Capital Market Integration and Innovation:

Firm-level Evidence from 43 Countries

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ABSTRACT Using a novel firm-level panel data set covering 43 countries over two decades, we find that capital account liberalization is significantly associated with higher patenting activity. The effect is identified through a difference-in-difference-in-differences estimation strategy. We show that the effects of capital account liberalization are more pronounced among firms in R&D intensive sectors. We further find that the impact is stronger for firms that are located in economies that have a relatively better legal environment. Our results provide the first global evidence on the real effect of capital market integration.

Keywords: capital account liberalization, firm innovation, financial constraints, R&D intensity

JEL Classification: F38; O31; O32

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1. Introduction

Globalization and innovation are two important themes of our time. On the one hand, innovation is at the heart of sustainable long-term growth and development. On the other hand, the world we lived in has become 'flat' thanks to globalization, both in lifting barriers to cross-border trade flows (trade liberalization) and capital flows (capital account liberalization), despite recent setbacks (Friedman 2007). Does going global spur more firm innovation? How does the advance of globalization impact on firm innovation? A substantial literature, both theoretical and empirical, examines the impact of trade liberalization, one aspect of globalization, on innovation by domestic firms; see for example, Rivera-Batiz and Romer (1991), Grossman and Helpman (1991), Bustos (2011), Bloom et al. (2016), Autor et al. (2016a), Aghion et al. (2017), Coelli et al. (2017) and Arkolakis, et al. (2018), among others. Yet, less is known about the impact of capital account liberalization, another important aspect of globalization, on innovation by domestic firms.[1] By constructing a comprehensive firm-level patent and financial characteristics data set that covers more than 40 countries over two decades, this paper fills the gap by evaluating empirically the impact of lifting barriers to cross-border capital flows on firm innovation.

We contribute to the literature in three ways. First, a key data challenge in the innovation literature lies in the matching of patents with firm-level data. Inconsistencies arise when performing matching by firm name only, as is typical in the existing studies, between firm names recorded on patents in global patent databases and firm names recoded in firm-level financial databases, which often results in substantial false negative matches. We address the data problem by using a novel

[1] As pointed out by Williamson (2007, p. 407), "a key weakness of the global capital markets literature is that it rarely assesses empirically its impact on the real economy", despite substantial increase in cross-border capital mobility in the last few decades.

internet-based matching approach recently pioneered by Autor et al. (2016b). The new method matches firms by both firm names and more importantly web URL, which improves the matching rate between patents in the global patent databases substantially. We obtain a novel cross-country firm-level panel dataset that integrates the best available firm-level patent data with internationally comparable firm-level financial information of listed firms. This dataset, combined with the latest available panel data on capital account liberalization measures, enables us to investigate the relationship between capital account liberalization and firm innovation by controlling for a plethora of firm-, industry- and country-level characteristics that might otherwise confound the identification of the impact of capital account liberalization to firm innovation. Our newly constructed firm-level dataset, after cleansing and integrating with country-level data, has more than 174,890 firm-year observations for 17,550 non-financial firms from 43 countries over the period 1995 to 2013.

Second, there are valid concerns regarding the endogeneity problem, as countries that tighten or liberalize capital controls tend to be systematically different from other countries in areas such as the level of financial and economic development, quality of institutions, etc. We address identification problem by applying a generalized difference-in-difference-in-differences (triple differences, or DDD) method to many groups (sectors, countries) and time periods as in Imbens and Wooldridge (2009) to identify the effect of capital market integration on firm innovation.[2] Combining our cross-country staggered capital account liberalization events with firm-level panel data, we exploit not only variations between pre-post changes in treatment group (countries that liberalize their capital accounts) and pre-post changes in control group (countries that do not

[2] In this paper, the terms capital market integration and capital account liberalization are used interchangeably.

liberalize their capital accounts) but more importantly, cross-sector variation within the treatment group. Our identification thus does not rely on the usual assumption of a common trend between the treatment and the control group, as in conventional difference-in-differences (DID) estimation. Instead, our identification comes from within-country variation across sectors where some sectors are technically, *a la* Rajan and Zingales (1998), more R&D intensive (exposed more to intervention) while others are not (exposed less to intervention). The DDD approach captures the treatment effect that is free from country-specific time-varying confounder effect such as the level of financial and economic development, quality of institutions, etc, which may be present if using DID estimation.

Third, we set up a simple theoretical model with heterogeneous firms making innovation investment decisions and operating in monopolistically-competitive markets, but faced with capital controls. Armed with this model we illustrate how firm innovation decision is affected by the lifting of capital controls. In particular, we show how industry and firm characteristics interact with changes in capital control policy in shaping the innovation landscape. The theoretical model thus provides a useful lens to examine the empirical results.

In our baseline regression, we find that the removal of capital controls is significantly positively associated with firms' patenting activity. This result holds not only for patent counts but also for patent quality measured by both patent family size and patent citations, which suggests that the increase in patenting activity is not simply a "lawyer effect", i.e., patenting more to protect intellectual property, further corroborating the idea that real innovation indeed takes place after

the liberalization. We additionally show that the results are not driven by country- or sector-specific trends by controlling for country, industry, firm, and year fixed effects.

Most importantly, we are able to identify the impact of capital market integration on innovation. Our identification comes from differential responses of firms in sectors with varying R&D intensity in the same treatment group (countries that liberalize their capital accounts). Specifically, under the generalized DDD framework, we interact capital account liberalization variable with a time-invariant R&D sector intensity variable, which is considered to be exogenous under the same assumptions used by Rajan and Zingales (1998). We find that the positive effect of capital account liberalization on firm innovation is more pronounced in sectors that are more R&D intensive, which identify the impact. Furthermore, we show that firms in more R&D intensive industries that are bigger in size at the beginning of the sample period, or firms that are more financially constrained or have better corporate governance before liberalization, increase their innovation activity after a country liberalizes its capital accounts, suggesting that capital account liberalization alleviates firms' financial constraints and promotes innovation activity. In addition, we verify that domestic institutions matter. We find that the impact is stronger for firms in countries that have a relatively better legal environment. The results are robust to different measures of capital account liberalization, different sub-samples and inclusions of various fixed effects.

Related Literature: There is a growing literature that examines the general economic impacts of capital account liberalization (see Bekaert and Harvey, 2000; Bekaert et al., 2005; Levine, 2001; Quinn and Toyoda, 2008; Rodrik and Subramanian, 2009; Stiglitz, 1999, Klein et al., 2008, among others). These studies typically use aggregate country-level data generating inconclusive evidence

of, for example, the impact of capital account liberalization on productivity and economic growth. One major shortcoming of using aggregate data is that it is limited in its ability to disentangle the differential effects of firms across sectors within a country. Perhaps more important though, is that aggregated data can also make it difficult to address the endogeneity problem as countries that tighten or liberalize capital controls tend to be systematically different from other countries in areas such as the level of financial and economic development, quality of institutions etc. (Henry 2007; Forbes et al. 2015). Our use of disaggregated firm-level panel data across 43 countries expand the tools available to tackle the endogeneity problem and thus offers clear benefits relative to aggregated data.

There is a paucity of research examining the effects of capital account liberalization taking firm-level data as the point of observation. Using data for 369 firms from 5 countries (about 74 firms in each country), Chari and Henry (2008) show that stock market liberalizations lead to an increase of the growth rate of the typical firm's capital stock. Harrison et al. (2004) study a cross-country firm-level data in 38 countries that cover over 7000 firms for the years 1988–1998 (about 185 firms in each country), and find that capital controls increase firms' financial constraint. Recently, Larrain (2014) examines the impact of capital account opening on wages using aggregate data from Eastern European countries. Larrain and Stumpner (2017) study how capital account liberalization impacts resource allocation in 10 Eastern European countries. A few studies turn to examine individual country case, with results showing that there are substantial costs involved at the firm-level when imposing capital controls (Alfaro et al., 2017; Forbes 2007; Forbes et. al. 2016). Using firm-level data from one country, Hungary, Varela (2017) investigates the impact of reducing distortions in the access to international capital markets on competition and productivity

and finds significant positive effects. Although single country studies have the advantage of examining the finer details of the impact of policies in a given country, they have limits in terms of scope for generalization of conclusions or applicability to other countries.

Although many studies examine the general economic impacts of capital account liberalization, little attention has been paid to its impact on firm innovation, which is at the heart of productivity and long-term economic growth. The closest to ours is Moshirian et al. (2018). However, our paper differs from this paper in several aspects. Firstly, their study focuses on equity market liberalization, which is only one out of the 10 categories of capital accounts opening. It is, however, difficult to separately identify the effect of reform coming from one category with those coming from other categories, which could have confounding impacts on firms' innovation activity. Secondly, our estimation is based on a firm-level panel data from multiple countries, while theirs focuses on the aggregate industry-level innovation activity. Our cross-country firm-level sample allows us (1) to use more powerful tools to mitigate the endogeneity concern; (2) to look deeper into firms' heterogeneous responses to globalization; (3) to control for the standard firm characteristics that have been documented to influence firms' innovation output, which isolates the component of firm innovation that is driven by a country's removal of capital controls, and not by firm-specific or industrial characteristics. Our paper provides the first large scale cross-country firm-level evidence on the impact of capital market integration on innovation by domestic firms.

The paper proceeds as follows. The next section develops a theoretical model illustrating the impact of capital account liberalization on innovation. Our empirical estimation strategy is presented in Section 3. Section 4 describes data and the sample selection. Section 5 presents the

main empirical results. Section 6 explores economic mechanisms of the impact and conducts various robustness tests. Section 7 concludes.

2. A stylized model

In this section, to guide our empirical analysis we set up a simple model of monopolistic competition between firms with heterogeneous productivity along the lines of Melitz (2003). There are two new ingredients in our model. First, firms engage in productivity-enhancing R&D and produce in a monopolistic competitive market. Second, there are capital controls preventing firms' direct access to international markets. We use the model as a lens to clarify how lifting of capital controls leads to firms to engage more in R&D activity and innovation conditioning on the firm's characteristics such as the level of initial productivity, the degree of financial constraint and, the sector's R&D intensity, as well as the country's financial development. Our model illustrates the channels through which capital account liberalization impacts on firm innovation.

2.1 Structure

The representative consumer has preference (U) over the output of sector i (X_i), $U=\sum_1^I \alpha_i \ln(X_i)$, where $\sum_1^I \alpha_i = 1$ and $\alpha_i \geq 0$. Differentiated varieties are produced in each sector and preference over each variety $x_i(\omega)$ takes the constant elasticity of substitution form, $X_i = \left[\int_{\omega\in\Omega_i} x_i(\omega)^{\frac{\sigma-1}{\sigma}} d(\omega)\right]^{\frac{\sigma}{\sigma-1}}$ where $\sigma > 1$. The price index for consumption of sector i's varieties is $P_i = \left[\int_{\omega\in\Omega_i} p_i(\omega)^{1-\sigma} d(\omega)\right]^{\frac{1}{1-\sigma}}$. Demand for each individual variety is given by

$$x_i(\omega)=p_i(\omega)^{-\sigma} X_i P_i^{\sigma-1}. \quad (1)$$

There are fixed costs of entry and production so that each firm will choose to produce a different variety. After paying entry costs, a firm obtains a random draw of productivity φ from a distribution $g(\varphi)$. Upon learning φ, a firm makes its decision on innovation intensity, which will improve its productivity in the subsequent production stage.

Production of each variety incurs a fixed cost of f units of composite inputs and a variable cost that is inversely related to its productivity φ and also in units of composite inputs. The production of composite inputs involves both capital and labor, with unit cost of this composite input z being $z = (R)^{\beta}(W)^{1-\beta}$, and where R and W are the costs of capital and labor respectively. The total cost of production of q units of output of a variety is thus

$$\Gamma(\varphi)=\left[f + \frac{q}{\varphi}\right] z. \quad (2)$$

Note that we can index firms by φ since firms with same productivity will behave symmetrically.

The marginal cost of production is $MC(\varphi) = \frac{z}{\varphi}$. Profit maximization of a firm requires that the equilibrium price of a variety is a constant markup over marginal cost: $p(\varphi) = \frac{\sigma}{\sigma-1}\frac{1}{\varphi}(R)^{\beta}(W)^{1-\beta}$.

