

The Impact of Trade Policy on Innovation : Evidence from Patent Data*

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Abstract

This paper tests the effect of trade liberalization during the Great Liberalization of the 1990s on innovation in 48 countries using international firm-level patent data. The empirical strategy exploits ex-ante differences in firms' exposure to different markets, allowing us to construct various firm-specific measures of trade barriers. This provides a novel source of firm-level variation that enables us to establish the causal impact of trade policy on patenting. Our results suggest that trade liberalization has economically significant effects on innovation and, ultimately, technical change. According to our estimate, about 6 percent of knowledge creation during the 1990s can be explained by trade policy. Furthermore, we find that the increase in patenting reflects more innovation, rather than simply more protection of existing knowledge. Finally, a more detailed analysis of the channels through which trade liberalization affects firms' innovation allows us to conclude that the positive impact resulting from increased competition and larger market size prevail on the negative Schumpeterian force.

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1 Introduction

What is the impact of trade policy liberalization on innovation? Direct evidence of the extent to which trade policy promotes innovation is still limited. There has been a rise in empirical work analysing the impact of trade policy on firms' performance. However, due to scarce availability of direct measures of innovative activity at the firm level, most microeconomic evidence on the effect of trade policy on innovation is indirect.¹ Hence, in this paper we examine whether - and through what channels - trade policy spurs innovation, as measured by patenting, for a large sample of firms located in over 40 different developed and developing countries..

The empirical literature on trade and innovation has mainly focused on the effect of trade liberalization on productivity. However, this literature provides little insight into the mechanisms through which firm productivity improves. The prevailing approach has been to estimate productivity as a residual in the production function. The estimated residuals then reflect a number of differences across firms in addition to technical efficiency, such as differences in market power, higher share of skilled labor, etc. As a result, changes in measured TFP induced by trade liberalization may not reflect changes in innovative activity. We argue that looking at patents, which constitutes a direct measure of innovation, has a clear advantage since it allows us to isolate the impact of trade on one particular mechanism through which firm productivity may improve.

The theoretical literature on trade and innovation identifies two main channels through which trade liberalization affects firms' innovation. First, lowering import barriers increases competition. The effect of increased competition on innovation is, however, ambiguous. A more competitive marketplace may foster innovation due to an increased threat to monopoly rents, which may induce incumbent firms to innovate more in order to "escape" competition (Aghion et al., 1997, and Aghion et al., 2005). On the other hand, the fundamental Schumpeterian force implies that competition lowers price-cost margins, thereby reduces the rents from innovation and reduces the incentives to innovate (Aghion and Howitt, 1992). Second, lowering trade barriers leads to increased market size. Access to a larger market raises firms' revenues, allowing them to spread the fixed costs of innovation and encouraging firms to innovate. (e.g. Grossman and Helpman, 1992, Krugman, 1980, and Yeaple, 2005). Finally, a

¹Recent contributions to the literature on trade and innovation relying on more direct measures of innovation activity include Teshima (2009) on the impact of reduced output tariffs on Mexican firms, Bustos (2009) on the impact of Mercosur on Argentinian firms, and Bloom et al. (2016) on the impact of Chinese competition on European firms' innovation. Teshima finds that the reduction in Mexican output tariffs increased innovative activity of Mexican firms as a result of increased competition. Bustos finds positive effects of falling trading partner's tariffs on technology adoption by Argentinean firms. Bloom et al find that Chinese import competition increased innovation among European firms.

line of theory also highlights the role of international knowledge spillovers. Trade liberalization allows firms to get better access to overseas' knowledge, for example through the imports of intermediate inputs which boost the innovative activity of domestic firms. Lower import barriers allow local firms to access knowledge coming in from abroad. This spillover effect increases the stock on knowledge available to firms and increases their innovation. Falling trade tariffs also lower the cost of imported inputs and capital used in the R&D process, reducing the cost of innovation activity.

Our point of departure is the period of large global reductions in import tariffs during the 1990s, referred to as the Great Liberalization of the 1990s by Estevadeordal and Taylor (2013). Sparked off by the conclusion of the GATT Uruguay round, average import tariffs declined substantially for the majority of developed and developing countries.² We test the impact of this wave of trade liberalization on innovation using firm level patent data from the European Patent Office Worldwide Patent Statistical Database (PATSTAT), that covers close to the population of all worldwide patents since the mid 1960s. We combine the firm level patent data with country-level tariff and trade agreement data. Our empirical strategy exploits differences in firms' exposure to markets. For every firm, we observe their headquarter location and which countries they were active in prior to the policy change. Hence, firms were ex-ante exposed to different markets. This provides us with firm-level variation in exposure to the Great Liberalization, even firms within the same country, and it allows us to difference out all country and industry trends in patenting activity. We are thus able to estimate the causal impact of trade policy on knowledge creation. In addition to providing microeconomic evidence on the effect of trade policy on firms' innovation, we are also able to identify separately the effects of trade operating through the two different channels, market access and competition.

Our results show that trade policy matters and that trade liberalization promotes innovation. According to our empirical evidence, the Great Trade Liberalization had a significant positive and economically meaningful impact on firms' innovation rates. According to our estimates, this period of trade liberalization can explain roughly 6% of knowledge creation during the 1990s. We find that the benign impact of trade liberalization on exporters is stronger than that on non-exporters. This suggests that even for firms that never export, the competition effect coming from lower import barriers spurs innovation. Furthermore, using cumulative citations as measure of knowledge creation, we are able to show that the increase in patenting reflects more innovation, rather than simply more protection of existing knowledge.

²Estevadeordal and Taylor (2013) find that the developed world lowered tariffs from on average 10% falling to about 5%, and that the developing world lowered tariffs from almost 30% falling to about 15%.

Our analysis speaks to different strands of literature. First, our work is related to the empirical analyses of firm level data on the impact of foreign sourcing on firm performance. Halpern, Koren, and Szeidl (2015) estimate a model of importers using Hungarian micro data and find that importing more varieties leads to large measured productivity effects. Recent work by Gopinath and Neiman (2013) also find large negative measured productivity effects from a collapse in imports following the Argentine crisis of 2001-2002. The empirical studies of Amiti and Konings (2007), Goldberg et al. (2010) and Khandelwal and Topalova (2011) all find that declines in input tariffs are associated with sizable measured productivity gains. Compared to our work, these papers focus on the impact of trade on firm performance but do not separately identify what are the channels that allow for the benign impact of imported inputs and in particular the impact of trade on innovation.³ Along the same line of work, but somehow closer to this paper is Boler et al. (2015) who explores the complementarities between international sourcing of intermediates and R&D investment and their joint impact on firm performance.

Second, our work relates to the literature on complementarities between exports and technology adoption. Closest in the spirit to our analysis is empirical work by Bustos (2009) and Lileeva and Trefler (2010) who show that trade integration can induce exporters to upgrade technology, Bloom, Draca, and Van Reenen (2016) who focus on the effect of imports from China on technology upgrading and productivity in OECD countries, and Teshima (2009) who examines the impact of reduced output tariffs on Mexican firms and finds that the reduction in Mexican output tariffs increased innovative activity of Mexican firms due to increased competition. What distinguishes our paper from these contributions is the fact that we focus on the global impact of multilateral trade liberalization rather than on unilateral or bilateral trade liberalization episodes. Moreover, our international firm-level data set and the high number of countries in our sample provide external validity. Finally, our paper is also related to Aghion et al. (2014) and Calel and Dechezleprêtre (2014), who also use PATSTAT data and a related empirical approach, although they focus on very different questions, being the impact of environmental policies on technical change.

