. The coefficient estimates of *Lib* × *Intensity* × *PE* and *Lib* × *Intensity* × *SA* are both positive and significant. These results suggest that the presence of private equity or venture capital and of strategic alliances or joint ventures significantly improves private firms' propensity to engage in innovative activities after a country opens up its stock market.

Taken together, the findings in this section suggest that although the spillover of the innovation effect of liberalization to private firms, on average, is limited due to various frictions, certain factors such as competitive pressures in an industry, improvements in the institutional environment in a country, and the presence of private equity or venture capital and strategic alliances or joint ventures in an industry do motivate private firms to follow their public peers to innovate more.

5.2. Patent originality, patent generality, and backward citations to foreign patents

While previous studies argue that patent counts and patent citation counts measure the quantity and quality of a country's innovation output, respectively, we compute industrial patent originality and generality measures and two measures that capture domestic firms' foreign technology adoption to further capture the fundamental nature and importance of innovation and firms' technological learning process.

According to Hall et al. (2001), a patent's originality score is calculated as one minus the Herfindahl concentration index of technological classes for all prior patents that it cites, and a patent's generality score is calculated as one minus the Herfindahl concentration index of technological classes for all the citations it receives.[44] Therefore, a patent with a high originality score is inspired by prior inventions from a wide range of technological classes instead of only closely related technological classes, and a patent with a high generality score has a widespread impact on future patents from various technological classes. An improvement in patent originality and generality is partic-

[42] Previous literature has shown the beneficial role of private equity or venture capital (Lerner et al., 2011; Kortum and Lerner, 2000) and strategic alliances or joint ventures (Robinson, 2008; Li et al., 2019) in corporate innovation.

[43] Orbis identifies firms as either public or private. Within private firms, Orbis identifies large and small firms according to the following criteria. Large private firms are those with either operating revenues greater than \$13 million, total assets exceeding \$26 million, or the number of employees greater than 150. Firms for which operating revenues, total assets, and the number of employees are unknown are classified as large if paid-in capital is greater than \$650,000. All other private firms are classified as small. Orbis classifies all public firms as large.

[44] We use the three-digit IPC class to define patent originality and generality scores. Our results are robust to using one-digit or two-digit IPC class to define the scores.

ularly meaningful for emerging economies because it not only reflects the intricate novelty of inventions but also indicates the profound influence of their inventions on innovation in other scientific areas. We aggregate individual patents' originality and generality scores to the industry level and compute patent originality and generality (*Originality* and *Generality*) in each two-digit SIC industry for each country in each year. To reduce the skewness of these measures, we use the logarithm of one plus the industrial originality and generality scores as dependent variables in the baseline model. We report the results in Columns 1 and 2 of Table 11. The coefficient estimates of *Lib* × *Intensity* are positive and significant at the 1% level, suggesting that the openness of a country's stock market enhances

Table 10
A sample of private firms.