Optimal firm revenue can then be derived as

$$r(\varphi) = Bz^{1-\sigma}\varphi^{\sigma-1}, \text{ where } B = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} X_i P_i^{\sigma-1}. \quad (3)$$

The equilibrium firm profit net of fixed production cost are obtained as

$$\pi(\varphi) = \frac{r(\varphi)}{\sigma} - fz \quad (4)$$

2.2 Innovation decision

Innovation improves productivity but requires costly investment. Following Aghion et al. (2017), we assume that the cost of innovation investment is a quadratic function of innovation, $C(\lambda) =$

$\frac{1}{2}a\lambda^2 z$, where λ measures innovation which takes the firm's initial productivity φ to $\left(\lambda^{\frac{1}{\sigma-1}}\right)\varphi$ with $\lambda > 1$ and a measures innovation efficiency (Guadalupe et al. 2012).

A firm with an initial random productivity draw φ chooses a level of innovation λ^* to maximize its firm value.

$$\pi(\lambda, \varphi) = \frac{Bz^{1-\sigma}\lambda\varphi^{\sigma-1}}{\sigma} - fz - \frac{1}{2}a\lambda^2 z \quad (5)$$

The first order condition with respect to λ delivers:

$$\frac{Bz^{1-\sigma}\varphi^{\sigma-1}}{\sigma} = a\lambda z \quad (6)$$

The optimal innovation level is given by

$$\lambda^* = \frac{Bz^{-\sigma}\varphi^{\sigma-1}}{a\sigma}. \quad (7)$$

2.3 Capital controls

A competitive financial intermediary sector ('bank') takes local or foreign savings and lends it to firms. It charges an intermediation cost ε which reflects the level of domestic financial development. The higher the level of domestic financial development, the lower the intermediation cost ε. Capital control manifests in this model by imposing the restriction that only banks can finance through the international capital market, paying a cross-border transaction cost μ. The cost of bank financing through domestic and foreign savings becomes R^D and $R^* + \mu$ respectively where R^D represents the local deposit rate and R^* is the prevailing interest rate in the international market. If stringent capital controls result in a prohibitively high cross-border transaction cost μ, we have $R^D < R^* + \mu$ (or $R - \varepsilon < R^* + \mu$) where R is firm's cost of borrowing. On the other hand, under capital controls, lending to firms gives banks a net return of $R - \varepsilon$ which is higher

than the return from lending to the international market $R^* - \mu$. Thus, with capital controls (high μ), there are no capital inflows. Capital account liberalization reduces cross-border transaction cost μ and thus a firm's cost of borrowing R. In equilibrium, $R = R^* + \varepsilon + \mu$. We now establish the relationship between capital account liberalization (a reduction of μ and R) and firm innovation.

Proposition 1. Capital account liberalization leads to more firm innovation. The higher a firm's initial productivity, the greater increase in firm innovation following capital account liberalization.

Proof: We measure capital account liberalization by a reduction in cross-border transaction cost μ which results in lower R. From (7), we have

$$\frac{\partial \lambda^*}{\partial \mathrm{R}} = -\frac{B\varphi^{\sigma-1}}{a} z^{-(\sigma+1)} \beta R^{(\beta-1)} < 0 \tag{8}$$

The response of λ^* to changes in R depends on a firm's initial productivity.

$$\frac{\partial \lambda^*}{\partial \mathrm{R}\, \partial \varphi} = -(\sigma - 1)\frac{B\varphi^{\sigma-2}}{a} z^{-(\sigma+1)} \beta R^{(\beta-1)} < 0 \tag{9}$$

QED

Whether a firm expands its innovation activity depends crucially on whether it is an R&D intensive sector. For firms in R&D intensive sector, innovation is essential for survival and expansion. The response of firm's innovation activity following capital account liberalization will vary from sector to sector.

Proposition 2. Firms in more R&D intensive sectors engage more in innovation activity following capital account liberalization.

Proof: We measure a sector's R&D intensity, *RD*, by the ratio of innovation cost to sales.

$$RD = \frac{\frac{1}{2}a\lambda^2 z}{Bz^{1-\sigma}\varphi^{\sigma-1}} = \frac{\frac{1}{2}a\lambda^2 z}{az\sigma\lambda} = \frac{\lambda}{2\sigma} \tag{10}$$

From (1), we have

$$\frac{\partial \lambda^*}{\partial \mathrm{R}\,\partial \mathrm{RD}} = -2\sigma^2 z^{-1}\beta R^{(\beta-1)} < 0 \tag{11}$$

Thus the response of λ^* to changes in R depends upon the sector's R&D intensity. **QED**

2.4 Credit constraint

Firm credit constraints are introduced through a simple 'costly enforcement model' where, due to the possibility of a firm reneging on its debt, a firm can only borrow up to a fraction θ of its operating profit $\frac{r(\varphi)}{\sigma}$. With credit constraint, a firm's profit maximization problem is given by

$$\text{Max } \pi(\lambda, \varphi) = \frac{Bz^{1-\sigma}\lambda\varphi^{\sigma-1}}{\sigma} - fz - \frac{1}{2}a\lambda^2 z \tag{12}$$

$$\text{s.t. } \frac{1}{2}a\lambda^2 z = \theta\frac{Bz^{1-\sigma}\lambda\varphi^{\sigma-1}}{\sigma} \tag{13}$$

The first order condition with respect to λ requires that the firms innovate up to the level where marginal benefit meets marginal cost:

$$\lambda^* = \left(\frac{1+\mu\theta}{1+\mu}\right)\frac{Bz^{-\sigma}\varphi^{\sigma-1}}{a\sigma} \tag{14}$$

where μ is the Lagrange multiplier of the credit constraint. Together with the budget constraint equation, we can solve for μ and thus the optimal level of innovation under credit constraint is

$$\lambda^* = 2\theta\frac{Bz^{-\sigma}\varphi^{\sigma-1}}{a\sigma} \tag{15}$$

We thus have the following proposition.

Proposition 3. Credit constrained firms engage more on innovation after capital account liberalization.

Proof: From (8), we have

$$\frac{\partial \lambda^*}{\partial \mathrm{R}} = -2\theta\frac{B\varphi^{\sigma-1}}{a}z^{-(\sigma+1)}\beta R^{(\beta-1)} < 0 \tag{16}$$

The response of λ^* to changes in R depends on a firm's credit constraint. **QED**

3. Empirical Strategy

To estimate the impact of capital account liberalization on innovation and to identify the effect, we follow a two-step strategy. First, to estimate the impact we employ a generalized difference-in-differences method (DID). Second, to identify the effect, we apply a generalized difference-in-difference-in-differences approach (DDD).

3.1 Impact analysis

Our data covers country- and firm-level information across 43 countries over two decades. During the period of study, countries varied in their timing with respect to opening up (or tightening) of their capital accounts. Thus, the capital account liberalization 'events' are staggered over time, which provides us a unique opportunity to exploit the cross-country, cross-year variation. A generalized DID method is appropriate in such a data setting where our objective is estimating the impact of capital account liberalization on innovation by domestic firms. It extends the DID approach into a multi-period, multi-group setting and has been widely used (Bertrand, Duflo, and Mullainathan (2004), Hansen (2007), Imbens and Wooldridge (2009)) and Larrain (2014)). Intuitively, given the staggered liberalization events, we calculate the pre-post change in innovation for firms in the treatment countries and then compare it with the pre-post change in innovation for firms in the control countries in the same year, assuming that sample countries share the same global trend. As in Imbens and Wooldridge (2009), the policy variable can be a continuous variable (capturing the degree of capital account liberalization).

The ‘control’ group includes the non-‘event’ countries, i.e., countries that do not make changes to their capital accounts in a given year.[3] The treatment group includes countries that make changes to their capital accounts in that year. The identifying assumption is that the two groups of countries share common global trend which, if satisfied, delivers an unbiased estimate of the impact. The DID thus remove shocks that are common to both the treatment and control groups.

One potential concern is that there might be factors specific to the treatment group, other than lifting barriers to capital accounts, that might affect innovation. At the country-level, for example, trade liberalization could be a factor. To control for the impact of lifting of trade barriers on innovation, we include in the regression the *de facto* measure of a country’s trade openness which is the sum of imports and exports of goods and services divided by GDP (*TradeOpen*). This variable captures the *actual* changes of trade barriers that might also affect innovation by domestic firms in the “treatment” group. In addition, we also control for other factors such as the level of patent protection (*P_INDEX*), government expenditure (*GovExpense*) and domestic financial development which is proxied by the ratio of private credit by deposit money banks to GDP (*CREDIT*). In all regressions, we control for time-invariant country and firm fixed effects as well as year fixed effects that might confound the estimates of the impact of capital account liberalization on firm innovation. The inclusion of a rich set of controls will help alleviate the concern that there might be omitted factors that are correlated with both capital account liberalization and firm innovation. Finally, when conducting robustness checks on our main results, we provide estimates from sub-region analyses on the assumption that countries located in the same geographical sub-regions are more likely to share a common trend due to closer trade and

[3] It should be noted though, that the control group does include countries which make changes to their capital accounts either before, or after, the year in question.

investment ties. Sub-group analysis also provides estimates excluding countries that do not make changes to their capital accounts during the period of study.

3.2 Endogeneity

It is more challenging to identify the impact of capital account liberalization on firm innovation. There is an immediate concern of endogeneity that needs to be addressed. A cursory logic might dismiss the potential influence a firm level variable could have to a national aggregate such as capital account liberalization, and vice versa. Yet under consideration, and conditional on the context we are exploring, such a pattern of association is very likely. A well-functioning government institution would observe and then respond to the needs and behavior of the firms in the economy. Moreover, if the government is effective, we should see corresponding responses by firms and hence a pattern of bi-directional causality is intuitively established. For example, it is possible that countries having a lack of dynamics in innovation choose to liberalize its capital accounts in anticipation of driving down its cost of capital and encouraging risk-sharing, thus promoting innovation. It is also possible that there are unobserved factors that drive both capital account liberalization and innovation activity. That is, the standard DID estimate might conflate changes in capital account liberalization with changes in other country-specific variables, violating the common trend assumption.

To address the endogeneity concern, we employ a more robust estimation strategy, namely the generalized difference-in-difference-in-differences approach following Imbens and Wooldridge (2009). The idea is that upon the base of DID we introduce another layer of treatment-control groups within the same country, with new the layer capturing exogenous variation in sectoral R&D

intensity. The new control group layer includes firms from low R&D intensive sectors which are not exposed to treatment (in both treatment and control countries) but are subject to country-specific time-varying factors such as the level of financial and economic development, a lack of innovation dynamic, quality of institutions, etc. Intuitively, a DDD approach compares the difference in pre-post changes in the innovation of *firms from high R&D intensity sector* in the "capital account liberalization" country and the "non-capital account liberalization" country with the similar difference in *low R&D intensity sector* in the "capital account liberalization" country and the "non-capital account liberalization" country, thus isolating the impact of capital account liberalization.

The generalized DDD approach can also be understood as subtracting two DIDs. The first DID is to estimate the differential effects between pre-post changes in innovation for *firms from low R&D intensity sector* in the "treatment" country (not exposed to treatment) and pre-post changes in innovation for firms from low R&D intensive sectors in the "control" country (not exposed to treatment), with results capturing only the effect of the country-specific time-varying confounder, but not the treatment effect. The second DID is to estimate the differential effects between pre-post changes in innovation for *all firms* in the treatment country and pre-post changes in innovation for *all firms* in the control country, which captures *both* country-specific time-varying confounder effect *and* the treatment effect. Subtracting the first DID from the second DID, i.e., the triple difference (DDD), therefore isolates the treatment effect that is free from country-specific time-varying confounder effect. Since the generalized DDD estimate is not driven by country-specific time-varying factors such as the level of financial and economic development, a lack of innovation

dynamic, quality of institutions, etc., it thus offers identification of the impact of capital account liberalization on firm innovation.

4. Data

We measure a firm's innovation output using patent data obtained from European Patent Office World Patent Statistical Database (here after EPO PATSTAT).[4] This database has information on patent assignees, patent family links, and patent citations, which facilitates the computation of different measures of the *quality* of innovation along with *quantity* measure (see Section 4.1 below for discussion of the measurements).

We collect firm-level financial data from Capital IQ Global and North America. The sample represents all firms covered by Capital IQ Global and North America with necessary data for our empirical analyses. We exclude firms from financial sectors (SIC 2-digit: 60-69) and restrict firms to have necessary data to compute the firm-level control variables.[5] We obtain country-level variables from World Bank Development Indicators. We calculate sectoral indexes using United States data from Capital IQ North America.