The paper is organized as follows. Section two describes the data. Section three provides descriptive evidence on the trade liberalization that followed the Uruguay Round as well as on trends in patenting worldwide. Section four presents the empirical strategy. Section five presents and discusses the empirical results.

³Note that Goldberg et al. (2010) find that lower input tariffs are associated with increased R&D expenditures.

2 Data

2.1 Patents

Our measure of innovation is patenting. For the purpose of our analysis, there are two main advantages of using patent data. First, they are available at the firm level, whereas cross-country R&D expenditure data are often only available at a more aggregate level, usually at the sector level. Second, patents are a measure of the actual output of an innovation process, while R&D expenditure is a measure of the input that goes into the innovation process. Being interested in the innovations that actually take place, we argue that patents are as such a superior measure, while noting that the empirical evidence suggests that patenting is as such strongly correlated with R&D expenditures (see e.g. Griliches, 1990).

We use data from the European Patent Office (EPO) Worldwide Patent Statistical Database (henceforth PATSTAT), the April 2015 version. PATSTAT offers bibliographic data, family links and citations of 90 million applications of nearly 100 countries. It contains population of all patents globally since mid 1960s. The patent documents as provided by PATSTAT are a rich source of information. We have name of the applicant, date of filing and publication and whether or not the patent was granted. We know the geography of the patent in the sense that we have information on both source and destination country. Source country is the residence country of the applicant. Destination is the country of the patent authority (e.g. USPTO, EPO, JPO, etc). One patent may have a set of destination countries. We have information on industry and technology classification of patents (NACE 2 digit and IPC codes) and we have complete information on patent citations. Since names of applicants are harmonized we have unique firm IDs. Hence, for each firm we have information on the citations included in the firm's patent applications as well as on whether and to what extent a patent by this firm has been cited in other applications. PATSTAT allows us to construct an international firm-level dataset and to follow the patenting activity of a firm through time. The number of patents applied for in each year is our basic measure of the innovative activity of a firm. Using information from PATSTAT we are able to identify unique patent owners, to construct a patent portfolio for each of them, and to follow them over time. Our period of interest are the years following the completion of the Uruguay Round, and we cover 3.5 million patents and 60000 firms over the period 1992 to 2000 and nearly 100 source and destination countries.

However, tariff data turns out to be our constraint, and limits the coverage of the analysis to around 50 countries.

2.2 Trade liberalization

Launched in Punta del Este, Uruguay, on 20 September 1986, the Uruguay Round of Multilateral Trade Negotiations was formally concluded in Marrakesh, Morocco, on April 15 1994, when 125 Governments and the European Communities, accounting for more than 90% of world trade, concluded a historical agreement to reform international trade. As stated in the Marrakesh declaration,⁴ the Uruguay Round achieved a global reduction by 40 per cent of tariffs and wider market-opening agreements on goods, and the increased predictability and security represented by a major expansion in the scope of tariff commitments. In addition, participation in the Uruguay Round was considerably wider than in any previous multilateral trade negotiation and, in particular, developing countries played a notably active role in it. While only few developing countries took part in earlier GATT rounds, and trade barriers reduction was negligible,⁵ the Uruguay round achieved important tariff reductions in both developed and developing countries. Hence, after eight rounds of troubled negotiations, the most ambitious and far reaching multilateral trade negotiation ever started led to the biggest reform of the world's trading system since the GATT was created. The Uruguay Round implied commitments to cut and bind tariffs on the imports of goods. The tariff reductions agreed on were explicit on both the timing and magnitude in cut. The deadlines for cut ended in 2000.

We use worldwide tariff data in order to account for the impact of the trade policy reforms of the 90s. The main source of tariff data is the UNCTAD Trade Analysis and Information System (TRAINS), which contains tariff and non-tariff measures at the most disaggregated level of the Harmonized System (HS) for more than 150 countries. Data are available from 1988 onwards. From this database we extract country-level tariff data from 1988 to 2009. We use a simple average tariff, which measures the average level of nominal tariff protection. Table 5 in the Appendix shows mean, median and standard deviation of average world tariffs from 1992 to 2009. Table 6 in the Appendix shows the change in average world tariffs for the same period. Reductions were larger in the earlier part of the period considered and decreased over time. The standard deviation is also higher in the beginning of the studied period, reflecting the high tariff reductions of countries, such as China and India, that started with very high levels of trade barriers and that undertook a great liberalization.

In addition to UNCTAD TRAINS data, we use information on existing regional trade agreements (RTAs) between world pairs of countries. This allows us to take into account the fact that some countries are part of trade agreements, and as such cannot be treated as having the same level of protection as countries where such agreements are not in force.

⁴https://www.wto.org/english/docs_e/legal_e/marrakesh_decl_e.pdf

⁵Exceptions are represented by the East Asian NICs.

The information on RTAs comes from the CEPII gravity dataset, which provides data on bilateral trade agreement for around 200 countries from 1948 to 2006.

3 Empirical strategy

3.1 Innovation and Knowledge creation

Our variable of interest is firms’ innovation. To measure firms’ innovation we use patenting. We think of the change in stock of patents over a certain time period as knowledge creation. Define a firm i ’s stock of knowledge at time t as

$$K_{it} = \sum_{s=1965}^t p_{is} \tag{1}$$

where p_{it} as a firm’s number of patents filed in a given year. In our analysis, one patent count corresponds to a unique invention and is identified as a patent family, that is the set of patents protecting the same invention in various countries.⁶ We date patents by application filing year. This is a common approach in the empirical literature because the application filing date is more closely timed with the R&D process than the patent publication⁷ and grant date. Note that patents filed in multiple locations are harmonized in PATSTAT (“patent family”) which means that we are not double counting the same innovation. We count patents starting with the first year for which we have observations from PATSTAT being 1965.

We also look at knowledge creation by considering the citations received by the patents filed by a firm i in year t . We do so by counting the number of citations per patent over the three years after the patent has been filed and let the count be denoted by c_p . The average citation count for firm i ’s patents filed in year t is

$$\bar{c}_{it} = \frac{1}{N_{it}} \sum_{p \in \Omega_{it}} c_p,$$

Figure 1 shows the development in patenting as well as citations per patent for patents filed from 1980 to 2014. It is interesting to notice that, while the total number of patent applications increases over time, the average number of patents per firm decreases.⁸

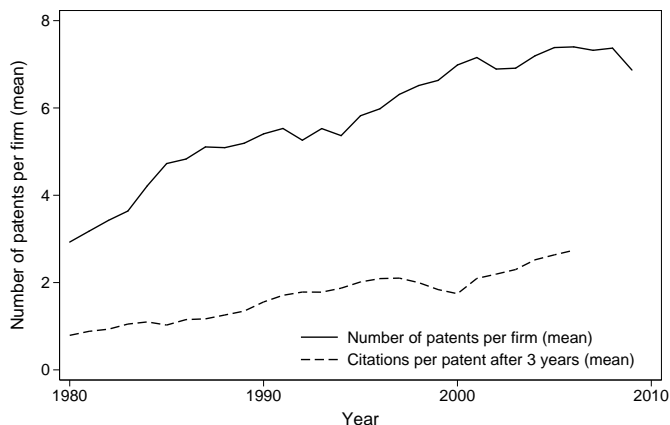
Table 10 in the Appendix describes the geographical coverage of patent protection and

⁶We use DOCDB patent family.

