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

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Preliminary draft, February 2016

Abstract

This paper tests the effect of trade liberalization over two decades on innovation using an international firm-level dataset. 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 innovation. Our results suggest that trade liberalization has economically significant effects on innovation and, ultimately, technical change.

*We thank Bjarne J. Kvam from the Norwegian Industrial Property Office for helpful clarifications and comments.

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1 Introduction

The international trade environment impinges upon the incentives that firms have to innovate and create new knowledge. Hence, trade policy and trade liberalization matter for specialization, exploitation of economies of scale and within-industry reallocation of resources, but also for firm performance and innovation. Sparked off by the conclusion of the Uruguay round, trade barriers have declined substantially across the globe over the last two to three decades. At the same time the number of patents applied for, as well as granted, has increased steadily. However, our knowledge of the extent to which this wave of trade liberalization has promoted the rise in firms' innovation worldwide is still limited. While there has been a rise in empirical analyses analysing the impact of trade on firms' performance,due to scarce availability of direct measures of innovative activity at the firm level, most microeconomic evidence on the effect of trade on innovation is indirect.[1] Hence, in this paper we examine whether - and through what channels - the tariffs decline in the Great Trade Liberalization of the 1990s (Estevadeordal and Taylor, 2013) have influenced innovation, measured directly through patenting, globally. Morover, we do not focus on the role of trade as such, but explicitly on the role of trade liberalization as as result of trade policy initiatives.

The empirical literature on trade and innovation has mainly focused on the effect of trade liberalization on productivity. This provides important insights into whether trade affects firm performance. However, it 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. But the estimated residuals may 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, namely innovation.

The point of departure for our empirical analysis is the theoretical literature on trade and innovation that identifies two main channels through which trade liberalization affects firms' innovation. First, lowering import barriers increases competition. The effect of increased

[1] Recent 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.

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 reducing the rents from innovation and reducing 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, allows them to spread the fixed costs of innovation and encourages firms to innovate. (e.g. Grossman and Helpman (1992), Krugman (1980), and Yeaple, 2005).

Finally, a 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 of 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.

The global trade liberalization of the 1990s in the aftermath of the Uruguay Round makes the question of the effect of trade on innovation concrete. Over these years we saw deep and broad tariff cuts for both developed and developing countries. 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 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 and competition. We know the headquarter location and the markets fims were active in prior to the liberalization. Firms were ex-ante exposed to different markets. This provides us with firm-level variation in exposure to the Great Liberalization and allows us to difference out all country and industry trends in patenting. 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 exposure.

Our results show that trade policy matters, and that trade liberalization promotes firm level innovation. Our estimates suggest that about 6 percent of knowledge creation during the 1990s can be explained by trade policy. Furthermore, our results indicate that the positive impact resulting from increased competition and the larger market size prevail on the negative Schumpeterian force.

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 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 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. [2] 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, international firm-level data set and the high number of countries in our sample gives us the possibility to provide external validity. Finally, from a methodology point of view as well as with respect to the data used to measure innovation, our approach is similar to that of Aghion et al. (2014) and Calel and Dechezleprêtre (2014)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.

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

2 Data

2.1 Patents

Our meaure 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), April 2015 version. PATSTAT offers bibliographic data, family links and citations of 90 million applications of nearly 100 countries. It contains close to 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 September 20, 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,[3] 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,[4] 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. Table2 in the Appendix shows mean, median and standard deviation of average world tariffs from 1992 to 2009. Table 3 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.

[3] https://www.wto.org/english/docs_e/legal_e/marrakesh_decl_e.pdf

[4] Exceptions 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} is 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.[5] 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 publication[6] 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 i's patents filed in year t is

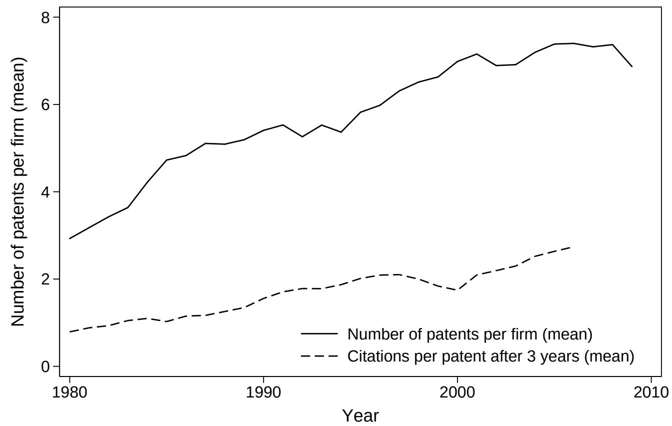
$$\bar{c}_{it} = \frac{1}{N_{it}} \sum_{p \in \Omega_{it}} c_p,$$

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

[5]We use DOCDB patent family.