One of the biggest obstacles faced by cross-country innovation studies is the difficulty of matching across different data sources. First, as patent offices typically allow patent applicants to state the name of the assignee, there are tremendous variations in spelling or even spelling errors of company names in the patent database. Second, as different databases have different naming conventions, even the identification with rule-based or dictionary-based approach could not fully

[4] Data are retrieved from the online EPO PATSTAT Autumn 2016 version.
[5] This data step is common in the literature. See Brown et al. (2013) and Bereskin et al. (2018) for example.

address the mismatch problem. In addition, firms' financial data is often reported at a consolidated level while the patent data is often at the subsidiary level. Without dataset containing information on corporate ownership structure, it will be difficult, if not impossible, to match firm subsidiaries in one list to ultimate owners in another list.

In this paper, we address this challenge by employing the refined matching procedure proposed by Autor et al. (2016b). Specifically, we match data on the PATSTAT assignee names from EPO PATSTAT with financial database Capital IQ Global and North America by both firm name and firm web URLs matching. This matching technique corrects for an enormous amount of false negatives when matching by company names only.

The procedure of the matching technique is as follows: First, following Autor et al. (2016b), we clean the firm names by removing punctuation and accents, and standardize the commonly used words such as LTD, Corp, Corporation in all firm names in both the patent and financial data. We then perform an initial matching by these standardized names. This gives us only about 59,000 lines of matched firms from these two datasets. Next, we search the internet for the names of each patent assignee and each Capital IQ Global and North America firm (standardized format, 57,172). Our computer program helps retrieve the URLs of the top five search results for each firm name, which serves as the input to the next step of the algorithm. Based on the URLs, we consider a patent assignee and a Capital IQ firm to be a match if: (a) the top search results for the patent assignee contain the company website listed in Capital IQ or (b) the top five search results for the patent assignee and the Capital IQ firm share at least two URLs in common. This gives us about

280,000 lines of matched firms in these two datasets (see Appendix B for a detailed description of the matching process and the matching results of IBM in Appendix Table A2 as an example).

Then, we match another international data source, FactSet Lionshares, with our joint database of patents and financial data, based on international security identifier ISIN and CUSIP (for North America firms). In addition, we calculate sectoral indexes from US publicly listed firms and then match it to our combined dataset by SIC 2-digit indicator. Lastly, we match several country-level measures that are used as control variables and partition measures to our combined dataset by ISO alpha-3 country code. Our final sample on innovation relies on the joint availability of innovation measures, financial variables and capital account liberalization index data, and consists of 174,890 firm-year observations for 17,550 non-financial firms from 43 countries from 1995 to 2013 (See Table 1 for detailed sample breakdown by country).

< Table 1 is about here >

4.1 Firm-level Innovation Variables

Following previous literature (e.g., Balsmeier et al., 2017; Luong et al., 2017), we use patent counts as the measurement of firms' innovation quantity. Patent applications of firm *i* in year *t* are counted as PAT_{it}. Fortunately, EPO PATSTAT organizes patents within "patent families", where each unique patent corresponds to a unique family identifier. Hence in our estimation, each patent represents a unique invention, that is, applications are identified with family ID so that the same patent will not be repeatedly counted if it is filed in subsequent years or in multiple countries. Another advantage of this database is that it has harmonized applicant names, multiple applications filed by the same firm will be identified with the same harmonized applicant name.

As for patent quality, we follow Harhoff et al. (2003) and use two measures that are documented to be positively correlated with the value of patent rights: patent "family size" and patent citations.[6] Patent "family size" is computed as the number of jurisdictions in which patent protection was sought for the same invention. Patent citation is the total number of forward citations received by patent applications of each firm within a 5-year window period.

Similar to Luong et al. (2017), we address several concerns related to the innovation measures calculated based on data from PATSTAT. First, we avoid truncation problems related to patents by using published patents and calculate citations within 5-year windows from the year of publication. Second, we avoid double-counting concerns by retrieving patents with a unique family ID. Third, we address the right skewness issue of patent count and citation distributions by winsorizing these variables at 1% tails and then use the natural logarithms of 1 plus the actual values to avoid losing firm-year observations with 0 patents or citations.

4.2 Capital Account Liberalization

Measuring the degree of a country's capital account liberalization with the rest of the world is challenging due to the nature of gradual progress of liberalization itself. In this paper, we use an integrated capital account restrictions index, *KA*, for an unbalanced panel of 100 countries from 1995 to 2013 constructed by Fernández et al. (2016) and based on the information from IMF's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER). This is a *de*

[6] It has been well documented in the empirical works that the number of countries in which a patent is filed is correlated with other indicators of patent value. See, e.g., Grupp (1996, 1998), Lanjouw, Pakes, and Putnam (1998), Harhoff, Scherer, and Vopel (2003), Dernis and Khan (2004), and Guellec and van Pottelsberghe (2004).

jure indicator of capital account restrictions in that it is based on the officially designated policy reforms and is less sensitive to reverse causality issues in panel regressions (Collins, 2007).[7] Different from alternative *de jure* measures proposed in Quinn and Toyoda (2008) and Chinn and Ito (2008), this measure reflects detailed information regarding restrictions on capital inflows and outflows, and importantly covers a substantial number of countries. The index measures a country's degree of financial openness based on a series of binary dummy variables capturing restrictions on international transactions across ten asset categories: equity, bond, collective investments (also referred to as funds), derivatives, financial credits, commercial credits, real estate, direct investment, money market instruments, and guarantees, sureties & financial backup facilities. This measure ranges from 0 (capital account fully open) to 1 (capital account fully restricted). We rescale the variable by using one minus the original index such that a value of zero indicates full capital controls and a value of 1 indicates no restrictions on the overall capital accounts.[8] That is, the higher the index *KA*, the more open a country's capital accounts. Figure 1 shows the average degree of capital account liberalization in 2010 across the world. As we can see, countries in North America and Western Europe are mostly fully liberalized while other countries in Asia, Africa and Latin America are still progressing towards more capital market integration.

4.3 Control Variables

Following previous literature, during estimation we will control for both firm level controls and country level controls that could affect a firm's innovation output. Firm level characteristics are measured by firm's financial information taken from the Capital IQ database. We include firm age

[7] See in Fernández et al. (2016) for more details about the methodology and measurements.
[8] As a robustness check, we also use KAOPEN index from Chinn and Ito (2008), as well as Quinn index from Quinn and Toyoda (2008) in robustness checks, the results are largely similar.

(*ln(AGE)*), firm size (*ln(SALE)*), capital expenditure (*CAPEX*), research and development expense (*RD*), total property, plant and equipment (*PPE*), firm's book leverage (*LEV*), asset growth (*GROWTH*), return on assets (*ROA*), growth opportunities (*TOBINS_Q*) and financial constraints (*WW*). We also control for industry concentration (*HHI),* as well as its square (HHI^2) to control for the potentially non-linear effect of competition to firm innovation. To eliminate the concern that outliers may affect our analysis, following previous studies we winsorize all continuous firm-level control variables at 1% tails.

To control for country level characteristics, we include several measurements that are documented to be related to firm innovation. We control for GDP per capita (*ln(GDP*)), trade openness (*TradeOpen*), government expenditure (*GovExpense*), and private credit to GDP (*CREDIT*). In addition, we follow Aghion et al. (2015) to control for the patent legal environment by including patent right protection index obtained from Park(2008) (*P_INDEX*). Furthermore, in order to control for the firm (industry and country) heterogeneities, we also add firm (country and industry) fixed effects in our estimation. Detailed variable definitions are provided in Appendix Table A1.

4.4 Descriptive Statistics

Panel A of Table 1 shows the mean of innovation and capita account liberalization sample data by country. In total, the sample covers 43 different jurisdictions with the Unites States having the largest number of firms (5,382), followed by Japan (2,698), China (1,737), United Kingdom (978). There are only three countries, Peru, Portugal and Slovenia, having less than 20 firms in the sample. Firms in Japan have on average the largest number of patents per year (47), followed by firms in Switzerland (42), Ireland (40), and Netherlands (34). The pattern applies to both patent family size

and citations. On average, a firm in a high income economy has more patents and citations than that from emerging economies. For capital account liberalization, high income economies have on average higher value of liberalization indexes than middle income countries. Over time, as shown in Panel B of Table 1, firms in the sample registered more patents, from on average of 12 patents per firm in 1995 to 23 patents per firm in 2013. However, there is a substantial decrease in the average patent citations per firm over the period (from 155 citation per firm in 1995 to just 20 citation per firm in 2013).

Panel A of Table 2 presents the means and medians of the innovation measures, capital account liberalization indexes, as well as firm- and country-level characteristics for the sample. On average, each firm files 20 patents in each year and receives 115 citations within a 5-year window after publication of the application. The mean of the capital account liberalization index (KA) is 0.777, suggesting that on average countries in the sample have a high degree of openness in capital accounts during the sample period. As for the firm-level variables, the mean and median of firm size is 5.412 and 5.489 respectively; the mean value of asset growth is 19.6%; the average Tobin's Q ratio (*TOBINS_Q*) is 1.910.

Panel B of Table 2 shows the Pearson's correlation among the main variables, based on the final sample with no missing patents in PATSTAT and fully observed *KA* index scores. As we can see, the *KA* index is positively correlated with all our three measures for innovation, and the positive association with patent family size and citations is relatively stronger than with patent counts. This observation provides preliminary evidence that firms domiciled in countries that have a higher degree of capital account liberalization innovate more.

< Table 2 is about here >

5. Main Results

5.1 Baseline regression results

We estimate the impact of capital account liberalization on firm innovation by employing the cross-country firm-level panel data set described earlier. The generalized difference-in-differences regression is specified as follows:

$$INNOVATION_{i,j,c,t} = \alpha + \beta_1 KA_{c,t-1} + \vartheta X_{i,j,c,t-1} + \vartheta C_{c,t-1} + \varphi_i + \mu_j + \delta_c + \gamma_t + \varepsilon_{i,j,c,t} \quad (17)$$

where *i*, *j*, *c*, *t* refer to firm, industry, country and year, respectively. $INNOVATION_{i,j,c,t}$ captures firm innovation output in year *t* for firm *i* from country *c* in industry *j*.[9] We use three measures of firm innovation outcomes: patent quantity is measured by the natural logarithm of 1 plus patent counts (ln(PATENT)); patent quality is measured by the natural logarithm of 1 plus patent family size (ln(FAMPAT)) and the natural logarithm of 1 plus patent citations (ln(CITEPAT)). KA_{ct-1} is a continuous policy variable which captures the degree of capital account liberalization for country *c* in year *t-1*. $X_{i,j,c,t-1}$ is a group of firm-level control variables measures in year t-1. $C_{c,t-1}$ is a group of country-level control variables measured in year t-1 as well. α is a constant and β_1 captures the effect of capital account liberalization on firm innovation outcome. φ_i, μ_j , δ_c , γ_t capture firm-, industry-, country- and time-fixed effects, respectively. In all regressions, we report standard errors that are robust to heteroskedasticity and clustered by country and year.

[9] We lag all explanatory variables by 1 year following Balsmeier, Fleming and Manso (2017) and Luong et al. (2017).

Table 3 presents the results of the baseline regressions in Equation (17). Column 1 to 3 report the results on patent counts from pooled OLS regressions with firm and year fixed effects. Firm fixed effects absorb time-invariant unobservable variables that could affect both capital account liberalization and firm innovation. The univariate regression of firm innovation on *KA* as shown in Column (1) yields a positive coefficient of 0.466 and is statistically significant at the 1% level, indicating the existence of a positive association. The magnitude of impact is economically meaningful. Quantitatively, a 0.1 unit increase in capital account openness index *KA*, for example from its mean of 0.77 to 0.87, is associated with about 4.7% increase in the number of patents registered by domestic firms from its mean of 20 patents to 21 patents per year.

However, the result could be driven by omitted variables at the firm-level or country-level leading to omitted variable bias estimates. Liberalizing countries may have firms that are systemically different from non-liberalizing countries, for example, younger in firm age, bigger in firm size, or lower in firm leverage, among others. Country-varying industry characteristics may also affect firm innovation. For example, Aghion et al. (2005) shows that product market competition has a non-linear effect on innovation output. We thus control for observable firm-level variables that are commonly found in the literature to have an effect on innovation, with estimation results shown in column (2) of Table (3). We also control for non-linear country- and time-varying product market competition at the sector level, as captured by *HHI* and HHI^2. As discussed in Section 3, one concern is that there are country-level factors specific to the "treatment" group other than capital account liberalization that might affect innovation for which trade liberalization, for example, could be one potential factor. To control for the impact of lifting trade barriers upon innovation, we include in the regression a measure of a country's trade openness (*TradeOpen*). This variable

intends to capture the actual changes of trade barriers that might also affect innovation by domestic firms within the treatment group. We further control for country time-varying factors such as country size (GDP in logarithm), government expenditure, inflation etc. As shown in columns (2) and (3), the estimates of the impact of capital account liberalization on firm innovation remain positive and statistically significant and convey a similar magnitude of impact.