⁷Patent applications are usually published 18 month after the first application.

⁸Table 8 in the Appendix shows the total number of patents filed each year and the number of applicants actually applying for a patent in a specific year. It also provides the mean, the median and the standard deviations of the number of patent applications.

Figure 1: Patenting and Citations. 1980-2009.



Note: The figure shows the average number of patents per firm per year and the average number of citations per patent 3 years after the patent application date. The population of firms is restricted to all surviving firms in the 1980-2009 period.

shows that most patents worldwide are filed in Japan, in the US, at the European Patent Office and in Germany. The number of inventions patented in Japan, with 68% of total applications worldwide, is outstanding. However, the high share of patents filed at the JPO partially reflects the compositional characteristics of our sample of firms. As can be seen in Figure 10, Japanese applicants constitute 28% of firms in the sample. Figure 2 shows the development in patenting and citations per patent for firms headquartered in the US, Germany and Japan.⁹

3.2 The Empirical Model

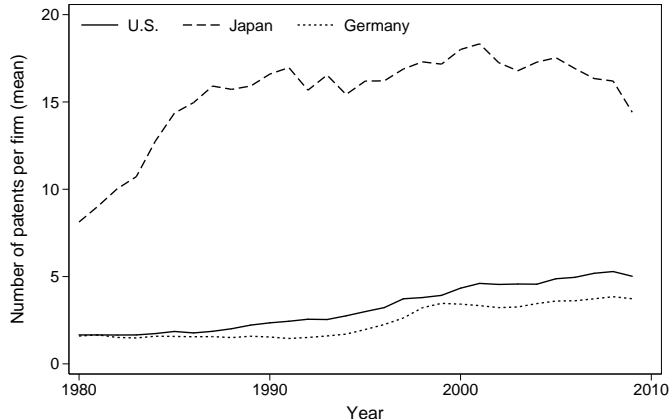
We want to estimate the impact of trade policy reform on firm innovation. Our approach to this is to compare growth in the knowledge stock for firms exposed to trade policy shocks relative to firms not exposed to them. To do so, consider the following specification for the determination of knowledge creation over a period of time:

$$\Delta \ln K_{it} = \alpha_{jh} + \beta_1 \Delta \tau_{it} + \beta_2 \Delta \mu_{it} + \gamma X_{i(h),Pre} + \epsilon_i \quad (2)$$

We let $\Delta \ln K_{it}$ denote the increase in knowledge stock over our period of interest, while $\Delta \tau_{it}$ and $\Delta \mu_{it}$ denote the change in firm-specific trade barrier over the same period. The fact that the trade barriers are firm specific reflects the fact that firms are differentially exposed to

⁹Table 11 provides detailed information on patenting in the top inventor countries.

Figure 2: Patenting by headquarter country. 1980-2009.



Note: The figure shows the average number of patents per firm per year headquartered in the U.S., Japan and Germany. The population of firms is restricted to all surviving firms in the 1980-2009 period.

different markets depending on their market share in each country. We choose a specification that allows us to distinguish between two types of measures of trade barriers since we want to exploit information on import tariffs as well as regional trade agreements (RTAs). Hence, we let τ_{it} denote firm-specific barriers based on import tariffs and μ_{it} denote firm-specific barriers based on import tariffs based on RTAs in year t . Our firm-level approach controls for country and industry-specific trends in patenting by including α_{jh} , which depicts industry (NACE 2 digit)-headquarters pair fixed effects. We also control for pre-sample period firm characteristics ($X_{i(h),Pre}$) being number of export markets in the pre-sample period and the log of the knowledge stock in the first year for which we have observations being 1965.

3.3 Identification

Our empirical strategy exploits differences in tariff reduction across countries over time combined with differences in firms' ex-ante exposure to different markets to construct firm specific trade barriers. This gives us a source of variation at the firm level which allows us to provide microeconomic evidence of the effect of trade policy on innovation. To operationalize this approach we construct a trade barrier variable for each firm as a weighted average of trade barriers based on a proxy of where the firm believes its future market to be. We distinguish between two types of measures of trade barriers, import tariffs as well as regional trade agreements (RTAs), and construct a firm specific measure of trade barriers based on

each of them.

We let weighted mean import tariffs for firm i at time t be

$$\tau_{it} = \sum_c \omega_{ic} \tau_{ct}, \quad (3)$$

where τ_{ct} is the simple average tariff of country c and ω_{ic} is a firm specific market weight reflecting the importance of market c as an outlet for firm i 's products.¹⁰ We calculate τ_{ct} based on tariff information from UNCTAD TRAINS (see the Appendix for details) which allows us to create a balanced panel for 48 countries. To construct the market weights we follow a similar approach to that of Aghion et al. (2014) and define ω_{ic} as the fraction of patents filed in a given country c by firm i :

$$\omega_{ic} = \frac{x_{ic}}{\sum_c x_{ic}} \quad (4)$$

x_{ic} denote a count of the patents filed in country c , and the denominator is the sum of all patent applications filed by firm i across all countries. One could argue that we would have wanted trade data rather than intellectual property (IP) protection data in order to construct the weights for market exposure. However, we believe that the patent portfolio of a firm is a good proxy of market exposure because firms seek IP protection in markets where they intend to sell in. The underlying assumption is that since patenting is costly, a firm will only apply for legal protection in countries where it plans to sell in the future. We also note that Aghion et al. (2014) find a high correlation between sales and patents weights.

To understand the calculation of market weights, it is constructive to consider an example. Suppose applicant $i = Honda$ filed three patent applications, 1 in Japan and 2 in the US, then $\omega_{iJapan} = 1/3$ and $\omega_{iUS} = 2/3$, and the trade tariff of each of these two countries in year t would receive a weight of $1/3$ for Japan and $2/3$ for the US.

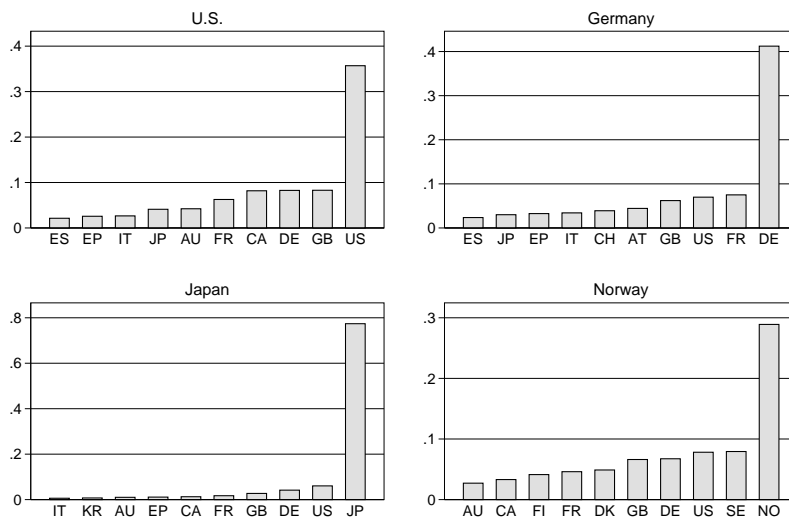
Based on information on regional trade agreements (RTAs) we construct a parallel measure to that based on import tariffs using weighted RTAs for firm i at time t :

$$\mu_{it} = \sum_c \omega_{ic} RTA_{h(i)ct} \quad (5)$$

where $h(i)$ denotes the headquarter country of firm i and $RTA_{h(i)c} = 1$ if the headquarter country of firm i has an RTA with country c . We set $RTA_{kct} = 1$ when $k = c$, i.e. for the firm i 's home country.