[6]Patent applications are usually published 18 month after the first application.

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.

applications increases over time, the average number of patents per firm decreases.[7]

Table 7 in the Appendix describes the geographical coverage of patent protection and 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.[8]

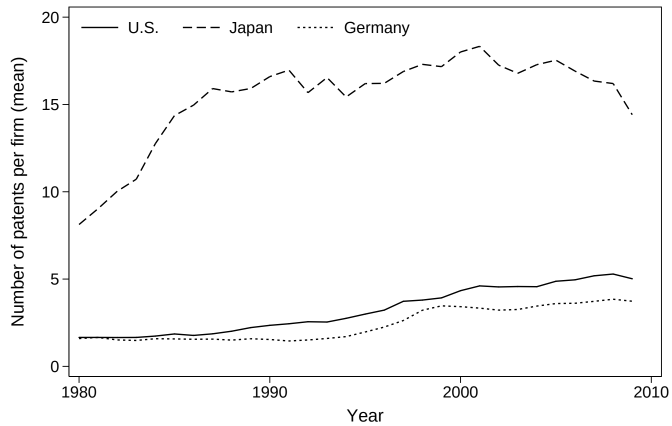
3.2 The empirical model

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

[7] Table 5 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.

[8] Table 8 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.

determination of knowledge creation over a period of time:

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

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 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.

As pointed out above, we distinguish between two types of measures of trade barriers, import tariffs as well as regional trade agreements (RTAs).

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

$$\tau_{it} = \sum_{c} \omega_{ic} \tau_{ct}, \tag{3}$$

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.[9] 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:

$$\omega_{ic} = \frac{x_{ic}}{\sum_c x_{ic}} \tag{4}$$

x_{ic} denotes 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 that intellectual property (IP) protection data in order to construct the weights for market expsoure. 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 with sales and patents weights.

To understand the calculation of market weights, it is instructive 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 parallell mea-

[9] National 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.

sure to that based on import tariffs of weighted RTAs for firm i at time t:

$$\mu_{it} = \sum_{c} \omega_{ic} RTA_{h(i)ct} \tag{5}$$

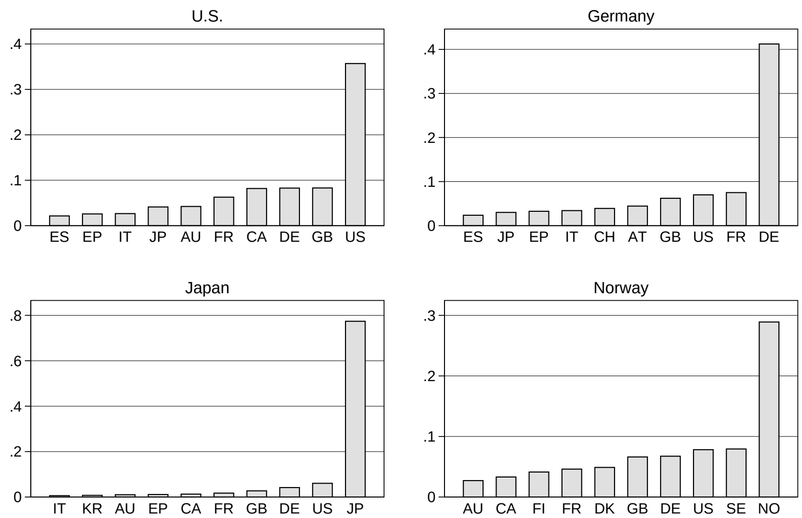
where $h(i)$ denotes the headquarter country of firm i and $RTA_{h(i)c} = 1$ if the headquarter country of firm i has an RTA with country c.

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 illustrates 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 expoures 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.