Could the estimates capture a "lawyer effect" whereby domestic firms patent more to protect own intellectual property as countries liberalize its capital accounts? To check whether real innovation indeed takes place after the liberalization, we present regression results on the impact of capital account liberalization on patent quality, as proxied by patent family size and patent citations, as shown in columns (4) through (9) of Table (3). Columns (4) to (6) present the results on patent family size while columns (7) to (9) on patent citations. As can be seen, the estimated coefficients on *KA* are all positive and statistically significant at the 1% level using either of the patent quality measures.

For firm-level control variables, the estimated coefficients on firm size are positive and significant, suggesting larger firms tend to innovate more and receive more patent citations. Firms that spend more on R&D also tend to innovate more. In addition, firms that have higher leverage are associated with lower innovation output while firms that have a higher return on assets are associated with less innovation. Finally, financially constrained firms are associated with less innovation output. All these results are in general consistent with previous studies, e.g., Luong et al. (2017). For country-level control variables, the coefficient on the natural logarithm of GDP per capita is positive and significant, suggesting that countries with higher GDP per capita are

associated with more innovation output. Countries with higher trade openness are associated with higher innovation output. However, government expenditure is negatively related to firm innovation output. Overall, our results confirm our Proposition 1 that there is indeed a real impact on firm innovation from the removal of capital controls.

< Table 3 is about here >

5.2 Identification

To identify the impact of capital control liberalization on firm innovation, as discussed in Section 3, we employ a generalized difference-in-difference-in-differences (DDD) approach following Imbens and Wooldridge (2009). Specifically, we add an interaction term of R&D intensity measure and the capital account liberalization (*KA index*) and estimate the following regression:

$$INNOVATION_{i,j,c,t} = \alpha + \beta_1 KA_{c,t-1} + \beta_2 KA_{c,t-1} * RD\_Intensity_{j} + \beta_3 RD\_Intensity_{j} + \vartheta X_{i,j,c,t-1} + \vartheta C_{c,t-1} + \varphi_i + \gamma_t + \mu_j + \varepsilon_{i,j,c,t} \quad (18)$$

where $RD\_INTENSITY_j$ is the time-invariant industry-level measure of R&D intensity. Note that industry-specific effects absorb the effect of $RD\_INTENSITY_j$ such that β_3 is omitted in the estimation output.

To proxy for sector specific R&D intensity, we use three measures calculated at the SIC 2-digit industry level calculated using the sample of US publicly listed firms from 1980 to 1989 following the literature (Li, 2011). [10] The first industry measure, *R&D Intensity*, is the industry median ratio of R&D spending to total assets. The second industry measure, *R&D Intensity2*, is the industry median ratio of R&D spending to total sales. The third industry measure, *Investment Intensity*, is

[10] The US ratios are then applied to all other countries.

the investment intensity at SIC 2-digit industry level, calculated as the industry median ratio of total assets scaled by property, plant and equipment following Rajan and Zingales (1998). This measure is positively related to R&D intensity in the sense that firms having lower share of tangible assets in its total assets tend to have more R&D, since R&D is typically recognized as intangible assets in the balance sheet.

We are interested in the coefficient on the interaction term $KA_{c,t-1} * RD\_Intensity_{j}$, as it captures the differential effect between the pre-post change in firms' innovation in more R&D intensive industries and the pre-post change in firms' innovation in less R&D intensive industries, after the lifting of capital controls. As it exploits the within country, cross-sectional variation in the degree of R&D intensity, it addresses the concern of reverse causality as discussed in Section 3. Given our generalized DDD estimation framework, we expect that capital account liberalization will impact disproportionally more on firms in more R&D intensive sectors. That is, we expect that the coefficients on the interaction term of capital account liberalization variable and R&D intensity proxies are positive, as predicted by Proposition 2.

Table 4 presents results on the impact of capital account liberalization on the innovation of firms operating in industries with varying degrees of R&D intensity, as captured by the interaction term between removal of capital controls and sectoral R&D intensity. The dependent variables are patent quantity (column 1, 4 and 7) and patent quality as measured by patent family (column 2, 5 and 8) and patent citations (column 3, 6 and 9). Consistent with Proposition 2, the coefficient estimates on the interaction term of capital account liberalization and R&D intensity in all columns are all positive and statistically significant, suggesting that when a country liberalize its capital

accounts, firms in more R&D intensive sectors tend to have higher patent counts, bigger patent family size and receive more patent citations. Note that the results are obtained after controlling for time-varying firm-, industry- and country-factors as in Table 3, though not reported for simplicity. Similarly, all regressions included year and firm fixed effects with robust standard errors clustered by country and year.

< Table 4 is about here >

6. Economic Mechanisms

In the previous section, we examine observe a differential impact of capital account liberalization to innovation, that varies at the sectoral level in terms of R&D intensity. A large literature in the last decade, in particular in the areas of international trade and increasingly more in finance, documents that there exists substantial heterogeneity among firms even within narrowly defined industries. In this section, we explore how capital account liberalization impacts firm innovation differently across various dimensions of firm heterogeneity, for example initial size, profitability, degree of financial constraints and corporate governance.

6.1 Firm heterogeneity

In many industries, there are fixed costs associated with entry, production and R&D activity. Consequently larger and more productive firms are more capable of overcoming the fixed cost of entry and R&D and thereby take advantage of the opportunities offered by globalization.[11] Do firms that are different in size, and thus productivity, respond differently in innovation to the

[11] As there is a general lack of data on firm employment which is not widely reported for listed firms in many countries, it is difficult to calculate firm productivity such as labor productivity and total factor productivity. However, as the literature has established the fact that large firms are more productive (Melitz 2003), we use firm size as an indicator of firm heterogeneity.

impact of capital account liberalization? By separating firms based on sales into two subsamples, one above and the other below the sample mean by industry and country at the initial year of the sample, we investigate whether larger firms (and implicitly more productive firms) in more R&D intensive sector respond more in innovation to a country's capital account liberalization, as predicted in Proposition 1.

Panel A of Table 5 reports results of the effects on the innovation of large firms and small firms separately in response to capital account liberalization. As shown in columns 1, 3 and 5 of panel A, for the group of larger firms, defined as those that are higher than the mean in total sales (in logarithm) by industry and country in initial year, the impacts of capital account liberalization on patent quantity and quality (patent family and patent citations) in more R&D intensive sectors are positive and statistically significantly at the 1% level. Conversely its impacts on small firms are insignificant (columns 2, 4 and 6), suggesting that the benefits of capital account liberalization concentrate more on larger firms located in the R&D intensive sectors. Similarly to previous findings more profitable firms in more R&D intensive sectors benefits more from capital account liberalization,[12] as shown in panel B of Table 5.

The finding that capital account liberalization gives rise to stronger impacts on innovation among more productive firms is broadly consistent with several previous studies, e.g. Melitz (2003), Aghion et al. (2005), and Autor et al. (2016a). In a recent study using data from French firms, Aghion et al. (2017) find that in terms of manufacturing firms' patenting activity, more productive corporations responds more positively to export-demand shocks, which are consistent with our

[12] Profitable firms are defined as those that are higher than the mean in return on assets (ROA) by industry and country in the initial year of the sample.

findings here that firms with higher initial productivity seem to be more responsive to capital shocks and are more likely to take advantage of innovation opportunities brought about by liberalization.

< Table 5 is about here >

6.2 Financial constraint

Prior literature documents that financing constraints may be particularly restrictive for R&D activity relative to other forms of firm investment (Hall et al., 2016). We investigate whether firms that are more financially constrained respond more positively to capital account liberalization. Specifically, we run regressions that include an interaction term between a measure of firm's financial constraint and a country's capital account liberalization measure *KA* as follows.

$$INNOVATION_{i,j,c,t} = \beta_1 KA_{c,t-1} * RD\_Intensity_j * FC_{i,j,c,t-1}$$
$$+\beta_2 KA_{c,t-1} * RD\_Intensity_j + \beta_3 KA_{c,t-1} * FC_{i,j,c,t-1}$$
$$+\beta_4 RD\_Intensity_j * FC_{i,j,c,t-1} + \beta_5 KA_{c,t-1} + \beta_6 RD\_Intensity_j$$
$$+\beta_7 FC_{i,j,c,t-1} + \vartheta \mathrm{X}_{i,j,c,t-1} + \vartheta \mathrm{C}_{c,t-1} + \alpha + \varphi_i + \gamma_t + \varepsilon_{i,j,c,t} \quad (19)$$

where *i*, *j*, *c*, *t* refer to firm, industry, country and year, respectively. $FC_{i,j,c,t-1}$ is the time-varying firm-level measure of financial constraints in year *t*-1.

We use two proxies that are commonly adopted in the literature for measuring firm-level financial constraints. First, we construct *SA* index following Hadlock and Pierce (2010), which is a nonlinear combination of firm age and firm size (see detailed variable definition in Appendix). In order to avoid the possible effect of extreme outliers in this measure, we construct a dummy variable that equals to 1 when a firm's *SA* index is above the sample median and zero otherwise, to differentiate

firms that are financially constrained from those that are not. The estimation results are shown in columns 1 to 3 of Table 6. Second, as an alternative definition we treat small cap firms as the metric for identifying a firm as financially constrained or otherwise. The estimation results are shown in columns 4 to 6 of Table 6. Consistent with Proposition 3, the coefficient estimates on the interaction term of capital account liberalization, R&D intensity and financial constraints are positive and significant in most cases, suggesting that capital account liberalization benefits firms' innovation output, especially for those firms that are financially constrained.

< Table 6 is about here >

6.3 Corporate governance

Prior literature establishes that corporate governance plays an important role in firm innovation. We examine whether firms with different levels of corporate governance respond differently to capital account liberalization. Though important, there is no consensus in the literature in the empirical measurement of firm-level corporate governance. For studies that use US firm-level data, the G-index or board characteristics are often used. Unfortunately, these indexes are not readily available for our cross-country firm-level data set. Nevertheless, there are studies that document a strong positive relationship between institutional ownership and good corporate governance practice, e.g., Aggarwal et al. (2011), McCahery et al. (2016). We thus employ two measures of firm-level institutional ownership as proxies of the level of firms' governance. One is the share of institutional ownership (*IO*) calculated as the number of shares held by institutional investors as a percentage of total market capitalization while the other is a firm's independent institutional ownership calculated as the number of shares held by independent institutional investors in percentage of total market capitalization (*IO_indep*). We partition our sample using these two firm-

level corporate governance measures. The partition of firms into two groups are based on whether a firm falls above or below the sample mean by country and year. The estimation results are shown in Table 7. The coefficient estimates on the interaction term of capital account liberalization and R&D intensity are positive and significant for firms with better corporate governance. These results suggest that capital account liberalization benefits firms' innovation output, especially for those firms with better corporate governance.

< Table 7 is about here >

6.4 Legal Protection

The literature establishes that the national institutional environments are important for innovation (North 1991; Acemoglu et al. 2005). Doidge et al. (2007) show that countries matter a lot for corporate governance. To investigate whether the impact of capital account liberalization on firms' innovation varies in different institutional environments, we consider two commonly used measures of a country's legal environment that are closely related to patenting activity. The Patent Protection index (*P_INDEX*) measures to what extent intellectual property rights are protected in a country, which is taken from Park (2008). Higher values indicate patent laws with stronger intellectual property rights. The government effectiveness indicator (*Goodgov*) captures the perceptions of the quality of government services and is taken from Kaufmann et al. (2011). We split firms into subsamples based on whether they fall above or below the sample mean in their country level measures. The estimation results are shown in Table 8. Across all specifications, the coefficient estimates on the interaction term of capital account liberalization and R&D intensity are mostly positive and significant for samples that are above the mean measures of both patent protection and government effectiveness. This suggests that capital account liberalization benefits

firms' innovation output, especially for those firms which are from countries with higher IP protection and countries with more effective governments.

< Table 8 is about here >

6.5 R&D Inputs

The above evidence taken together shows that there are three possible economic channels through which capital account liberalization can affect firms innovation activity: firms' initial conditions, financial constraints, and corporate governance. To further check whether firms are patenting for new inventions or just to protect their existing intellectual property rights, we investigate the impacts of capital account liberalization on firms' R&D inputs to see whether firms do expand their R&D investment when a country liberalizes its capital accounts.