The sample contains large private firms of manufacturing industries in countries experiencing stock market liberalization, which are jointly covered by Bureau van Dijk's Orbis patent database, United Nations Industrial Development Organization (UNIDO) Industrial Statistics database, and Penn World Table (PWT) version 8.0 database from 1981 to 2008. *Pat, Tcite*, and *Nfirm* are the total number of patents, the total number of citations adjusted for time–technology class fixed effects, and the total number of innovative firms in each industry for each country each year, respectively, which are measured in year *t*. *Lib* is a binary variable that takes the value of one if the observation is in the year since a country's official liberalization and zero otherwise, measured in year *t*-3. In Panel B, *HHI* is the Herfindahl-Hirschman Index constructed using US public firms in Compustat, measured in year *t*-1. *Institution* is the quality of institutions, which includes three components of the composite politic rating in the International Country Risk Guide (ICRG), namely, "law and order," "bureaucratic quality," and "corruption," measured in year *t*-1. *PE* is a binary variable that equals one if an industry has private equity or venture capital investment and zero otherwise, measured in year *t*-1. *SA* is a binary variable that equals one if an industry has activities of a joint venture or a strategic alliance and zero otherwise, measured in year *t*-1. The definitions of other variables are in Table 3. Control variables and their interactions with industry innovation intensity are included in all regressions but are not tabulated in Panel B. Robust standard errors in parentheses are clustered by country-industry. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Variable	*Ln*(1+*Pat*) (1)	*Ln*(1+*Tcite*) (2)	*Ln*(1+*Nfirm*) (3)
Panel A: The effect of stock market liberalization on innovation of large private firms			
Lib × *Intensity*	0.034	0.080	−0.004
	(0.05)	(0.06)	(0.04)
Lib	−0.062	−0.055	0.010
	(0.09)	(0.10)	(0.06)
VA	−5.549***	−5.192**	−4.050***
	(2.05)	(2.21)	(1.50)
GDP	0.686***	0.924***	0.580***
	(0.17)	(0.20)	(0.13)
VGDP	2.137	0.413	1.463
	(1.54)	(1.67)	(1.06)
HumCap	2.005***	1.894***	1.531***
	(0.66)	(0.71)	(0.42)
Trade	−1.125***	−1.145***	−0.870***
	(0.35)	(0.36)	(0.25)
Gov	−1.859**	−2.454**	−0.964
	(0.93)	(1.20)	(0.60)
Intensity	−0.507**	−0.511*	−0.424**
	(0.25)	(0.27)	(0.18)
VA × *Intensity*	3.969***	3.453***	2.982***
	(1.21)	(1.22)	(0.84)
GDP × *Intensity*	0.125**	0.110	0.077*
	(0.06)	(0.07)	(0.05)
VGDP × *Intensity*	−1.316	−1.100	−0.999*
	(0.88)	(0.94)	(0.60)
HumCap × *Intensity*	−0.199	−0.155	−0.027
	(0.21)	(0.24)	(0.14)
Trade × *Intensity*	0.250	0.279	0.217*
	(0.18)	(0.19)	(0.13)
Gov × *Intensity*	0.675	0.799	0.415
	(0.49)	(0.62)	(0.31)
Year fixed effects	Yes	Yes	Yes
Country-industry fixed effects	Yes	Yes	Yes
Number of observations	10,391	10,391	10,391
R-squared	0.18	0.10	0.22

(*continued on next page*)

Table 10 (*continued*)

Variable	*Ln*(1+*Pat*) (1)	*Ln*(1+*Tcite*) (2)	*Ln*(1+*Nfirm*) (3)
Panel B: Cross-sectional difference in results for large private firms			
Effect of industry competitive pressure			
Partitioning variable: one minus Herfindahl-Hirschman Index (N = 10,391)			
Lib × *Intensity* × (1-*HHI*)	1.261**	1.534**	0.921**
	(0.57)	(0.63)	(0.40)
Lib × *Intensity*	−1.112**	−1.307**	−0.846**
	(0.50)	(0.55)	(0.35)
Lib × (1-*HHI*)	−0.598	−1.299	−0.362
	(0.89)	(0.95)	(0.65)
Intensity × (1-*HHI*)	0.675	0.529	0.244
	(0.70)	(0.79)	(0.44)
Lib	0.446	1.081	0.320
	(0.77)	(0.81)	(0.56)
1-*HHI*	−0.844	−0.499	−0.369
	(1.10)	(1.23)	(0.74)
Intensity	−1.025	−0.893	−0.583
	(0.66)	(0.75)	(0.43)
R-squared	0.20	0.11	0.23
Effect of the institutional environment			
Partitioning variable: quality of institutions (N = 9,115)			
Lib × *Intensity* × *Institution*	0.038***	0.044***	0.022***
	(0.01)	(0.01)	(0.01)
Lib × *Intensity*	−0.330***	−0.359***	−0.216***
	(0.11)	(0.13)	(0.07)
Lib × *Institution*	0.014	−0.019	0.022
	(0.02)	(0.02)	(0.01)
Intensity × *Institution*	−0.047**	−0.041*	−0.027*
	(0.02)	(0.02)	(0.01)
Lib	−0.181	0.187	−0.200
	(0.20)	(0.23)	(0.13)
Institution	−0.033	0.003	−0.021
	(0.03)	(0.03)	(0.02)
Intensity	−0.370	−0.357	−0.361**
	(0.23)	(0.27)	(0.16)
R-squared	0.17	0.08	0.22
Effect of the presence of private equity and strategic alliances			
Partitioning variable: the presence of private equity (N = 10,391)			
Lib × *Intensity* × *PE*	0.704**	0.744**	0.356*
	(0.30)	(0.31)	(0.20)
Lib × *Intensity*	−0.016	0.029	−0.037
	(0.05)	(0.05)	(0.03)
Lib × *PE*	−0.675	−0.928*	−0.231
	(0.49)	(0.50)	(0.33)
Intensity × *PE*	−0.254	−0.230	−0.057
	(0.28)	(0.28)	(0.19)
Lib	−0.007	0.011	0.042
	(0.08)	(0.10)	(0.06)
PE	0.175	0.229	−0.049
	(0.45)	(0.44)	(0.29)
Intensity	−0.348	−0.365	−0.301*
	(0.21)	(0.23)	(0.15)
R-squared	0.20	0.11	0.24
Partitioning variable: the presence of strategic alliances (N = 10,391)			
Lib × *Intensity* × *SA*	0.330**	0.355**	0.215***
	(0.13)	(0.15)	(0.08)
Lib × *Intensity*	−0.034	0.004	−0.057
	(0.05)	(0.06)	(0.04)
Lib × *SA*	−0.564***	−0.566**	−0.291**
	(0.22)	(0.24)	(0.13)
Intensity × *SA*	−0.110	−0.113	−0.051
	(0.12)	(0.13)	(0.07)
Lib	0.034	0.045	0.070
	(0.09)	(0.10)	(0.06)
SA	0.247	0.201	0.047
	(0.20)	(0.21)	(0.11)
Intensity	−0.466*	−0.468*	−0.396**
	(0.25)	(0.26)	(0.18)
R-squared	0.19	0.11	0.22