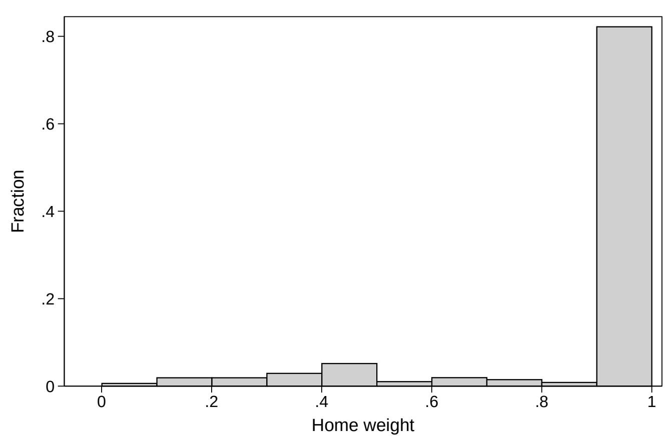
Turning to weighted average trade barriers, Figures 5 and 6 show the development in the weighted import tariffs for firms headquartered in the US, Germany, Japan, the UK, South-Korea, China and India. They shows that average firm specific tariffs decreased after 1990 and that there is considerable variation in the tariff levels.Table4 in the Appendix 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.

Figure 3: Aggregate Market Weights



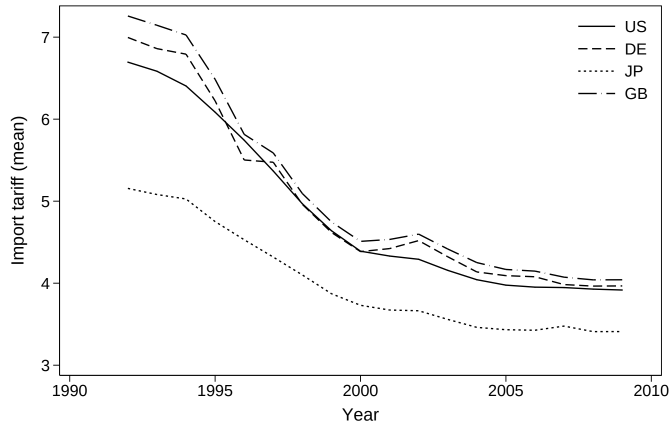
Note: The figure shows the share of patents by U.S./German/Japanese/Norwegian firms that is filed in destination country y. Only the top 10 destinations are shown. The population of firms is the pre-sample firms, i.e. firms that file at least one patent during the pre-period.

Figure 4: Home Bias in Patenting



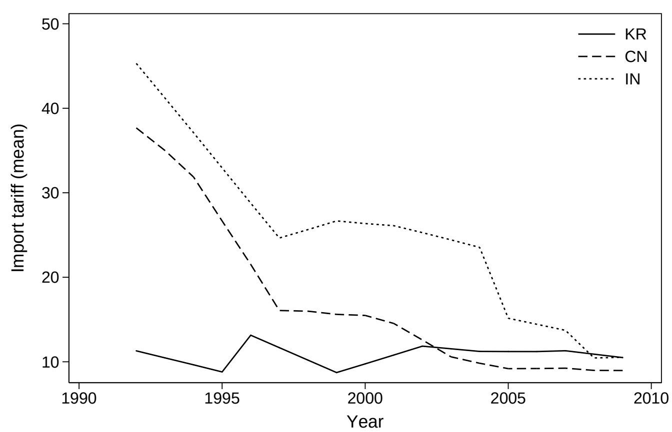
Note: The figure shows the histogram of home weights ω_{iHome} across all firms in the pre-sample period.

Figure 5: Average Weighted Import Tariffs, I



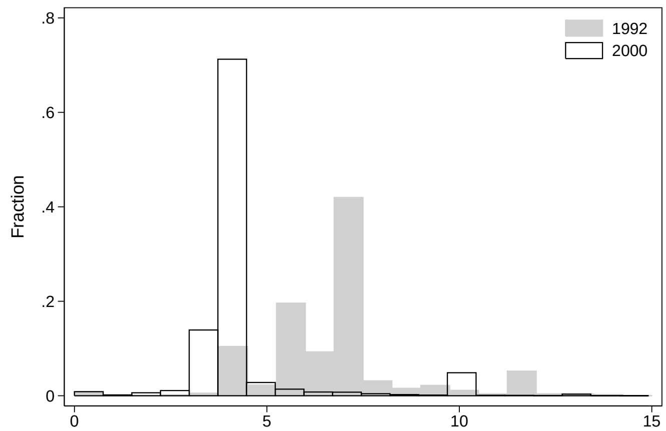
Note: The figure shows the annual average τ_{it} across firms according to headquarters country. The population of firms is restricted to all surviving firms in the 1980-2009 period.