We use firm-level R&D expenditure scaled by total assets as the dependent variable and rerun the above tests. The estimation results are shown in Table 9. As can be seen, firms that fall above the sample means, i.e. larger, more profitable and with better corporate governance, have positive and significant coefficient estimates on the interaction term between the *KA* index and R&D intensity, while firms that fall below the sample mean do not show such a result (even negative coefficients), indicating that firms with better initial conditions and better corporate governance tend to have more R&D investments in response to liberalization compared with their less productive counterparts in the R&D intensive sectors. These results lend further support, from the perspective of firms' innovation input, to what we find in Section 5.1 i.e. that the observed effects are not driven by a "lawyer effect" as patent quality (firms' innovation output) has improved.

< Table 9 is about here >

6.6 Additional Robustness Checks

In this subsection, we conduct several robustness checks. First, we test the baseline regression with country, industry and year fixed effects. The estimation results are shown in Panel A of Table 10. Similar to the results in Table 3, the coefficients on *KA* index is significantly positive, suggesting that the positive effect of capital account liberalization on firm innovation is not driven by country- or industry-level specific characteristics.

Second, we address the concern that our results may be driven by specific country (country groups) by (1) removal of countries that have no changes in the liberalization index; (2) excluding the United States from our sample; (3) excluding China from our sample. Panel B of Table 10 shows the results of these three tests. As we can see, the effects are even stronger when we exclude these specific countries, suggesting that our findings are not driven by specific country (country groups).

Finally, we use alternative measures of capital account liberalization to estimate the baseline regression: (1) KAOPEN is the financial openness index from Chinn and Ito (2008); (2) Quinn is the financial account liberalization index from Quinn and Toyoda (2008). As shown in Panel C of Table 10, the coefficients on both capital account liberalization measures are in general positive and significant, which alleviates the concern that measurement error related to the main independent variable of capital account liberalization could be driving our results. Taken together, the evidence that capital account liberalization promotes firms' innovation is robust to various forms of estimation models and alternative measures of capital account liberalization.

< Table 10 is about here >

7. Concluding Remarks

Trade and capital market integration are two important aspects of globalization. Although there is a huge and still growing literature on the real impact of *trade* liberalization, the literature features relatively few studies on the effects of *capital account* liberalization. Even less attention has been paid to how capital market integration impacts innovation by domestic firms, an issue that is of interest to policy makers worldwide. This paper investigates, both theoretically and empirically, the impact of removal of controls on a country's capital accounts to innovation by domestic firms.

We set up a monopolistic-competition model of heterogeneous firms that incorporates both innovation decisions at the firm level, and capital account liberalization at the country level, to show how opening up of capital accounts affects firms' innovation activity. We then construct a novel cross-country firm-level panel data set that integrates country-level measures of capital account restrictions with firm-level measures of patent and financial information, covering more than 40 countries over two decades. We obtain a novel cross-country firm-level panel data set with a much improved matching rate between firm patent and firm financial data exploiting a recently developed internet-based "name matching" technique suggested by Autor et al. (2016b).

Using the theoretical model as a lens, we find that capital account liberalization is significantly associated with higher patenting activity. In more R&D intensive industries, those firms that are initially larger, more financially constrained, and with better corporate governance respond significantly more to the opening up of capital accounts by increasing their R&D inputs which

yields more innovation output. The observed innovation effect is not merely a "lawyer effect" as the impact is established for patent quality measures as well.

More important, by employing a generalized DDD estimation framework and exploiting within-country variation in R&D intensity at the industrial level, we are able to identify the impact. We show that the effects are more pronounced for firms in more R&D intensive sectors. We further find that the impact is stronger for firms in economies that have a relatively better legal environment. The results are robust to the variations in the measurement of capital account liberalization, the inclusion of firm-level and country-level characteristics, and other specifications in the estimation model. Overall, our results provide robust global firm-level evidence on the real effect of capital market integration.

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Tables and Figures

Table 1. Sample Composition

This table reports the sample composition of the major data sample used in the empirical analysis. Panel A reports the means of innovation and capital account liberalization indexes by country. *Income Group* indicates the income level of the countries which is defined in the World Bank database. *No. of Firms* is the number of unique firms in each sample country. *No. of Firm-Years* is the number of firm-year observations in each sample country. *PATENT* is the total number of patent applications (unique family ID) filed by each firm in each year. *FAMPAT* is the total family size of the patent applications by each firm in each year. *CITEPAT* is the total number of citations received by each firm for patents applied in each year. *KA* is 1 minus the overall capital account restrictions index from Fernández et al. (2016). *KAOPEN* is the capital account openness index from Chinn and Ito (2008). *Quinn* is the financial liberalization index from Quinn et al. (2008). Panel B shows the sample distribution by year. Definitions of variables are detailed in Appendix table A1.

Panel A. Sample composition by country

				Innovation (MEAN)			Capital Account Liberalization (MEAN)		
Country	Income Group	No. of Firms	No. of Firm-Years	PATENT	FAMPAT	CITEPAT	KA	KAOPEN	Quinn
Argentina	Middle	22	203	0.635	1.892	1.355	0.487	0.422	0.850
Australia	High	649	5,853	2.842	15.859	16.960	0.711	0.754	0.875
Austria	High	59	669	8.895	40.982	24.359	0.873	1.000	0.938
Belgium	High	60	639	18.285	110.507	133.518	0.931	0.952	1.000
Brazil	Middle	139	992	3.266	9.984	4.758	0.438	0.366	0.320
Canada	High	666	6,262	4.926	28.637	49.516	0.949	1.000	1.000
Chile	High	28	337	0.460	1.332	0.659	0.584	0.677	0.906
China	Middle	1,737	13,378	15.031	23.221	20.522	0.024	0.165	0.300
Denmark	High	84	939	31.093	193.534	250.726	0.939	1.000	1.000
Finland	High	79	1,050	21.838	92.230	101.126	0.910	1.000	1.000
France	High	328	3,411	21.207	94.540	123.327	0.931	1.000	0.938
Germany	High	461	4,765	29.110	108.813	149.104	0.866	1.000	1.000
Greece	High	45	402	1.085	4.453	4.731	0.961	0.965	1.000
Hong Kong	High	298	3,469	7.855	14.420	12.271	0.988	1.000	1.000
India	Middle	743	5,729	9.430	42.774	44.041	0.058	0.165	0.575
Indonesia	Middle	31	428	0.801	4.126	4.757	0.388	0.691	0.750
Ireland	High	53	650	40.146	202.772	333.338	0.952	0.997	0.988
Israel	High	197	1,522	9.912	43.251	69.072	0.862	0.773	0.831
Italy	High	145	1,318	5.551	30.017	29.291	0.970	1.000	1.000
Japan	High	2,698	31,465	47.174	125.305	176.379	0.997	0.984	0.875
Korea, Rep.	High	789	5,785	24.876	56.459	56.687	0.616	0.424	0.700
Malaysia	Middle	179	2,116	0.662	2.552	2.523	0.206	0.423	0.813
Mexico	Middle	37	451	16.239	67.248	85.845	0.423	0.671	0.938
Netherlands	High	108	1,214	33.540	148.009	213.191	1.000	1.000	1.000

New Zealand	High	69	673	3.352	19.692	30.395	0.899	1.000	1.000
Norway	High	110	999	5.581	35.644	35.054	0.953	0.968	1.000
Pakistan	Middle	46	462	26.658	105.541	150.478	0.274	0.156	0.500
Peru	Middle	15	171	1.912	6.684	9.953	0.988	1.000	1.000
Philippines	Middle	38	459	0.795	4.142	5.031	0.157	0.402	0.831
Poland	High	129	862	2.123	12.833	9.732	0.253	0.378	0.723
Portugal	High	15	146	0.205	0.295	0.370	0.862	0.990	1.000
Russia	High	25	199	0.704	1.864	1.668	0.375	0.398	0.602
Singapore	High	301	3,348	4.755	16.904	26.435	0.852	0.974	1.000
Slovenia	High	13	107	3.692	16.692	16.280	0.730	0.792	
South Africa	Middle	146	1,524	3.494	16.630	25.110	0.382	0.178	0.363
Spain	High	83	615	4.057	28.462	9.772	0.974	0.980	1.000
Sri Lanka	Middle	31	288	0.462	0.774	0.851	0.000	0.447	0.763
Sweden	High	218	2,172	11.655	56.011	68.846	0.946	0.990	1.000
Switzerland	High	153	1,998	42.274	191.098	289.399	0.898	1.000	1.000
Thailand	Middle	100	1,156	1.300	2.833	3.012	0.262	0.334	0.550
Turkey	Middle	63	508	8.608	26.819	16.321	0.621	0.268	0.781
United Kingdom	High	978	10,096	7.737	36.836	58.790	0.997	1.000	1.000
United States	High	5,382	56,060	16.900	76.746	168.385	0.863	1.000	1.000
Developed	High	14,223	147,025	22.020	78.504	132.269	0.853	0.917	0.925
Emerging	Middle	3,327	27,865	10.475	25.040	25.184	0.149	0.284	0.444
All economies	ALL	17,550	174,890	20.181	69.986	115.207	0.777	0.845	0.916

Panel B. Sample distribution by year

		Innovation (MEAN)			Capital Account Liberalization (MEAN)		
Year	No. of Firms	PATENT	FAMPAT	CITEPAT	KA	KAOPEN	Quinn
1995	4,115	12.237	54.208	155.907	0.688	0.784	0.873
1996	4,700	12.348	55.207	150.809	0.698	0.746	0.875
1997	5,304	12.818	57.906	155.928	0.664	0.706	0.856
1998	5,625	12.724	58.336	153.920	0.660	0.674	0.834
1999	7,518	21.034	73.627	169.648	0.660	0.696	0.841
2000	8,461	22.679	79.399	171.439	0.676	0.711	0.833
2001	9,216	21.819	76.651	175.625	0.681	0.707	0.836
2002	9,539	20.428	70.672	159.376	0.701	0.733	0.839
2003	9,752	20.844	75.738	158.806	0.698	0.743	0.847
2004	10,077	20.642	73.711	145.648	0.707	0.753	0.852
2005	10,441	20.326	72.702	132.914	0.686	0.759	-
2006	10,757	20.310	73.111	125.859	0.701	0.759	-
2007	11,098	20.254	71.285	111.511	0.692	0.755	-
2008	11,097	20.377	70.142	100.593	0.687	0.772	-
2009	11,106	20.147	68.346	87.243	0.679	0.760	-
2010	11,345	20.495	67.800	72.336	0.677	0.746	-
2011	11,466	21.672	68.787	56.932	0.680	0.738	-
2012	11,796	22.643	69.172	38.673	0.673	0.734	-
2013	11,477	23.590	68.560	20.058	0.662	0.730	-

Table 2. Descriptive Statistics

This table reports the summary statistics of main variables used in the empirical analysis. Panel A reports the descriptive statistics. *N* is the total number of firm-year observations. *Mean* is the average value of each variable. *Median* is the median value of each variable. *SD* is the standard deviation of each variable. *Min* is the minimum of each variable. *Max* is the maximum of each variable. Panel B reports Pearson's correlation between main variables. All variables are defined in Table A1. The sample period is from 1995 to 2013. Following prior literature, all firm-level continuous variables are winsorized at 1% tails.