Table 11
Stock market liberalization, patent originality and generality, and backward citations to foreign patents.

The sample contains public firms of manufacturing industries in countries experiencing stock market liberalization, which are jointly covered by Bureau van Dijk's Orbis patent database, United Nations Industrial Development Organization (UNIDO) Industrial Statistics database, and Penn World Table (PWT) version 8.0 database from 1981 to 2008. *Originality* (*Generality*) is defined as the total originality (generality) score of all patents in an industry for each country in each year, measured in year *t*. The originality (generality) score of a patent is calculated as one minus the Herfindahl-Hirschman Index of the technology class distribution of all the patents that this patent cites (that cite this patent), measured in year *t. FnCite* is the number of domestic patents' backward citations to foreign patents in each industry for each country each year. *%FnCite_ave* is the share of foreign backward citations in total backward citations of an average firm in each industry for each country each year. *Lib* is a binary variable that takes the value of one if the observation is in the year since a country's official liberalization and zero otherwise, measured in year *t*-3. The definitions of other variables are in the legend of Table 3. Robust standard errors in parentheses are clustered by country-industry. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Variable	*Ln*(1+*Originality*) (1)	*Ln*(1+*Generality*) (2)	*Ln*(1+*FnCite*) (3)	*%FnCite_ave* (4)
Lib × *Intensity*	0.116***	0.092***	0.163***	0.022***
	(0.03)	(0.02)	(0.04)	(0.01)
Lib	−0.284***	−0.197***	−0.357***	−0.013
	(0.06)	(0.05)	(0.09)	(0.02)
VA	1.249	0.382	2.531	0.411
	(1.10)	(0.80)	(1.66)	(0.39)
GDP	0.404***	0.315***	0.723***	0.215***
	(0.10)	(0.08)	(0.15)	(0.03)
VGDP	2.137**	0.683	3.750***	0.743***
	(0.84)	(0.60)	(1.22)	(0.29)
HumCap	−1.734***	−0.641**	−1.955***	0.096
	(0.49)	(0.30)	(0.70)	(0.13)
Trade	−0.781***	−0.510***	−0.988***	−0.166***
	(0.21)	(0.14)	(0.26)	(0.06)
Gov	1.005*	−0.016	1.943**	0.132
	(0.59)	(0.42)	(0.94)	(0.17)
Intensity	−0.213*	−0.130*	−0.253	−0.047
	(0.11)	(0.07)	(0.17)	(0.03)
VA × *Intensity*	0.277	0.340	0.046	−0.004
	(0.47)	(0.36)	(0.72)	(0.13)
GDP × *Intensity*	0.052**	0.044***	0.069*	0.010
	(0.02)	(0.02)	(0.04)	(0.01)
VGDP × *Intensity*	0.257	0.054	−0.047	−0.170
	(0.39)	(0.30)	(0.51)	(0.13)
HumCap × *Intensity*	−0.064	−0.086	0.049	0.072***
	(0.10)	(0.07)	(0.14)	(0.03)
Trade × *Intensity*	−0.000	−0.021	−0.114	−0.059***
	(0.07)	(0.05)	(0.09)	(0.02)
Gov × *Intensity*	0.038	−0.018	−0.322	−0.152**
	(0.23)	(0.17)	(0.39)	(0.08)
Year fixed effects	Yes	Yes	Yes	Yes
Country-industry fixed effects	Yes	Yes	Yes	Yes
Number of observations	9,071	9,071	9,071	9,071
R-squared	0.25	0.18	0.22	0.10