¹⁰National average tariffs are our measure of countries' nominal tariff protection. We use simple average tariff calculated as the ratio between the sum of duties and the number of duties.

Figure 3: Aggregate Market Weights



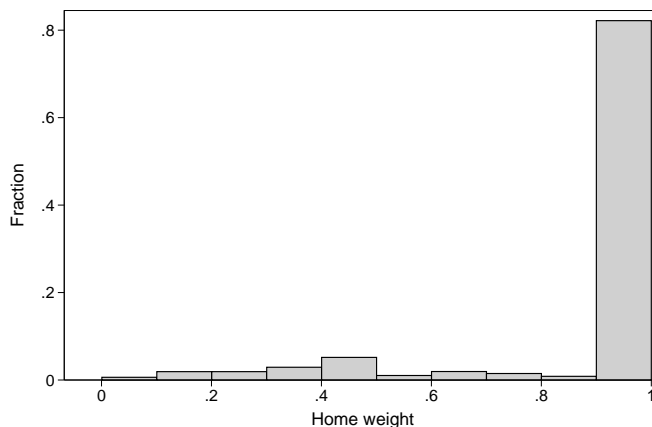
Note: The figure shows the share of patents by U.S./German/Japanese/Norwegian firms that is filed in destination country y . Only the top 10 destinations are shown. The population of firms is the pre-sample firms, i.e. firms that file at least one patent during the pre-period.

In order to calculate our weights, we define a pre-sample period starting in 1965, when Patstat’s coverage of worldwide patents begins, and ending in 1985, before the negotiations of the Uruguay Round were launched in 1986. Weights are calculated using only patents filed during this pre-liberalization window. This is done to make sure that weights are weakly exogenous as patent location could be influenced by trade policy changes as well as shocks to innovation.

To illustrate our identification strategy, we take a closer look at the calculated market weights and weighted trade barriers. Figure 3 illustrate the heterogeneity in market exposure from the point view of firms headquartered in the US, Germany, Japan and Norway. While they share many of the same markets, their exposures is clearly different. We note that on an aggregate basis there is a distinct home market bias with respect to the filing of patents across locations. However, Figure 4 shows that there is still great variation in the degree of home bias in patenting across firms.

Turning to weighted average trade barriers, Figures 5 and 6 show the development in the weighted import tariffs for firms headquartered in the US, Germany, Japan, the UK, South-Korea, China and India. They show that average firm specific tariffs decreased after 1990 and that there is considerable variation in the tariff levels. Table 7 in the Appendix

Figure 4: Home Bias in Patenting



Note: The figure shows the histogram of home weights ω_{iHome} across all firms in the pre-sample period.

displays mean, median and standard deviation of the firm specific weighted average tariffs for the whole sample. Again we note the general decline in tariffs during the 90s and the heterogeneity across firms illustrated by the standard deviation, and the decline in this over time.

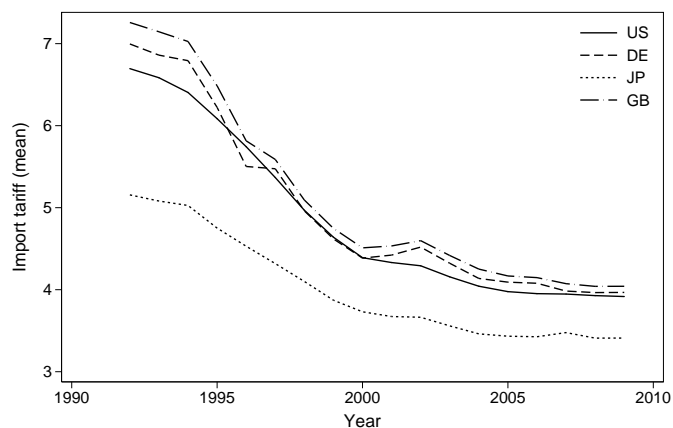
4 Results

We proceed by estimating the model described in equation (2). Our period of interest is 1992 to 2000, and we therefore specify that $\Delta \ln K_{it} = \ln K_{i2000} - \ln K_{i1992}$, $\Delta \tau_{it} = \tau_{i00} - \tau_{i92}$, and $\Delta \mu_{it} = \mu_{i00} - \mu_{i92}$. Table 1 shows the results. The first column includes headquarter country-industry fixed effects; in column two we add pre-sample firm characteristics (number of patenting markets in the pre-sample period and the log of the knowledge stock in 1965), while in column three we include headquarter country time trends and firm fixed effects.

The results show a positive and significant effect of lower tariff barriers on firms' innovative activity. The establishing of RTAs does not appear to have any robust significant influence on firms' innovation.

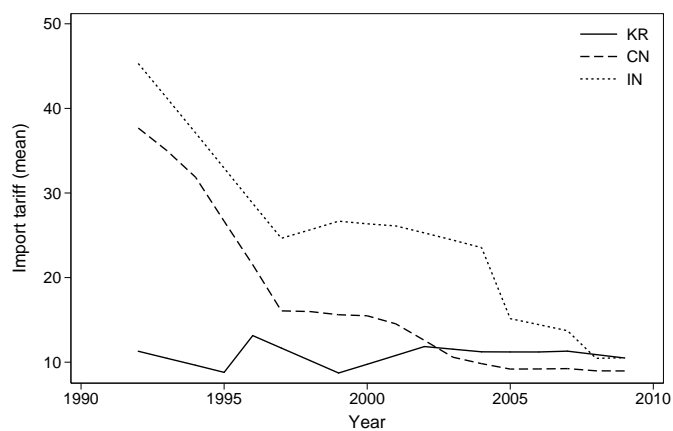
A reduction of a firm's selling markets tariff by one percentage point led to one percent higher knowledge stock. Our data shows that over the period 1992 to 2000 mean knowledge stock among firms globally went up by 50 percent, while the mean reduction in the firm specific tariff measure (τ_{it}) was almost three percentage points. Hence, our empirical results suggest that roughly 6 (3/50) percent of the observed patented knowledge creation can be

Figure 5: Average Weighted Import Tariffs, I



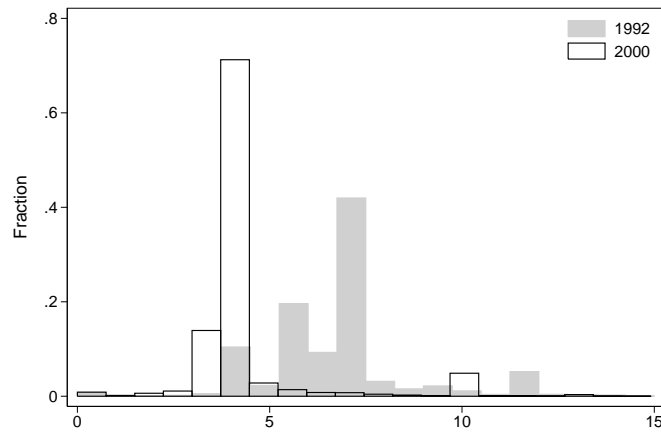
Note: The figure shows the annual average τ_{it} across firms according to headquarters country. The population of firms is restricted to all surviving firms in the 1980-2009 period.