Panel A. Summary Statistics

Variable	N	Mean	Median	SD	Min	Max
PATENT	174,890	20.181	1.000	74.456	0.000	538.000
FAMPAT	174,890	69.986	1.000	257.259	0.000	1767.000
CITEPAT	174,890	115.207	0.000	447.497	0.000	3187.000
ln(PATENT)	174,890	1.173	0.693	1.565	0.000	6.290
ln(FAMPAT)	174,890	1.570	0.693	2.023	0.000	7.478
ln(CITEPAT)	174,890	1.511	0.000	2.180	0.000	8.067
KA	174,890	0.777	0.870	0.312	0.000	1.000
KAOPEN	174,836	0.845	1.000	0.298	0.000	1.000
Quinn	73,562	0.916	1.000	0.187	0.125	1.000
Firm Characteristics						
ln(AGE)	174,890	2.404	2.485	0.717	0.693	4.159
CAPEX	174,890	0.066	0.039	0.093	0.000	0.836
ln(SALE)	174,890	5.412	5.489	2.376	-11.152	13.073
RD	174,890	0.043	0.000	0.105	0.000	0.645
PPE	174,890	0.618	0.529	0.456	0.000	2.736
LEV	174,890	0.152	0.081	0.207	0.000	1.349
GROWTH	174,890	0.196	0.067	0.683	-0.758	6.000
ROA	174,890	0.058	0.099	0.311	-2.655	0.609
TOBINS_Q	174,890	1.910	0.972	4.340	0.151	49.969
HHI	174,890	0.381	0.281	0.292	0.016	1.000
HHI^2	174,890	0.231	0.079	0.314	0.000	1.000
WW	174,890	-0.278	-0.288	0.119	-0.506	0.249
Country Characteristics						
ln(GDP)	174,890	10.101	10.492	1.030	5.944	11.542
TradeOpen	173,298	0.575	0.342	0.689	0.152	4.427
GovExpense	174,890	0.164	0.161	0.034	0.057	0.279
CREDIT	171,881	87.380	91.586	39.781	17.783	194.725
P_INDEX	174,783	4.466	4.667	0.516	1.233	4.875

Panel B. Pearson's correlation

		ln(PATENT)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1)	*ln(FAMPAT)*	0.968	1.000													
(2)	*ln(CITEPAT)*	0.873	0.905	1.000												
(3)	*KA*	0.073	0.107	0.129	1.000											
(4)	*ln(AGE)*	0.149	0.144	0.103	0.139	1.000										
(5)	*CAPEX*	-0.036	-0.035	-0.010	-0.128	-0.161	1.000									
(6)	*ln(SALE)*	0.299	0.266	0.219	0.061	0.369	-0.042	1.000								
(7)	*RD*	0.101	0.149	0.180	0.128	-0.107	0.026	-0.373	1.000							
(8)	*PPE*	0.013	0.001	-0.010	-0.010	0.109	0.451	0.156	-0.133	1.000						
(9)	*LEV*	-0.038	-0.023	-0.010	0.043	0.073	0.215	0.154	-0.039	0.275	1.000					
(10)	*GROWTH*	-0.015	-0.005	0.023	-0.041	-0.198	0.429	-0.145	0.278	0.171	0.199	1.000				
(11)	*ROA*	0.044	0.022	0.014	-0.068	0.115	-0.026	0.485	-0.526	0.080	0.003	-0.230	1.000			
(12)	*TOBINS_Q*	0.026	0.035	0.053	-0.021	-0.073	0.073	-0.178	0.242	-0.023	0.017	0.110	-0.285	1.000		
(13)	*HHI*	-0.046	-0.036	-0.066	0.064	-0.046	-0.022	0.083	-0.123	0.029	0.018	-0.034	0.064	-0.010	1.000	
(14)	HHI^2	-0.049	-0.039	-0.067	0.045	-0.050	-0.016	0.081	-0.112	0.030	0.017	-0.031	0.062	-0.007	0.969	1.000
(15)	*WW*	-0.307	-0.273	-0.209	0.019	-0.353	0.012	-0.902	0.390	-0.186	-0.114	0.110	-0.484	0.201	-0.066	-0.067

Table 3. Baseline Regressions

This table reports the overall impact of capital account liberalization on firm innovation. The dependent variables are the three measures of patent quantity and patent quality. The main independent variable is the capital account liberalization (*KA*) index from Fernández et al. (2016). The higher the index, the more open a country's capital account is. Columns 1 to 3 (4 to 6; 7 to 9) show the pooled ordinary least squares (OLS) (Firm and year fixed effects) regression results on total number of patents *ln(PATENT)*, patent family size *ln(FAMPAT)*, and patent citations *ln(CITEPAT)*. The dependent variables are shown as the column heading in columns (1)-(9). Following prior literature, all explanatory variables are lagged by 1 year. Standard errors in parentheses are robust to heteroskedasticity and clustered by country and year. All variables are defined in the Appendix table A1. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	ln(PATENT)	ln(PATENT)	ln(PATENT)	ln(FAMPAT)	ln(FAMPAT)	ln(FAMPAT)	ln(CITEPAT)	ln(CITEPAT)	ln(CITEPAT)
KA	0.466***	0.432***	0.384***	0.645***	0.599***	0.543***	0.788***	0.634***	0.521***
	(0.124)	(0.112)	(0.081)	(0.157)	(0.144)	(0.103)	(0.133)	(0.117)	(0.126)
Firm-level controls									
ln(AGE)		0.002	-0.089***		0.016	-0.089***		0.248***	0.089**
		(0.014)	(0.015)		(0.019)	(0.019)		(0.046)	(0.041)
CAPEX		-0.013	-0.007		0.029	0.031		0.053	0.078
		(0.043)	(0.036)		(0.059)	(0.051)		(0.068)	(0.059)
ln(SALE)		0.086***	0.059***		0.095***	0.065***		0.088***	0.040***
		(0.012)	(0.005)		(0.014)	(0.007)		(0.016)	(0.008)
R&D		0.218***	0.200***		0.388***	0.369***		0.647***	0.622***
		(0.056)	(0.055)		(0.081)	(0.080)		(0.125)	(0.121)
PPE		-0.002	-0.002		-0.010	-0.011		-0.015	-0.009
		(0.012)	(0.010)		(0.016)	(0.015)		(0.022)	(0.021)
LEV		-0.003	0.002		-0.020	-0.012		-0.090***	-0.093***
		(0.014)	(0.013)		(0.022)	(0.021)		(0.023)	(0.023)
GROWTH		0.002	-0.001		0.009	0.005		0.028***	0.022**
		(0.004)	(0.004)		(0.006)	(0.006)		(0.009)	(0.009)
ROA		-0.119***	-0.081***		-0.120***	-0.076***		-0.129***	-0.059***
		(0.018)	(0.011)		(0.023)	(0.017)		(0.025)	(0.019)
TOBINS_Q		0.002***	0.002**		0.003***	0.003***		0.006***	0.005***
		(0.001)	(0.001)		(0.001)	(0.001)		(0.001)	(0.001)
HHI		-0.394***	0.008		-0.459***	-0.005		-0.974***	-0.279**
		(0.108)	(0.063)		(0.125)	(0.087)		(0.184)	(0.123)
HHI^2		0.265***	0.015		0.304***	0.029		0.689***	0.265***
		(0.075)	(0.051)		(0.090)	(0.070)		(0.131)	(0.099)
WW		-0.885***	-0.886***		-1.091***	-1.101***		-1.235***	-1.181***
		(0.083)	(0.078)		(0.115)	(0.111)		(0.144)	(0.142)
Country-level controls									
ln(GDP)			0.504***			0.607***			0.806***
			(0.077)			(0.092)			(0.088)
TradeOpen			0.211***			0.280***			0.372***

			(0.030)			(0.039)			(0.079)
GovExpense			-2.731***			-2.250***			-4.542***
			(0.717)			(0.818)			(1.753)
CREDIT			-0.001***			-0.002***			-0.000
			(0.000)			(0.000)			(0.001)
P_INDEX			0.132**			0.145**			0.266***
			(0.058)			(0.066)			(0.077)
Observations	174,890	174,890	170,395	174,890	174,890	170,395	174,890	174,890	170,395
Adjusted R-squared	0.819	0.821	0.827	0.779	0.781	0.786	0.733	0.736	0.742
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster by Country & Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 4. Identification: Capital Account Liberalization, R&D Intensity and Firm Innovation

This table presents results from generalized difference-in-difference-in-differences regressions on how capital account liberalization impact disproportionally on innovation by firms in more R&D intensive sectors. The dependent variables are the three measures of patent quantity and patent quality. The main independent variable is the capital account liberalization (*KA*) index from Fernández et al. (2016). We use three sectoral measures of R&D intensity constructed based on the sample of US publicly listed firms from year 1980 to 1989: *R&D Intensity* is a measure of SIC 2-digit industry level R&D intensity, calculated as the industry median ratio of R&D spending scaled by total assets following Li (2011) . *R&D Intensity2* is a measure of SIC 2-digit industry level R&D intensity, calculated as the industry median ratio of R&D spending scaled by total sales following Li (2011) . *Investment Intensity* is a measure of SIC 2-digit industry level investment intensity, calculated as the industry median ratio of capital expenditure scaled by net property, plant and equipment following Rajan and Zingales (1998). All explanatory variables are lagged by 1 year. Time-varying firm-level and country-level control variables, as reported in Table 3, are included in the regression but not reported here for brevity. All variables are defined in the Appendix table A1. Standard errors in parentheses are robust to heteroskedasticity and clustered by country and year. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

VARIABLES	(1) ln(PATENT)	(2) ln(FAMPAT)	(3) ln(CITEPAT)	(4) ln(PATENT)	(5) ln(FAMPAT)	(6) ln(CITEPAT)	(7) ln(PATENT)	(8) ln(FAMPAT)	(9) ln(CITEPAT)
KA R&D Intensity*	4.006***	6.184***	8.328**						
	(1.514)	(2.033)	(3.495)						
KA R&D Intensity2*				2.995***	4.364***	4.630**			
				(0.897)	(1.247)	(2.064)			
*KA*Investment Intensity*							1.488*	2.008**	2.774***
							(0.764)	(0.955)	(1.046)
KA	0.274***	0.373***	0.291**	0.301***	0.422***	0.391***	0.023	0.055	-0.154
	(0.076)	(0.094)	(0.145)	(0.079)	(0.099)	(0.134)	(0.153)	(0.192)	(0.224)
Observations	169,949	169,949	169,949	169,949	169,949	169,949	170,343	170,343	170,343
Adjusted R-squared	0.827	0.786	0.742	0.827	0.786	0.742	0.827	0.786	0.742
Firm factors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country factors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster by Country & Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 5. Capital Account Liberalization on Innovation: Firm Heterogeneity

This table presents the heterogeneous impact of capital account liberalization on firm innovation. The dependent variables are the three measures of patent quantity and patent quality. The main independent variable is the capital account liberalization (*KA*) index from Fernández et al. (2016). This table builds on Table 4 in that DDD framework is employed. We use two indicators of firm performance: firm size proxied by the natural logarithm of total sales (*ln(sale)*), and firm profitability proxied by return on assets (*ROA*). We separate firms into subsamples based on whether they fall above or below the sample mean by industry and country for two indicators of firm performance in the initial time period. All explanatory variables are lagged by 1 year. Time-varying firm-level and country-level control variables, as reported in Table 3, are included in the regression but not reported here for brevity. All variables are defined in the Appendix table A1. Standard errors in parentheses are robust to heteroskedasticity and clustered by country and year. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Panel A. Initial Firm Size(ln(sale))

	(1)	(2)	(3)	(4)	(5)	(6)
	> Initial Mean ln(sale)	<= Initial Mean ln(sale)	> Initial Mean ln(sale)	<= Initial Mean ln(sale)	> Initial Mean ln(sale)	<= Initial Mean ln(sale)
VARIABLES	ln(PATENT)	ln(PATENT)	ln(FAMPAT)	ln(FAMPAT)	ln(CITEPAT)	ln(CITEPAT)
KA R&D Intensity*	9.297***	-0.901	14.619***	-0.489	21.513***	-2.651
	(3.239)	(1.756)	(4.025)	(2.695)	(6.670)	(3.374)
KA	0.203*	0.343***	0.263*	0.480***	0.229	0.794***
	(0.109)	(0.099)	(0.138)	(0.132)	(0.251)	(0.185)
Observations	58,157	65,563	58,157	65,563	58,157	65,563
Adjusted R-squared	0.844	0.818	0.813	0.750	0.771	0.692
Firm factors	Yes	Yes	Yes	Yes	Yes	Yes
Country factors	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Cluster by Country & Year	Yes	Yes	Yes	Yes	Yes	Yes

Panel B. Initial Profitability (ROA)

VARIABLES	(1) > Initial Mean ROA ln(PATENT)	(2) <= Initial Mean ROA ln(PATENT)	(3) > Initial Mean ROA ln(FAMPAT)	(4) <= Initial Mean ROA ln(FAMPAT)	(5) > initial ROA ln(CITEPAT)	(6) <= Initial Mean ROA ln(CITEPAT)
*KA * R&D Intensity*	8.681**	-0.278	14.300***	0.150	17.360**	0.404
	(4.029)	(2.705)	(5.248)	(3.444)	(7.052)	(3.525)
KA	0.101	0.408***	0.134	0.548***	0.262	0.607***
	(0.163)	(0.112)	(0.204)	(0.139)	(0.227)	(0.161)
Observations	53,051	69,277	53,051	69,277	53,051	69,277
Adjusted R-squared	0.857	0.813	0.818	0.761	0.774	0.710
Firm factors	Yes	Yes	Yes	Yes	Yes	Yes
Country factors	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Cluster by Country & Year	Yes	Yes	Yes	Yes	Yes	Yes

Table 6. Capital Account Liberalization and Firm Innovation: Financial Constraints

This table presents the impacts of exposure to capital account liberalization on firm innovation when we partition the sample by firms' financial constraints. The main independent variable is the capital account liberalization (*KA*) index from Fernández et al. (2016). We use two measurements of firms' financial constraints: *SA* index constructed following Hadlock and Pierce (2010); *Size* measured by the natural logarithm of total assets of the firm. We use dummy variables instead of continuous values to avoid the biased outcome due to extreme values in these measures: the dummy variable *SA_dummy* (*Small*) equals to 1 if the firm's *SA (Small)* index is above (below) the sample mean among firms in the same year from the same country, and zero otherwise. All explanatory variables are lagged by 1 year. Time-varying firm-level and country-level control variables, as reported in Table 3, are included in the regression but not reported here for brevity. All variables are defined in the Appendix table A1. Standard errors in parentheses are robust to heteroskedasticity and clustered by country and year. ***, **, and * indicates significance at the 1%, 5%, and 10% levels, respectively.