the originality and generality of innovation, particularly in more innovative industries.

Apart from patent originality and generality, we follow previous literature (e.g., MacGarvie, 2006; Kong et al., 2019) and use domestic patents' backward citations to foreign patents as a proxy for domestic firms' adoption of foreign technology, with a backward citation of each domestic patent defined as a foreign backward citation if the owner of the cited patent is a foreign company according to the information on patent owners' domicile provided by Orbis. We create two variables using domestic patents' foreign backward citations. The first measure is the total number of foreign backward citations (*FnCite*), which is computed by adding up the number of foreign backward citations of patents owned by domestic firms in each industry for each country each year. To mitigate the concern that more foreign backward citations are due to more backward citations in general, our second measure of foreign technology adoption is the share of foreign backward citations in the total backward citations of an average firm in each industry for each country each year (*%FnCite_ave*). Intuitively, a higher value of *FnCite* and *%FnCite_ave* indicates the adoption of more foreign technology by domestic firms when they create their own patents.

The adoption of foreign technology in the innovation process is crucial for domestic firms, particularly in emerging markets, to update their technology base, enhance their innovation performance, and catch up with the technology advances (Kim and Nelson, 2000; Liu and Buck, 2007). To examine the effect of stock market liberalization on domestic firms' foreign technology adoption, we replace the dependent variable in the baseline model with the logarithm of one plus *FnCite* [i.e., *Ln*(1+*FnCite*)] and *%FnCite_ave*, respectively, and reestimate the regressions. The results are presented in Columns 3 and 4 of Table 11. The coefficient estimates of *Lib* × *Intensity* are positive and significant in both columns, suggesting that the total number and the share of domestic patents' backward citations to foreign patents in more innovative industries significantly increase after a country opens up its stock market to foreign investors.

In sum, these results suggest that stock market liberalization enhances the openness of domestic firms to foreign technology and encourages their adoption of global technology.[45]

5.3. The effect of stock market liberalization on economic growth

Thus far, our findings show that the innovation output of more innovative industries improves after a country liberalizes its equity market. However, it is not clear whether the positive effect of liberalization on economic growth found by previous studies is through the technological innovation mechanism or not. Further, liberalization can drive investment growth and productivity growth, both of which in turn promote economic growth (Bekaert et al., 2011; Henry, 2000a; Chari and Henry, 2008; Gupta and Yuan, 2009). Previous studies (e.g., Kogan et al., 2017; Chang et al., 2018) show that innovation enhances economic growth mainly through promoting productivity growth. Hence, if the positive effect of stock market liberalization on innovation we show captures an improvement in productivity growth after liberalization, we expect that liberalization leads to a significantly higher productivity growth in more innovative industries relative to less innovative industries, but an insignificant difference in investment growth between more innovative industries and less innovative industries.

To test this conjecture, we start by examining the effect of liberalization on the growth of industry value added, the growth of industry capital stock, and the growth of industry TFP. These three variables serve as proxies for industry-level economic growth, investment growth, and productivity growth, respectively. We then compare the effects across industries with different degrees of innovativeness. To perform this test, we define the growth of industry value added [$\Delta Ln(\$VA)$] as the change in the logarithm of industry value added from year *t*-1 to *t*. Because industry capital stock ($\$K$) and industry TFP (*TFP*) data are not available from the UNIDO database, we follow previous literature (e.g., Harberger, 1978; Nehru and Dhareshwar, 1993; Caselli, 2005) and construct $\$K$ and *TFP* based on the perpetual inventory method and the Cobb-Douglas production function, respectively. We compute the growth of industry capital stock [$\Delta Ln(\$K)$] and the growth of industry TFP growth [$\Delta Ln(TFP)$] as the change in the logarithm of industry capital stock and the change in the logarithm of industry TFP from year *t*-1 to *t*, respectively. To be concise, we provide the details on the estimation of $\Delta Ln(\$K)$ and $\Delta Ln(TFP)$ in the Online Appendix.