Figure 6: Average Weighted Import Tariffs, II



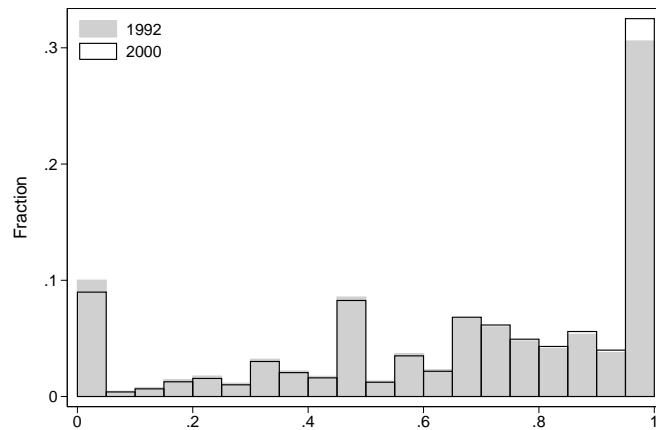
Note: The figure shows the annual average τ_{it} across firms according to headquarters country. The population of firms is restricted to all surviving firms in the 1980-2009 period.

Figure 7: Density of Weighted import Tariffs (τ_{it}) in 1992 and 2000.



Note: The figure shows the histogram of τ_i , the weighted average import tariff in firm i 's markets, in 1992 and 2000. The population of firms is restricted to all surviving firms in the 1980-2009 period.

Figure 8: Density of Weighted RTA Exposure (μ_i) in 1992 and 2000.



Note: The figure shows the histogram of μ_i , the weighted share of RTA's in firm i 's markets, in 1992 and 2000. The population of firms is restricted to all surviving firms in the 1980-2009 period with exposure to 2 or more markets in the pre-period.

Table 1: Trade Policy and Knowledge Creation.

Dep. variable: $\Delta \ln K_{it}$	(1)	(2)	(3)
$\Delta \tau_i$	-.012 ^a (.004)	-.011 ^a (.004)	-.005 ^a (.002)
$\Delta \mu_i$.028 (.050)	.028 (.051)	.047 ^c (.027)
Headquarter-industry FE	Yes	Yes	No
Pre-sample firm characteristics	No	Yes	No
Headquarter-year FE	No	No	Yes
Firm FE	No	No	Yes
Number of firms	58,259	58,259	174,777

Standard errors clustered by headquarters country in parentheses.

^a $p < 0.01$, ^b $p < 0.05$, ^c $p < 0.1$.

explained by trade policy.

Our results suggest that trade liberalization in sum encourages innovation. This may be due to a benign positive effect of increased competition or better market access or both. Below we explore the mechanisms behind the result further, but first we turn to some robustness analyses.

4.1 Robustness

One may argue that our measure of knowledge and innovation, namely patents, is an imprecise measure. There might have been an increase in patenting over time due to what one may refer to as a 'lawyer effect', encouraging firms to patent innovations they would not have patent previously. If so, we should see a drop in citations for treated firms, since highly valuable inventions are more extensively cited than low value patents (Harhoff et al., 1999). We therefore develop a measure of knowledge being the cumulative number of citations received by the patents filed by a firm until a given year t . We do so by counting the number of citations per patent over the three years after the patent has been filed and let the count be denoted by c_{ps}

$$C_{it} = \sum_{s=65}^t \sum_{p \in \Omega_{is}} c_{ps}, \quad (6)$$

and let average citations for patents filed until year t be given by $\bar{C} = C_{it}/K_{it}$. We proceed by using $\Delta \ln \bar{C}_i = \ln \bar{C}_{i2000} - \ln \bar{C}_{i1992}$ as dependent variable. The results are reported in Table 2. We see that if anything the results using cumulative citations as measure of knowledge

Table 2: Trade Policy and Cumulative Citations.

Dep. variable: $\Delta \ln \bar{C}_{it}$	(1)	(2)	(3)
$\Delta \tau_i$	-.014 (.009)	-.011 ^c (.006)	.000 (.005)
$\Delta \mu_i$	-.130 (.098)	-.096 (.092)	.080 ^c (.044)
Headquarter-industry FE	Yes	Yes	No
Pre-sample firm characteristics	No	Yes	No
Headquarter-year FE	No	No	Yes
Firm FE	No	No	Yes
Number of firms	31,489	31,489	104,483

Standard errors clustered by headquarters country in parentheses.

^a $p < 0.01$, ^b $p < 0.05$, ^c $p < 0.1$.

creation confirm our baseline results on the impact of trade liberalization on innovation. The results based on weighted import tariffs as well as RTAs are however weak, and only robust for one out of three specifications.

Another concern is that the TRIPS agreement, which was part of the WTO agreement, may be correlated with tariff cuts. TRIPS established minimum and common standards of IP protection to be adopted by all WTO members. While no significant changes affected developed countries, which had strong IP protection already, developing countries had to reform and strengthen their IP protection system to comply with the the new WTO rules. Developing countries were granted 5 years after entry into force of the WTO agreement to implement their obligations, deadline for this being 2000. To address this concern, we restrict our sample to developed countries only. Specifically, we select only firms with headquarter or sales in high income countries and estimate the model again. The results are shown in the third and fourth column of Table 3, and are consistent and in line with our main specification.

One may also argue that firms that were exposed to liberalized markets before the Great Liberalization of the 1990s have always higher patent growth compared to other firms. To address this concern, we conduct a placebo test: we regress past knowledge growth ($\ln K_{i1989} - \ln K_{i1980}$) on future trade policy change $\Delta \tau_i$ and $\Delta \mu_i$. Our results are shown in the first column of Table 3. We do not find significant evidence of higher patent growth for firms ex-ante exposed to liberalized markets.

Next, we take some additional steps to refine our analysis. First, we provide more detailed evidence by using industry-level data instead simple average country level tariff data. We

Table 3: Robustness.

Dep. variable: $\Delta \ln K_{it}$	1 Placebo	2 Industry τ	3 High income I	4 High income II	5 Triadic
$\Delta \tau_i$	-.002 (.010)	-.011 ^a (.003)	-.014 ^a (.002)	-.017 ^a (.006)	-.145 ^b (.06)
$\Delta \mu_i$	-.074 (.079)	.011 (.056)	.055 (.070)	-.122 (.151)	.138 (.728)
HQ-industry FE	Yes	Yes	Yes	Yes	Yes
Pre-sample firm ch.	Yes	Yes	Yes	Yes	Yes
Number of firms	37,617	58,259	55,114	44,949	2,738

Standard errors clustered by headquarters country in parentheses.

^a $p < 0.01$, ^b $p < 0.05$, ^c $p < 0.1$.

get HS6 digit tariffs from TRAINS, we average them at ISIC level, and, by using conversion tables, we obtain industry tariffs at the Nace Rev.2 level. We use the Nace code assigned to each firm to calculate industry specific (weighted) tariffs for each firm. The results, displayed in the second column of Table 3, confirm our main finding that a reduction of a firm's trade barrier increases firms' innovative activity as measured by patents. The estimated effect is similar in magnitude to our main specification and economically significant.