VARIABLES	(1) ln(PATENT)	(2) ln(FAMPAT)	(3) ln(CITEPAT)	(4) ln(PATENT)	(5) ln(FAMPAT)	(6) ln(CITEPAT)
*KA * R&D Intensity * SA_dummy*	2.581***	2.628**	-0.689			
	(0.869)	(1.100)	(1.653)			
*KA * R&D Intensity * Small*				2.842***	3.219***	-2.082
				(0.812)	(1.114)	(1.509)
*KA * SA_dummy*	0.046	0.023	0.014			
	(0.036)	(0.043)	(0.057)			
*RD intensity * SA_dummy*	-4.530***	-4.522***	1.391			
	(0.712)	(0.872)	(1.280)			
SA_dummy	-0.038	-0.050	-0.171***			
	(0.030)	(0.033)	(0.045)			
*KA * Small*				-0.000	-0.035	0.072
				(0.035)	(0.045)	(0.054)
*RD intensity * Small*				-4.489***	-4.791***	0.863
				(0.662)	(0.888)	(1.174)
Small				-0.007	-0.006	-0.142***
				(0.029)	(0.036)	(0.044)
KA	0.249***	0.345***	0.230	0.260***	0.361***	0.220
	(0.076)	(0.094)	(0.141)	(0.075)	(0.093)	(0.143)
*KA * R&D Intensity*	1.810	4.163*	9.090***	2.049	4.248*	9.613***
	(1.622)	(2.169)	(3.424)	(1.629)	(2.167)	(3.588)
Observations	170,291	170,291	170,291	170,291	170,291	170,291
Adjusted R-squared	0.827	0.786	0.743	0.827	0.786	0.743
Firm factors	Yes	Yes	Yes	Yes	Yes	Yes
Country factors	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Cluster by Country & Year	Yes	Yes	Yes	Yes	Yes	Yes

Table 7. Capital Account Liberalization and Firm Innovation: Corporate Governance

This table presents the impacts of exposure to capital account liberalization on firm innovation when we partition the sample by firms' corporate governance. The main independent variable is the capital account liberalization (*KA*) index from Fernández et al. (2016). We use two indicators of firm-level corporate governance: firms' institutional ownership calculated as the number of shares held by institutional investors in percentage of total market capitalization (*IO*), and firms' independent institutional ownership calculated as the number of shares held by independent institutional investors in percentage of total market (*IO_indep*). We separate firms into subsamples based on whether they fall above or below the sample mean of these variables among firms in the same year from the same country. All explanatory variables are lagged by 1 year. Time-varying firm-level and country-level control variables, as reported in Table 3, are included in the regression but not reported here for brevity. All variables are defined in the Appendix table A1. Standard errors in parentheses are robust to heteroskedasticity and clustered by country and year. ***, **, and * indicates significance at the 1%, 5%, and 10% levels, respectively.

Panel A. Institutional Ownership (IO)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	>=mean IO ln(PATENT)	<mean IO ln(PATENT)	>=mean IO ln(FAMPAT)	<mean IO ln(FAMPAT)	>=mean IO ln(CITEPAT)	<mean IO ln(CITEPAT)
*KA * R&D Intensity*	11.696***	3.274	17.107***	6.153**	23.120***	5.805
	(3.136)	(2.521)	(4.412)	(3.050)	(8.376)	(5.272)
KA	0.006	0.415***	0.070	0.516***	-0.229	0.251
	(0.140)	(0.127)	(0.187)	(0.160)	(0.335)	(0.202)
Observations	46,873	62,190	46,873	62,190	46,873	62,190
Adjusted R-squared	0.883	0.807	0.847	0.753	0.813	0.704
Firm factors	Yes	Yes	Yes	Yes	Yes	Yes
Country factors	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Cluster by Country & Year	Yes	Yes	Yes	Yes	Yes	Yes

Panel B. Independent Institutional Ownership (IO_indep)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	>=mean IO_indep ln(PATENT)	<mean IO_indep ln(PATENT)	>=mean IO_indep ln(FAMPAT)	<mean IO_indep ln(FAMPAT)	>=mean IO_indep ln(CITEPAT)	<mean IO_indep ln(CITEPAT)
*KA * R&D Intensity*	12.093***	2.549	17.242***	4.910*	22.490***	5.415
	(3.070)	(2.460)	(4.306)	(2.914)	(8.224)	(5.104)
KA	0.029	0.431***	0.092	0.538***	-0.200	0.248
	(0.142)	(0.125)	(0.185)	(0.158)	(0.340)	(0.200)
Observations	46,752	62,319	46,752	62,319	46,752	62,319
Adjusted R-squared	0.882	0.810	0.846	0.755	0.812	0.705
Firm factors	Yes	Yes	Yes	Yes	Yes	Yes
Country factors	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Cluster by Country & Year	Yes	Yes	Yes	Yes	Yes	Yes

Table 8. Capital Account Liberalization and Firm Innovation: Legal Protection

This table presents the impacts of exposure to capital account liberalization on firm innovation when we separate firms into subsamples based on whether they fall above or below the sample mean of country-level legal protection. The main independent variable is the capital account liberalization (*KA*) index from Fernández et al. (2016). We use two measurements of legal protection. The Patent Protection index (*P_INDEX*) measures intellectual property rights are to what extent protected in the country, and is taken from Park (2008). Higher values indicate patent laws with stronger protection of intellectual property rights. The government effectiveness indicator (*Goodgov)* captures the perceptions of government services' quality and is taken from Kaufmann et al. (2011). We separate firms into subsamples based on whether they fall above or below the sample mean of their country level measures. All explanatory variables are lagged by 1 year. Time-varying firm-level and country-level control variables, as reported in Table 3, are included in the regression but not reported here for brevity. All variables are defined in the Appendix table A1. Standard errors in parentheses are robust to heteroskedasticity and clustered by country and year. ***, **, and * indicates significance at the 1%, 5%, and 10% levels, respectively.

Panel A. Patent Protection index

	(1)	(2)	(3)	(4)	(5)	(6)
	>=mean	<mean	>=mean	<mean	>=mean	<mean
	P_INDEX	*P_INDEX*	*P_INDEX*	*P_INDEX*	*P_INDEX*	*P_INDEX*
VARIABLES	ln(PATENT)	ln(PATENT)	ln(FAMPAT)	ln(FAMPAT)	ln(CITEPAT)	ln(CITEPAT)
*KA * R&D Intensity*	3.902**	1.814	5.886**	3.791	6.485	6.772
	(1.762)	(2.491)	(2.325)	(3.456)	(4.036)	(4.263)
KA	0.261**	-0.024	0.357***	-0.083	0.538***	-0.288**
	(0.108)	(0.081)	(0.130)	(0.109)	(0.176)	(0.133)
Observations	147,460	22,715	147,460	22,715	147,460	22,715
Adjusted R-squared	0.837	0.722	0.793	0.691	0.745	0.650
Firm factors	Yes	Yes	Yes	Yes	Yes	Yes
Country factors	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Cluster by Country & Year	Yes	Yes	Yes	Yes	Yes	Yes

Panel B. Good governance

	(1)	(2)	(3)	(4)	(5)	(6)
	>= mean	<mean	>= mean	<mean	>= mean	<mean
	Goodgov	Goodgov	Goodgov	Goodgov	Goodgov	Goodgov
VARIABLES	ln(PATENT)	ln(PATENT)	ln(FAMPAT)	ln(FAMPAT)	ln(CITEPAT)	ln(CITEPAT)
*KA * R&D Intensity*	2.961	-0.422	5.402*	1.462	19.038***	-13.103
	(1.965)	(3.252)	(3.270)	(4.059)	(6.684)	(9.704)
KA	0.010	0.289*	0.058	0.265	-0.181	0.174
	(0.111)	(0.155)	(0.159)	(0.188)	(0.377)	(0.226)
Observations	115,234	28,677	115,234	28,677	115,234	28,677
Adjusted R-squared	0.853	0.723	0.806	0.700	0.757	0.648
Firm factors	Yes	Yes	Yes	Yes	Yes	Yes
Country factors	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Cluster by Country & Year	Yes	Yes	Yes	Yes	Yes	Yes

Table 9. Capital Account Liberalization on Firms' R&D Inputs

This table presents the impacts of exposure to capital account liberalization on firms' R&D inputs when we partition the sample by their initial conditions and corporate governance. The main independent variable is the capital account liberalization (*KA*) index from Fernández et al. (2016). The main dependent variable is firms' R&D expense scaled by total assets. We use two indicators of initial firm performance: firm size proxied by the natural logarithm of total sales (*ln(sale)*), and firm profitability proxied by return on assets (*ROA*). We separate firms into subsamples based on whether they fall above or below the sample mean among firms in the same industry from the same country for two indicators of firm performance in the initial time period. Firms' corporate governance is proxied by institutional ownership (*IO*). Similarly, we also separate firms into subsamples based on sample country-year mean of institutional ownership. All explanatory variables are lagged by 1 year. Time-varying firm-level and country-level control variables, as reported in Table 3, are included in the regression but not reported here for brevity. All variables are defined in the Appendix table A1. Standard errors in parentheses are robust to heteroskedasticity and clustered by country and year. ***, **, and * indicates significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
	> Initial Mean ln(sale)	<= Initial Mean ln(sale)	> Initial Mean ROA	<= Initial Mean ROA	>=Mean IO	<= Mean IO
VARIABLES	R&D	R&D	R&D	R&D	R&D	R&D
*KA*R&D Intensity*	0.491**	-0.302*	0.531**	-0.203	0.491**	0.035
	(0.220)	(0.180)	(0.254)	(0.161)	(0.238)	(0.225)
KA	-0.007	-0.003	-0.011**	-0.001	-0.007*	-0.002
	(0.005)	(0.004)	(0.005)	(0.004)	(0.004)	(0.005)
Observations	58,156	65,548	53,045	69,265	46,873	62,180
Adjusted R-squared	0.846	0.822	0.809	0.832	0.864	0.856
Firm factors	Yes	Yes	Yes	Yes	Yes	Yes
Country factors	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Cluster by Country & Year	Yes	Yes	Yes	Yes	Yes	Yes

Table 10. Robustness Tests

Note: This table reports the robustness tests of capital account liberalization on firm innovation. Panel A shows the baseline regressions with country, industry and year fixed effects. The main independent variable is the capital account liberalization (*KA*) index from Fernández et al. (2016). Panel B reports the baseline regression results on the sample excluding some specific countries: removal of countries with no change in *KA* index, excluding United States, and excluding China. Panel C shows the baseline regressions with alternative measures of capital account liberalization. *KAOPEN* is the capital account openness index from Chinn and Ito (2008). *Quinn* is the financial liberalization index from Quinn et al. (2008). All explanatory variables are lagged by 1 year. Time-varying firm-level and country-level control variables, as reported in Table 3, are included in the regression but not reported here for brevity. All variables are defined in the Appendix table A1. Standard errors in parentheses are robust to heteroskedasticity and clustered by country and year. ***, **, and * indicates significance at the 1%, 5%, and 10% levels, respectively.