We then respectively regress $\Delta Ln(\$VA)$, $\Delta Ln(\$K)$, and $\Delta Ln(TFP)$ on *Lib* measured in year *t*-1 and include the same set of control variables described in Section 2.3, measured in year *t*-1, and industry-country and year fixed effects in the regressions. The results are reported in Columns 1, 5, and 9 of Table 12. The coefficient estimate of *Lib* is positive and significant at the 1% level in all three columns, confirming the previous findings that stock market liberalization leads to a significant increase in economic growth by enhancing both investment growth and productivity growth (Bekaert et al., 2011; Gupta and Yuan, 2009).

Next, we include the interaction between *Lib* and *Intensity* in the regressions to compare the growth effects of liberalization across industries. The results are presented in Columns 2, 6, and 10 of Table 12. The coefficient estimate of *Lib* × *Intensity* is positive and significant at the 5% level when $\Delta Ln(\$VA)$ and $\Delta Ln(TFP)$ are the dependent variable, respectively, but insignificant when $\Delta Ln(\$K)$ is the dependent variable, suggesting that stock market liberalization promotes the growth of industry value added and the growth of industry TFP through fostering innovation in more innovative industries. These results provide support to the premise that innovation is a channel for stock market liberalization to improve productivity growth and, in turn, economic growth, particularly in more innovative industries.

Finally, we follow Bekaert et al. (2011) and examine the temporary and permanent effects of liberalization. We construct two indicators to denote the temporary and permanent effects of stock market liberalization. The first dummy variable, Lib_{temp}, which captures the temporary effect, equals one for observations in the first three years after a country liberalizes its stock market and zero otherwise. The second dummy variable, Lib_{perm}, which captures the permanent effect, equals one for observations in more than three years after a country liberalizes its stock market and zero otherwise. In Columns 3, 7, and 11 of Table 12, where the dependent variable is $\Delta Ln(\$VA)$, $\Delta Ln(\$K)$, and $\Delta Ln(TFP)$, respectively, we replace *Lib* with Lib_{temp} and Lib_{perm}, and reestimate the regressions.

We find that the positive effect of liberalization on the growth of industry value added, the growth of industry capital stock, and the growth of industry TFP is not only temporary but also permanent, because the coefficient estimates of Lib_{temp} and Lib_{perm} are both positive and significant at the 1% level. In Columns 4, 8, and 12, we further include Lib_{temp} × *Intensity* and Lib_{perm} × *Intensity* in the regressions. The results show that the coefficient estimate of Lib_{temp} × *Intensity* is insignificant in all three columns and that the coefficient estimate of Lib_{perm} × *Intensity* is positive and significant at the 5% level when $\Delta Ln(\$VA)$ and $\Delta Ln(TFP)$ are the dependent variable but insignificant when $\Delta Ln(\$K)$ is the dependent variable.[46] These findings suggest that stock market liberalization is beneficial to the economy in both the short run and the long run. More important, in the long run, the enhancement of in-

[45] We cannot entirely rule out the possibility that pro-FDI policies and trade openness that are coupled with stock market liberalization can also play an important role in the cross-border technology transfer.

[46] The result in Section 5.2 that firms are more open to foreign technology after liberalization also speaks to the productivity enhancement of domestic countries through the alignment of domestic firms' innovative investment with the global trend of technology development.

Table 12
Innovation, stock market liberalization, and economic growth.