Second, we restrict our sample to triadic patents. These are patents filed at the three main patent offices, namely the European Patent Office (EPO), the Japanese Patent Office (JPO) and the United States Patents and Trademark Office (USPTO).¹¹ Triadic patents are commonly used in the literature to retain only highly valuable inventions and to work with a more uniform and comparable set of patents. Indeed, the distribution of patent values is skewed, with many patents having low value and few patents representing high value innovations. Our results are robust to restricting the sample to triadic patents. This is shown in the last column of Table 3. However, the sample size is significantly reduced.

Finally, a last consideration is that our sample is limited to firms that file at least one patent at the end of the observation period (between 2009 and 2014). Thus, by construction, all our firms survive until the end of the period of analysis. However, firms may exit the market as a result of increased competition following trade liberalization. To address this concern, we estimate our model including all firms that have patents in the pre-sample period (1965-1985), loosening the requirement of filing at least one patent at the end of the period. The estimated effect on this larger sample of firms is roughly similar to our main finding,

¹¹See Dornis and Khan (2004) and Martinez (2010) for more detailed definition and explanation of how triadic patent families are constructed.

suggesting that firm exit does not bias our results.

4.2 Mechanisms

So far we have shown that trade liberalization had a benign impact on firms' innovation in the 90s. We would like to go on to explore the mechanisms behind this result. According to the theory we would expect there to be both negative and positive effects of trade on innovation. Whether trade liberalization in sum is positive or negative for firms's innovative activities depends on the magnitude of the different effects. For exporting firms trade liberalization means both better market access and tougher competition. The former is unambiguously positive, while the latter may be positive or negative. Non-exporting firms only face the competition effect of trade. The competition effect of trade is twofold: the Schumpeterian effect of competition is negative while the escape-competition effect is positive. Firms far from the knowledge frontier experience a negative Schumpeterian effect, while firms at the frontier experience the latter positive effect.

To test for the differential impact on exporters and non-exporters we interact $\Delta\tau_{it}$ with a home weight ω_{iHome} , which is constructed based on the patenting weights. If a firm only patents in the country where it has its headquarter, we define the firm as a non-exporter. Otherwise we consider it as an exporter. Differently from a dummy variable approach, the use of the home weight ω_{iHome} allows us to capture different degrees of a firm's exporting status. The results are reported in Table 4. We find that the benign impact of trade liberalization on exporters is stronger than that on non-exporters. While both exporters and importers face the competition effect of trade, the exporters also face better market access due to trade liberalization. This is likely to explain the differential impact of trade liberalization of the two groups of firms.

In order to test for the role of the Schumpeterian effect of trade we also interact the change in the weighted import tariff measure $\Delta\tau_i$ with pre-sample log knowledge stock. The results in Table 4 suggest that there is no significant Schumpeterian effect of trade liberalization.

5 Conclusions

In this paper we investigated the role of trade policy for knowledge creation and technical change. The motivation for this work is that international trade matters for innovation, but our knowledge of the extent to which the wave of trade liberalization started in the 1990s has promoted the observed rise in firms' innovation worldwide is still limited. We constructed a novel international firm-level dataset and exploited ex-ante differences in firms' exposure to

Table 4: Mechanisms: The Channels of Trade Liberalization

Dep. variable: $\Delta \ln K_{it}$		
$\Delta \tau_i$	-.014 ^a (.002)	-.011 ^a (.004)
$\Delta \tau_i \times \omega_{iHome}$.010 ^a (.003)	
$\Delta \tau_i \times \ln K_{i,Pre}$.001 (.001)
Headquarter-industry FE	Yes	Yes
Pre-sample firm characteristics	Yes	Yes
Number of firms	58,259	58,259

Standard errors clustered by headquarters country in parentheses. ^a p < 0.01, ^b p < 0.05, ^c p < 0.1.

markets and competition to estimate the causal effect of trade policy on innovation.

According to our empirical evidence the Great Trade Liberalization had a positive and significant effect on firms' innovative output. Our estimates suggest that about 6 percent of the knowledge creation during the 1990s can be explained by trade policy. However, we did not find evidence that RTAs alone matter for firms' innovation.

A deeper analysis of the mechanisms driving our results allowed us to identify separately the effects of trade operating through market access and competition. Our results provide evidence that the positive impact resulting from increased competition and the larger market size prevail on the negative Schumpeterian force.

Our work can be extended in several directions. First, we would like to develop a simple theoretical model as a guide to the exposition of the main predictions and implications of the theory. A tighter link to theory would assist us in presenting our empirical strategy and interpreting our results.

Second, zooming in on sharp liberalization episodes would be a nice complement to our analysis. This would allow us to have a closer look at the effect of huge tariff reductions that came as a shock.

Finally, a natural complement to and extension of this analysis would look at how trade liberalization affected the extensive margin. We are actively working on all these areas.

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Appendix

A PATSTAT

We use data from the European Patent Office (EPO) Worldwide Patent Statistical Database (henceforth PATSTAT). PATSTAT is the result of a unique effort to develop a worldwide patent database which was initiated by the Patent Statistics Task Force led by the Organisation for Economic Co-operation and Development (OECD).¹² The database is a snapshot of the EPO master documentation database (DOCDB) at a single point in time. Patstat is updated twice a year and offers bibliographic data, family links and citations of 90 million applications of nearly 100 countries. It covers close to the population of all worldwide patents since the mid 1960s. We use the April 2015 version of Patstat.

Patent documents as provided by Patstat are a rich source of information. Along with details on the technical features of inventions and the history of the application, Patstat provides a wealth of information on patent applicants. The information contained in the patent documents provided by Patstat can be grouped in three main categories: the history of the patent application, the technical features of the innovation, and the development of the invention. The first set of information can be seen as a chronology of the patent granting process, and it includes the application filing date for each country where legal protection is asked for, the priority date,¹³ the publication date and whether the patent was granted or not. The second group contains information such as the area of technology to which a new invention pertains¹⁴, and the list of cited patents and other scientific publications that are prior art relevant to the invention. The last category is a description of the development process of new inventions. It contains information on the inventors and applicants for each patent, i.e. the name of the firm or individual who filed the patent application and their residence country, and allocates them to different sectors such as private business enterprises, universities and higher education institutions, governmental agencies, and individuals. Available is also information on the industry category (nace 2) to which the applicant belongs.

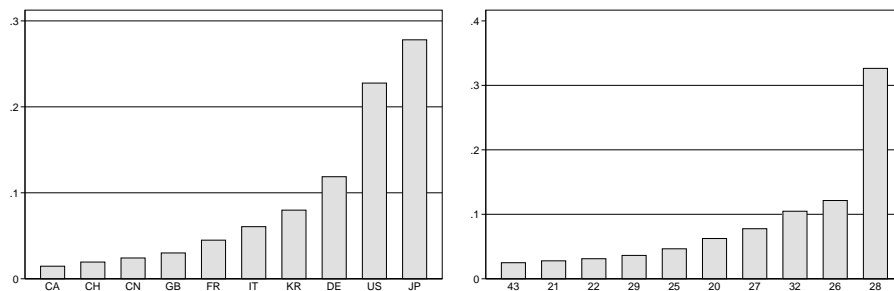
Figure 9 shows the distribution of patenting firms across headquarter countries and industries. We note the dominance of Japan and the US and by the industries machinery and equipment (28), computers, electronic and optical products (26), other manufacturing (32).