Panel A. KA with country, industry and year fixed effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	ln(PATENT)	ln(PATENT)	ln(PATENT)	ln(FAMPAT)	ln(FAMPAT)	ln(FAMPAT)	ln(CITEPAT)	ln(CITEPAT)	ln(CITEPAT)
KA	0.266*	0.441***	0.354***	0.388**	0.615***	0.540***	0.452***	0.661***	0.467***
	(0.136)	(0.113)	(0.088)	(0.163)	(0.139)	(0.110)	(0.139)	(0.128)	(0.129)
Observations	176,009	176,009	171,483	176,009	176,009	171,483	176,009	176,009	171,483
Adjusted R-squared	0.164	0.306	0.310	0.159	0.294	0.298	0.172	0.294	0.299
Firm factors		Yes	Yes		Yes	Yes		Yes	Yes
Country factors			Yes			Yes			Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster by Country & Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel B. Removal of specific countries in the sample

	Removal of countries with no change in KA index			United States excluded			China excluded		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	ln(PATENT)	ln(FAMPAT)	ln(CITEPAT)	ln(PATENT)	ln(FAMPAT)	ln(CITEPAT)	ln(PATENT)	ln(FAMPAT)	ln(CITEPAT)
KA	0.393***	0.548***	0.517***	0.403***	0.569***	0.520***	0.368***	0.503***	0.578***
	(0.082)	(0.104)	(0.127)	(0.078)	(0.101)	(0.124)	(0.060)	(0.077)	(0.113)
Observations	167,394	167,394	167,394	114,335	114,335	114,335	157,017	157,017	157,017
Adjusted R-squared	0.826	0.786	0.742	0.829	0.794	0.758	0.840	0.793	0.747
Firm factors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country factors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster by Country & Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel C. Alternative measures of capital account liberalization

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	ln(PATENT)	ln(FAMPAT)	ln(CITEPAT)	ln(PATENT)	ln(FAMPAT)	ln(CITEPAT)
Quinn	0.004***	0.005**	0.009***			
	(0.001)	(0.002)	(0.003)			
KAOPEN				0.235***	0.325***	0.063
				(0.082)	(0.098)	(0.140)
Observations	71,480	71,480	71,480	170,339	170,339	170,339
Adjusted R-squared	0.868	0.812	0.768	0.827	0.786	0.742
Firm factors	Yes	Yes	Yes	Yes	Yes	Yes
Country factors	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Cluster by Country & Year	Yes	Yes	Yes	Yes	Yes	Yes

Appendix

Table A1 Variable Definitions

Variables	Definitions	Main Source
PATENTS	The yearly total number of patent applications of a firm $$\mathrm{PAT_{i,t}} = \sum_{j \in J(t)} p_{j,t}$$ where $PAT_{i,t}$ is the total number of patents filed by firm *i* in year *t*. *J(t)* is the set of all patents applications the firm filed in year *t*. $P_{j,t}$ equals to 1 for patent *j* with a distinct family ID filed by firm *i* in year *t*.	PATSTAT 2016 Autumn
CITEPAT	The yearly total number of patent citations of a firm received within 5 years after the first publication date of the application. $$\mathrm{CIT_{i,T}} = \sum_{t=p_i}^{P_i+T} \sum_{j \in J(t)} C_{j,i} \; ; T \leq 5$$ where $CIT_{i,T}$ is the total number of forward citations received by patent applications *i* published in year P_i within *T* years from its publication date. $C_{j,i}$ is a dummy variable that equals to 1 if the patent application *j* is citing patent application *i*, and 0 otherwise. *J(t)* is the set of all patents applications published in year *t*.	PATSTAT 2016 Autumn
FAMPAT	The yearly total size of patent families of a firm $$\mathrm{FAM_{i,t}} = \sum_{j \in J(t)} f_{j,t}$$ where $FAM_{i,t}$ is the total number of patent families filed by firm *i* in year *t*. *J(t)* is the set of all patent applications the firm filed with distinct family ID in year *t*. $f_{j,t}$ is the family size for each distinct patent family ID including all patent applications filed in different patent office or different time periods that are sharing the same family ID.	PATSTAT 2016 Autumn
Ln(PATENT)	The natural Logarithm of 1 plus the total number of patents filed each firm in each year.	PATSTAT 2016 Autumn
ln(FAMPAT)	The natural Logarithm of 1 plus the total amount of patent family size filed by each firm in each year.	PATSTAT 2016 Autumn
ln(CITEPAT)	The natural Logarithm of 1 plus the total number of citations made to each firm's patents in each year.	PATSTAT 2016 Autumn
KA	The overall capital account restrictions index from Fernández et al. (2016) ranging from 0 (fully open) to 1 (fully restricted). We take 1 minus the original value as our major index to indicate the level of capital account liberalization.	Fernández et al. (2016)
KAOPEN	The Chinn and Ito (2008) financial openness index ranging from -1.856 (fully restricted) to 2.456 (fully open).	Chinn and Ito (2008)
Quinn	The financial current account liberalization index from Quinn and Toyoda (2008) ranging from 0 (fully open) to 1 (fully restricted).	Quinn and Toyoda (2008)
Firm Characteristics		
TA	Book value of total assets, measured at the end of the fiscal year in millions.	Capital IQ Global
ln(AGE)	The natural logarithm of the number of years a firm has been listed in Capital IQ Global.	Capital IQ Global
CAPEX	Capital expenditure scaled by beginning year of total assets.	Capital IQ Global
Ln(SALE)	Natural logarithm of net sales.	Capital IQ Global
R&D	Research and Development expenditure, scaled by beginning year of total assets.	Capital IQ Global
PPE	Total property, plant and equipment, scaled by beginning year of total assets.	Capital IQ Global
LEV	Book value of total debt (long-term debt plust debt in current liabilities) divided by beginning year of total assets.	Capital IQ Global
GROWTH	Asset growth rate, annual percentage change of total assets, measured at the fiscal year end.	Capital IQ Global
ROA	Return on assets, defined as operating income before depreciation divided by begging year of total assets.	Capital IQ Global
TOBINS_Q	Growth opportunities, measured as the sum of market value of equity and book value of debt, divided by fiscal year-end total assets.	Capital IQ Global

HHI	Herfindahl index of 4-digit SIC industry to which the firm belongs, measured at the fiscal year end.	Capital IQ Global
HHI²	The squared value of HHI.	Capital IQ Global
WW	$= -0.091 * \mathrm{CF}_{it} - 0.062 * \mathrm{DIVPOS}_{it} + 0.021 * \mathrm{TLTD}_{it} - 0.044 * \mathrm{LNTA}_{it} + 0.102 * \mathrm{ISG}_{it} - 0.035 * \mathrm{SG}_{it}$, where CF is cash flow from operations divided by total assets, DIVPOS is an indicator take the value of one if the firms pays cash dividends; TLTD is long term debt divided by total assets; LNTA is natural logarithm of total assets, ISG is the firm's three-digit SIC industry sales growth, SG is firm sales growth.	Capital IQ Global
SA	$=(-0.737 * \mathrm{Size}_{it}) + (0.043 * {\mathrm{Size}_{it}}^2) - (0.040 * \mathrm{Age}_{it})$, where Size is the natural logarithm of total assets, Age is the number of years the firm has been on Capital IQ Global with a non-missing stock price.	Capital IQ Global
Industry Characteristics		
R&D Intensity	R&D intensity the industry median ratio of R&D expenditures to total assets (total sales) following Li (2011), using all U.S. public firms from 1980 to 1990.	Capital IQ North America
Investment Intensity	Investment intensity, the share of capital expenditure in net property, plant, and equipment for the median publicly traded firm in each industry in the United States from 1980 to 1990 following Rajan and Zingales (1998).	Capital IQ North America
Country Characteristics		
Ln(GDP)	The natural logrithm of real GDP per capita (current US$).	World Economic outlook 2016
Imports	Imports of goods and services (BoP, current US$).	World Bank WDI
Exports	Exports of goods and services (BoP, current US$).	World Bank WDI
TradeOpen	Trade openness measured as the sum of imports and exports of goods and services divided by GDP.	World Bank WDI
GovExpense	General government final consumption expenditure (% of GDP).	World Bank WDI
CREDIT	Financial Development measured as Private credit by deposit money banks to GDP (%).	World Bank GFD database
P_INDEX	Patent protection index, originally from Park (2008), defined similarly following Luong et al. (2017).	Park (2008)

Table A2 Patents matched to IBM by Name Matching and Web URL Matching

This table comprises all the patent assignees with at least two published patents (by family ID) during 1980-2010 which have been matched to the US publicly listed company "IBM" by either name matching or web match algorithm. The listed assignee harmonized names have been subject to minimal cleaning, including standardizing cases, and removing of accents. No. of Patents is the total number of patents counted by unique family ID. No. of Applications ID is the total number of patents counted by unique application ID. No. of Citations is the total number of citations received (counted by unique family ID). Matching flag is a flag marking the matching source: 1 means the assignee is matched by web searching result with web URL in Capital IQ; 2 means the assignee is matched by web searching results both in PATSTAT and firms in Capital IQ; 3 means the assignee is matched by firm name.

Patent Assignee Harmonized Name in PATSTAT	Person Country Code	No. of Patents (family)	No. of applications	No. of Citations	Matching flag	Name Matching	Web Matching
IBM CORP	US	105791	283992	2127270	1		x
INTERNATIONAL BUSINESS MACHINES CORPORATION	-	1877	7097	23192	3	x	x
IBM	-	680	2260	5470	1		x
IBM DEUTSCHLAND GMBH	DE	475	2636	6325	1		x
IBM CORP IBM	US	267	838	7128	1		x
COMPAGNIE IBM FRANCE	-	76	491	1516	1		x
THINKING MACHINES CORP	-	71	184	3211	-		x
IBM CORP ARMONK NY	US	38	202	633	1		x
INTERNATIONAL BUSINESS MACHINES CORPORATION.	-	28	106	327	3	x	
GREAT LOTUS CORP	TW	27	30	49	1		x
IBM FR	FR	24	140	497	1		x
IBM CO	US	22	62	402	1		x
LOTUS DEV CORP	US	20	43	1336	1		x
ISSC TECH CORP	TW	18	41	59	1		x
IBM CORPROATION	US	17	55	240	1		x
GLI GLOBAL LIGHT IND GMBH	DE	14	61	103	1		x
TRACE STORAGE TECH CORP	TW	14	14	83	1		x
ENCENTUATE PTE LTD	SG	13	57	260	1		x
ERIC TECH CORP	CA	12	103	149	1		x
INTERNATIONAL BUSINESS MACHINES CORP	-	12	43	19	3	x	x
IBM DEUTSCHLAND	-	11	60	256	1		x
INTERNATIONAL MOBILE MACHINES CORPORATION	-	11	16	-	1		x
UNITED IND CORP	-	8	9	152	-		x
S&S TECH CORP	TW	7	13	18	1		x
INTERNATIONAL BUSINESS MACHINES CORP., ARMONK, N.Y., US	-	6	27	81	3	x	
CONNEXION TECH CORP	TW	5	5	2	1		x
EUROPEAN SIGN SYSTEMS ESS GMBH	DE	5	25	60	1		x
INT BUSINESS MACINES CORP	-	5	5	32	-		x
ITM INDUSTRIAL TECH & MACHINES AG	CH	5	16	45	1		x
MICROMUSE LTD	GB	5	24	202	1		x
IBM CORP.	-	4	10	45	1		x
INTEL MOBILE COMM TECH GMBH	DE	4	8	15	1		x
MICROMUSE INC	US	4	13	327	1		x
UNITED DEVELOP INTERNATIONAL CORP.	TW	4	4	-	1		x
ADVANCED MACHINES CORP AG	LI	3	30	12	1		x
HUMANO WATER CORP	CA	3	18	15	1		x
IBM FRANCE	-	3	27	81	1		x
INT BSUINESS MACHINES CORP	US	3	3	29	1		x
THINKING MACHINES CORPORATION	-	3	31	407	1		x
ADVANCES MACHINES CORP AG	LI	2	20	8	1		x
BLUE LION MOBILE GMBH	DE	2	4	2	1		x
COGNITIVE CODE CORP	US	2	10	18	1		x
DOUBLE MICROELECTRONICS CORPORATION OF SHANGHAI	-	2	2	4	1		x
GCD HARD & SOFTWARE GMBH	DE	2	3	5	1		x
IBM CANADA LTD	US	2	12	8	1		x

IBM CORP INC	US	2	4	45	1	x
IBM CORPORATAION	US	2	5	25	1	x
IBM CORPORATIION	US	2	13	39	1	x
IBM CORPORATIOIN	-	2	6	43	-	x
IBM UNITED STATES	US	2	4	24	1	x
IIBM CORP	US	2	2	44	1	x
SHANGHAI DOUBLE MICROELECTRONICS CORPORATION	-	2	2	2	1	x
SMITH RPM CORP	US	2	5	30	1	x
TECHLINE SERVICES & ENG SA	CH	2	12	6	1	x
WESTFORD TECH CORP	US	2	10	11	1	x