The sample contains public firms of manufacturing industries in countries experiencing stock market liberalization, which are jointly covered by Bureau van Dijk's Orbis patent database, United Nations Industrial Development Organization (UNIDO) Industrial Statistics database, and Penn World Table (PWT) version 8.0 database from 1981 to 2008. $\Delta Ln(\$VA)$, $\Delta Ln(\$K)$, and $\Delta Ln(TFP)$ are the annual growth rate of industry value added, industry capital stock, and industry total factor productivity in each two-digit Standard Industrial Classification (SIC) industry for each country each year, respectively. *Lib* is a binary variable that takes the value of one after a country liberalizes its equity market and zero otherwise. Lib_{temp} is a binary variable that takes the value of one for the first three years after a country liberalizes its equity market and zero otherwise. Lib_{perm} is a binary variable that takes the value of one from the fourth year after a country liberalizes its equity market and thereafter and zero otherwise. Variables in dollars are computed in real terms at constant national prices in 2005 US dollars. The definitions of other variables are in Table 3. Robust standard errors in parentheses are clustered by country-industry. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Variable	$\Delta Ln(\$VA)$				$\Delta Ln(\$K)$				$\Delta Ln(TFP)$			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Lib × *Intensity*		0.017***				−0.001				0.010**		
		(0.01)				(0.00)				(0.00)		
Lib	0.070***	0.027			0.033***	0.035***			0.076***	0.050***		
	(0.01)	(0.02)			(0.01)	(0.01)			(0.01)	(0.01)		
Lib_{temp} × *Intensity*				0.009				−0.002				0.009
				(0.01)				(0.00)				(0.01)
Lib_{perm} × *Intensity*				0.019***				−0.001				0.011**
				(0.01)				(0.00)				(0.00)
Lib_{temp}			0.077***	0.054**			0.032***	0.037***			0.087***	0.063***
			(0.01)	(0.02)			(0.01)	(0.01)			(0.01)	(0.02)
Lib_{perm}			0.045***	−0.003			0.035***	0.037***			0.041***	0.014
			(0.02)	(0.02)			(0.01)	(0.01)			(0.01)	(0.02)
VA	−2.586***	−2.639***	−2.590***	−2.646***	0.269***	0.273***	0.269***	0.272***	−1.955***	−1.988***	−1.960***	−1.993***
	(0.33)	(0.33)	(0.33)	(0.33)	(0.09)	(0.09)	(0.09)	(0.09)	(0.25)	(0.25)	(0.25)	(0.25)
GDP	−0.184***	−0.184***	−0.178***	−0.178***	−0.036***	−0.036***	−0.037***	−0.037***	−0.144***	−0.144***	−0.135***	−0.135***
	(0.03)	(0.02)	(0.03)	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)
VGDP	−1.127***	−1.131***	−1.100***	−1.103***	0.218*	0.218*	0.215*	0.216*	−0.911***	−0.914***	−0.874***	−0.877***
	(0.24)	(0.24)	(0.24)	(0.24)	(0.12)	(0.12)	(0.12)	(0.12)	(0.16)	(0.16)	(0.17)	(0.16)
HumCap	0.079	0.083	0.061	0.067	−0.000	−0.001	0.001	0.001	0.274***	0.277***	0.249***	0.252***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.05)	(0.05)	(0.05)	(0.05)	(0.08)	(0.08)	(0.08)	(0.08)
Trade	−0.003	−0.003	0.014	0.015	−0.050**	−0.050**	−0.051**	−0.051***	−0.073**	−0.073**	−0.049	−0.049
	(0.04)	(0.04)	(0.05)	(0.04)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)
Gov	0.650***	0.654***	0.642***	0.647***	0.216***	0.216***	0.217***	0.217***	0.104	0.107	0.093	0.096
	(0.12)	(0.12)	(0.12)	(0.12)	(0.05)	(0.05)	(0.05)	(0.05)	(0.08)	(0.08)	(0.08)	(0.08)
Intensity	−0.010**	−0.021***	−0.011**	−0.021***	−0.001	−0.001	−0.001	−0.001	−0.005	−0.011***	−0.005	−0.011***
	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	7,168	7,168	7,168	7,168	7,168	7,168	7,168	7,168	7,168	7,168	7,168	7,168
R-squared	0.15	0.15	0.15	0.15	0.13	0.13	0.13	0.13	0.16	0.16	0.16	0.16

novation output as a result of liberalization is likely to be the driver of productivity growth and in turn economic growth.

5.4. Stock market liberalization and capital allocative efficiency

Previous literature (e.g., Gupta and Yuan, 2009; Bekaert et al., 2011) shows the improvement of capital allocative efficiency as an important mechanism for financial openness to enhance productivity. In this section, we discuss whether stock market liberalization enhances the efficiency of capital allocation in firms' innovation process, thereby promoting productivity growth. Moreover, we link the three channels through which stock market liberalization promotes innovation discussed in Section 4 to the explanation of the overall growth effect, i.e., how these channels directly relate to investment and productivity growth.