¹²Other members of the task force are the World Intellectual Property Organisation (WIPO), the Japanese Patent Office (JPO), the US Patent and Trademark Office (USPTO), Korean Intellectual Property Office (KIPO), the US National Science Foundation (NSF) and European Commission (EC).

¹³The first application worldwide.

¹⁴The main technical classifications available in Patstat are the IPC and the CPC, but other classification schemes are provided.

Figure 9: Share of Firms by Country and Industry



Note: The figure shows the share of firms in the final dataset by head-quarters country and NACE 2-digit industry. Only the top 10 countries/industries are shown. The population of firms is restricted to firms that that filed at least on patent during the pre-period and one patent between 2009 and 2014.

B The Uruguay Round

A brief history

The negotiation process that led to the signature of the “Final Act Embodying the Results of the Uruguay Round of Multilateral Trade Negotiations” was long and troubled; several points of major disagreement among countries emerged during the talks and in some episodes the entire negotiation seemed doomed to fail. Already in December 1988, during the ministerial meeting in Montreal, the talks stalled on a mid-term review, which was only completed in the next year meeting in Geneva.

According to the negotiating agenda agreed upon in Punta del Este, the Uruguay Round should have reached an agreement during the closing ministerial meeting, scheduled for December 1990 in Brussels, but disagreement on how to reform agricultural trade led to a deadlock and to an extension of the talks. This was the bleakest period for the Uruguay Round. However, despite the difficulties, the negotiation continued and a first draft of a final legal agreement was compiled and put on the table of negotiation in 1991 in Geneva. This draft became the basis for the final agreement.

In the following years, the emergence of new points of major conflict threatened the successful conclusion of the negotiation, until the US and the EU achieved the so called “Blair House” breakthrough on agriculture in 1992 (in Washington), and the “QUAD” (US, EU, Japan and Canada) reached a market access breakthrough at the G7 summit in July 1993 (in Tokyo). This paved the way for the end of the negotiation in December 1993 in Geneva.

On 15 April 1994 the final agreement was signed in Marrakesh. The Marrakesh Agreement officially established the new World Trade Organization (WTO), which replaced the GATT on January 1, 1995, when it was created in Geneva. The WTO Agreement entered into force on 1 January 1995, or as early as possible after ratification of the member states.

In the end, after eight rounds of troubled negotiations, the most ambitious and far reaching multilateral trade negotiation ever started led to the biggest reform of the world's trading system since the GATT was created. The agreement established lower tariff and non-tariff barriers on industrial products, brought new areas of the economy like services into the world trading system, introduced new rules to protect intellectual property rights, reformed trade in sensitive sectors like agriculture and textiles, and revised and strengthened the rules for multilateral dispute settlement.

For the purpose of our analysis, we focus on the reduction in tariffs endorsed by the Uruguay Round.

The tariff reductions

The major results of the Uruguay Round were the individual commitments of the contracting parties to cut and bind their custom duty rates on imports of goods.

It is important to notice that the tariff reductions to be implemented after the entry into force of the WTO agreement were programmed during the negotiations. This feature of the Marrakesh Agreement is important for our identification strategy because it ensures the tariff reductions were pre-determined and therefore unlikely to be correlated with contemporaneous shocks, or to be driven by political pressure arising from the effects of trade liberalization.

After the Marrakesh Final Act was signed, the participating countries started to implement the tariff reductions they agreed upon. The process took from five to twelve years, depending on the sector concerned, and with differences between developed and developing countries, which were granted more time to comply with their commitments.

For non-agricultural products the agreed tariff reductions were implemented in five equal instalments.¹⁵ The first cut was made on the date of entry into force of the WTO agreement, and the following four on 1 January of each subsequent year.¹⁶ Over the five years, this process led to a 40% tariff cut on average on industrial products in developed countries, from an average of 6.3% to an average of 3.8%.

In addition to tariff cuts, the number of "bound" tariffs¹⁷ increased significantly, from

¹⁵Unless it is otherwise stated in a Member's Schedule.

¹⁶see Marrakesh Protocol to the General Agreement on Tariffs and Trade 1994 for more information.

¹⁷Bound tariffs are duty rates that are committed under WTO. Raising them above the bound rate is possible but hard: the process involves a negotiation with the most affected countries and it possibly requires a compensation for their loss of trade.

78% to 99% in developed countries, from 21% to 73% in developing countries, and from 73% to 98% in transition economies.

The agricultural sector experienced a "tarrification" process in which almost all restrictions to trade different from a tariff, such as quotas, were converted into tariffs with an equivalent level of protection. In a second step, tariffs were gradually reduced by an average of 36% for developed countries and 24% in the case of developing countries. For developed countries the process was phased in over six years, while for developing countries it lasted until the end of 2004.

Table 5: Mean, median standard deviation of world average tariffs for each year.

year	mean	median	sd deviation	nr. of countries
1992	12,28	7,66	11,18	48
1993	11,84	7,56	10,64	48
1994	11,14	7,34	9,20	48
1995	10,34	6,47	7,84	48
1996	9,74	5,60	7,08	48
1997	9,20	5,59	6,32	48
1998	8,90	5,16	6,48	48
1999	8,69	5,19	6,72	48
2000	8,31	4,42	6,65	48
2001	8,16	4,47	6,46	48
2002	8,14	4,61	6,55	48
2003	7,76	4,40	6,14	48
2004	7,15	4,21	5,62	48
2005	6,51	4,19	4,35	48
2006	6,32	4,18	4,07	48
2007	6,10	4,06	3,96	48
2008	5,94	4,04	3,74	48
2009	5,90	4,04	3,69	48

Note: The sample is restricted to a balanced panel of 48 countries from 1992 to 2009.

C Tables and Figures

Table 6: Mean, median standard deviation of world average Δ tariffs for each year.

year	mean	median	sd deviation	nr. of countries
1993	-0,44	-0,08	1,67	48
1994	-0,69	-0,01	1,91	48
1995	-0,80	-0,67	2,05	48
1996	-0,60	-0,84	1,82	48
1997	-0,54	0,00	1,65	48
1998	-0,29	-0,43	1,05	48
1999	-0,21	-0,36	0,92	48
2000	-0,38	-0,24	0,82	48
2001	-0,15	0,00	0,68	48
2002	-0,02	0,04	0,83	48
2003	-0,38	-0,21	1,03	48
2004	-0,61	-0,19	1,68	48
2005	-0,64	-0,02	1,83	48
2006	-0,19	-0,01	0,87	48
2007	-0,21	-0,04	0,92	48
2008	-0,17	-0,02	0,66	48
2009	-0,04	0,00	0,23	48

Note: The sample is restricted to a balanced panel of 48 countries from 1992 to 2009.

Table 7: Firm-specific import barriers: τ_{it} .

year	mean	median	sd deviation	min	max
1992	7,33	5,56	6,51	0	56,34
1993	7,06	5,56	5,91	0	51,09
1994	6,82	5,35	5,31	0	45,84
1995	6,29	5,14	4,45	0	40,59
1996	6,17	5,12	4,20	0	35,34
1997	5,71	4,87	3,29	0	30,09
1998	5,31	4,48	3,19	0	31,52
1999	4,94	4,14	3,04	0	32,95
2000	4,84	4,00	3,18	0	32,64
2001	4,86	3,92	3,22	0	32,32
2002	4,89	3,84	3,22	0	31,25
2003	4,68	3,75	3,02	0	30,19
2004	4,50	3,68	2,88	0	29,12
2005	4,42	3,68	2,69	0	18,30
2006	4,41	3,68	2,69	0	17,39
2007	4,41	3,72	2,70	0	16,48
2008	4,33	3,72	2,58	0	13,18
2009	4,30	3,72	2,50	0	13,60

Note: Firm-specific import barriers τ_{it} are calculated on a balanced panel of 48 countries from 1992 to 2009.