We first analyze the effect of the openness of a country's stock market on capital allocative efficiency in the innovation process. Using macroeconomic data at the country level, Bekaert et al. (2011) show a higher sensitivity of investment growth to global growth opportunities post-liberalization and conclude that stock market openness better aligns a country' investment with growth opportunities, which improves capital allocative efficiency and thus enhances productivity. Different from Bekaert et al. (2011), who focus on firms' conventional investment, we examine firms' innovative investment, which is excluded from their conventional investment.[47] We use patent count, citation count, and the number of innovative firms as the output of firms' innovative investment, and use the average number of patents applied by US firms in an industry to capture the global industry propensity to innovate (e.g., Acharya and Subramanian, 2009; Hsu et al., 2014).[48] We show in Table 4 that firms' innovative investment significantly increases in high innovation propensity industries after the opening of a country's stock market, suggesting that stock market liberalization improves capital allocative efficiency in firms' innovative investment.[49] Taken together, our findings complement Bekaert et al. (2011) by identifying a new channel, i.e., enhancing capital allocative efficiency in innovative investment, for stock market liberalization to improve productivity.

Next, we consider the efficiency of capital allocation across and within industries by linking the three channels and the liberalization effect on existing and new firms discussed in Section 4 to the explanation of the growth effect. The empirical evidence in Tables 6–8 indicates that liberalization facilitates cross-industry capital allocative efficiency by promoting the innovation output of firms in industries with a higher propensity to innovate but subject to financial constraints, lack of risk sharing, and weak governance. Furthermore, the results in Table 9 show that liberalization turns existing non-innovative firms into innovative firms and attracts more innovative firms to go public, suggesting that liberalization also promotes within-industry capital allocative efficiency and highlighting the beneficial role of liberalization in the process of creative destruction. Collectively, these results further support the notion that the improvement of cross-industry and within-industry capital allocative efficiency is an important mechanism for liberalization to promote productivity growth and thus economic growth.

6. Conclusion and discussion

In this paper, we have investigated the effect of stock market liberalization on technological innovation. Using a fixed effects identification strategy and a sample of 20 developed and emerging economies between 1981 and 2008, we find that stock market liberalization promotes innovation output and the effect is disproportionately stronger in more innovative industries. We find support for three economic channels underlying the positive impact of stock market liberalization on innovation: the financing channel, the risk-sharing channel, and the corporate governance channel. We further show that innovation is a plausible mechanism that links stock market liberalization with economic growth through enhancing productivity growth.

While we show that stock market liberalization appears to have a positive, causal effect on innovation, we note two important caveats when interpreting or generalizing our findings. First, even though we explore various model specifications and conduct different tests to address the endogeneity issue, unobservable, omitted time-varying country-industry factors still could drive the positive relation between stock market liberalization and innovation in more innovative industries. For example, we cannot completely rule out the possibility that firms shift their patenting strategy from patenting less important innovations to more important ones after a country liberalizes its stock market. This challenge is difficult to overcome because we can observe only a firm's patents, not its total innovation that includes both patents and unpatented innovations. Second, although our economic channels are based on economic theory, our tests are unable to perfectly identify these channels without suffering from potential endogeneity biases. The three channels we discuss are not necessarily mutually exclusive and could jointly contribute to the positive effect of stock market liberalization on innovation.

[47] According to the 2008 System of National Accounts (SNA) released by the United Nations, recording R&D expenditures as gross capital formation is recommended only from 2008 onward.

[48] An alternative measure of innovation is R&D expenditures across different industries. However, this leads to several difficulties in the cross-country setting. For example, accounting treatment of R&D expenditures as expenses or capitalized intangible assets varies across countries. Furthermore, as raised in Lerner, Sorensen, and Stromberg (2011), not all R&D expenditures are used productively and some are even wasteful, thus making the interpretation of R&D expenditures difficult.

[49] The results in Table 12 further confirm our premise. Although the investment on average significantly grows after a country liberalizes its stock market, the difference between industries with high and low innovation intensity is insignificant, highlighting the difference between conventional investment and innovative investment. In contrast, in addition to a general enhancement of productivity after the liberalization of a country's stock market, a disproportionately stronger enhancement of productivity exists in industries with higher innovation intensity.

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