Table 8: Total, mean, median, standard deviation of $Patents_{it}$ for each year t .

year	total	mean	median	sd deviation	nr of firms filing in year t
1986	319,852	33.1	2	415.6	9,660
1987	318,084	33.7	2	440.7	9,449
1988	317,559	35.6	2	442.2	8,924
1989	323,779	36.0	2	418.0	8,993
1990	336,739	37.8	2	430.3	8,905
1991	343,978	38.3	2	411.5	8,979
1992	327,566	35.0	2	341.7	9,356
1993	344,263	32.2	2	313.0	10,708
1994	334,440	29.5	2	264.5	11,329
1995	364,180	32.0	2	288.0	11,391
1996	373,721	30.6	2	278.5	12,222
1997	395,182	30.7	2	281.3	12,880
1998	406,734	29.5	2	278.3	13,784
1999	413,699	27.8	2	264.8	14,885
2000	436,879	27.1	2	257.3	16,140
2001	447,855	26.1	2	262.6	17,131
2002	431,712	25.1	2	250.3	17,226
2003	433,628	23.8	2	249.0	18,216
2004	451,661	23.9	2	266.6	18,861
2005	463,354	23.9	2	271.6	19,382
2006	463,649	22.8	2	254.4	20,317
2007	457,225	21.5	2	223.9	21,303
2008	460,018	20.8	3	210.5	22,163
2009	423,213	18.1	2	181.2	23,436
2010	439,156	12.3	2	144.3	35,794
Nr. of applicants					39,739
Nr. of patents					9,234,557

Table 9: *

Notes: The second column shows the total number of patents filed by patent holders in the sample each year. Column three, four and five show the mean, the median and the standard deviations of the number of patent applications. The last column displays the number of applicants applying for a patent each year. A patent refers to an innovation/patent family and the year refers to the earliest application date for each patent family. Patents in the dataset are those owned by firms or individuals identified in the pre-sample period and surviving until 2010. There are 39,739 patent holders in our sample. The total number of patents in the dataset is 9,234,557. Note that there are potentially many applicants per patent. Hence, the sum of patents in column two (9,828,126) differs from the total number of distinct patents in the sample.

Table 10: Geographical coverage of patent protection. Top 15 countries (1986-2010).

Inventions patented in:	Nr	Percentage	Total nr. of patents
JP	6,296,680	68.2	9,234,557
US	2,133,578	23.1	9,234,557
EP	1,109,861	12.0	9,234,557
DE	883,531	9.6	9,234,557
CN	727,984	7.9	9,234,557
KR	710,363	7.7	9,234,557
CA	330,232	3.6	9,234,557
AU	328,740	3.6	9,234,557
AT	205,941	2.2	9,234,557
TW	194,898	2.1	9,234,557
GB	171,957	1.9	9,234,557
ES	170,691	1.8	9,234,557
FR	124,026	1.3	9,234,557
BR	118,990	1.3	9,234,557
MX	77,892	0.8	9,234,557

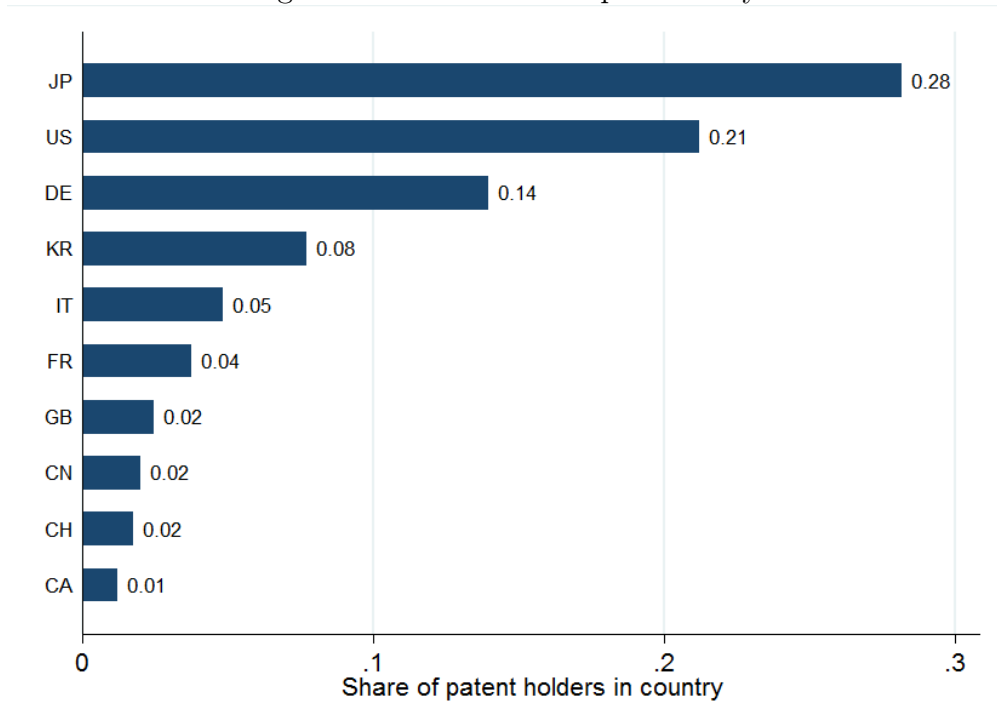
Notes: The table only shows the top 15 countries where patents are filed. A patent refers to an innovation/patent family. Patents in the dataset are those owned by firms or individuals identified in the pre-sample period and surviving until 2010. The total number of patents is 9,234,557.

Table 11: Top 15 inventor countries (1986-2010). Based on headquarter country of patent holders.

Country	Number of world inventions	Percentage of world inventions	Total number of patents
JP	6,607,325	71.5	9,234,557
US	1,197,632	13.0	9,234,557
DE	616,850	6.7	9,234,557
KR	494,535	5.4	9,234,557
CN	154,852	1.7	9,234,557
FR	121,965	1.3	9,234,557
GB	91,363	1.0	9,234,557
missing	73,827	0.8	9,234,557
NL	72,780	0.8	9,234,557
IT	65,527	0.7	9,234,557
CH	61,377	0.7	9,234,557
SE	50,744	0.5	9,234,557
TW	30,843	0.3	9,234,557
CA	27,601	0.3	9,234,557
FI	25,335	0.3	9,234,557

Notes: The table only shows the top 15 inventor countries. Patents in the dataset are those owned by firms or individuals identified in the pre-sample period and surviving until 2010. Missing refers to patent holders with missing information on headquarter country. Note that there are potentially more applicants per patent; in this case a country is counted once for each headquarter of the applicants.

Figure 10: Share of firms per country.



Notes: The graph shows the share of patent holders (individuals or companies) for each country in the sample; only the ten countries with the highest percentage of firms are shown. The sample consists of individual or companies that filed at least one application in the pre-sample period and survive until 2010. Note that for 3% of applicants we are not able to identify headquarter country; these patent holders are excluded from this figure, but counted in the total amount of applicants. Total number of patent holders is 39,739.