Figure 6: Average Weighted Import Tariffs, II



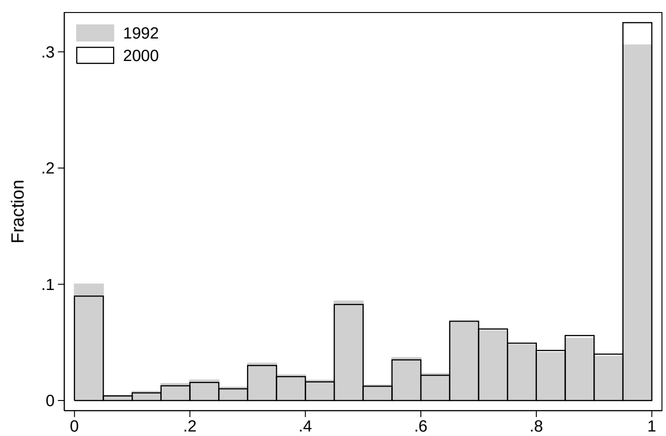
Note: The figure shows the annual average τ_{it} across firms according to headquarters country. The population of firms is restricted to all surviving firms in the 1980-2009 period.

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]	-.011[a]	-.005[a]
	(.004)	(.004)	(.002)
$\Delta\mu_i$	.028	.028	.047[c]
	(.050)	(.051)	(.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] $p< 0.1$.

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-industry firm fixed effects; in column two we add pre-sample firm characterististics, 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. A reduction of a firm's export 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 explained by trade policy. We do not find isolated evidence on any influence of the establishing of RTAs on firms' innovation. The results suggest that the positive impact from trade resulting from the increased competition and the larger market size prevail on the negative Schumpeterian force. Below we explore the mechanisms behind this result further.

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 difference in firms' exposure to markets and competition together with patent data 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 knowledge creation during the 1990s can be explained by trade policy. However, we did not find evidence that RTAs alone matter for firms' innovation. Our results indicate that the positive impact resulting from increased competition and the larger market size prevail on the negative Schumpeterian force.

Our work can be estended in several directions. First, we want to repeate this exercise by using more detailed tariff data, e.g. at the industry level. This would allow us to take into account different degrees of exposure to trade liberalization of firms operating in different industrial sectors.

Second, we would like to go on to explore the mechanims behind our results. 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 unambiguous postive 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 firms only experience the latter positive effect. We would like to use information on the destination countries of firms' patents to investigate the possibly differential impact on exporters and non-exporters.

Third, we would like to use citation data to verify whether the positive effect of innonation can be partly explained by a "lawyer effect". One may argue that patents are not knowledge and that in the face of increased competition firms may simply take out more patents to protect themselves from competitors. In this case, we would observe citations per patent to drop.

Fourth, a nice complement to our analysis would be to zoom in on sharp liberalization episodes, in order to have a closer look at the effect of huge tariff reductions that came as a shock. Finally, having a tighter link to theory would assist us in presenting our empirical strategy and interpreting our results. We are actively working on all there 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).[10] 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,[11] 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 pertains[12], 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.

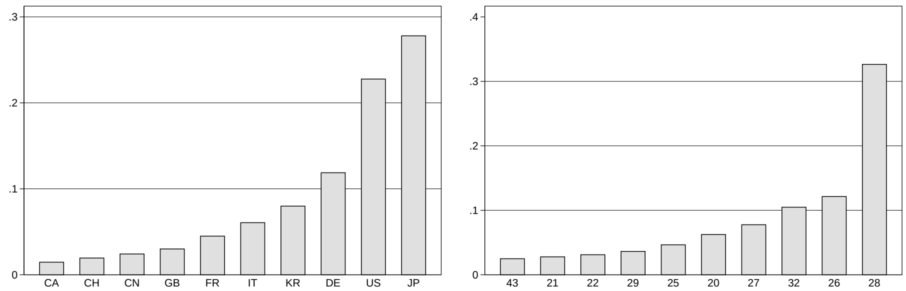
Figure 9 shos the distribution of patenting firms across headquarter countries and industries. We note the dominance of Japan and the US and by the industries Machinery and equipment (28), computers, electronic and optical products (26), other manufacturing (32).

[10]Other 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).

[11]The first application worldwide.

[12]The 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 headquarters 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.[13] 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.[14] 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 and average of 3.8%.

In addition to tariff cuts, the number of "bound" tariffs[15] increased significantly, from

[13]Unless it is otherwise stated in a Member's Schedule.

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

[15]Bound 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.

Table 2: 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.

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.

C Tables and Figures

Table 3: Mean, median standard deviation of world average Δtariffs 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 4: 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 5: 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 6: *

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 7: 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

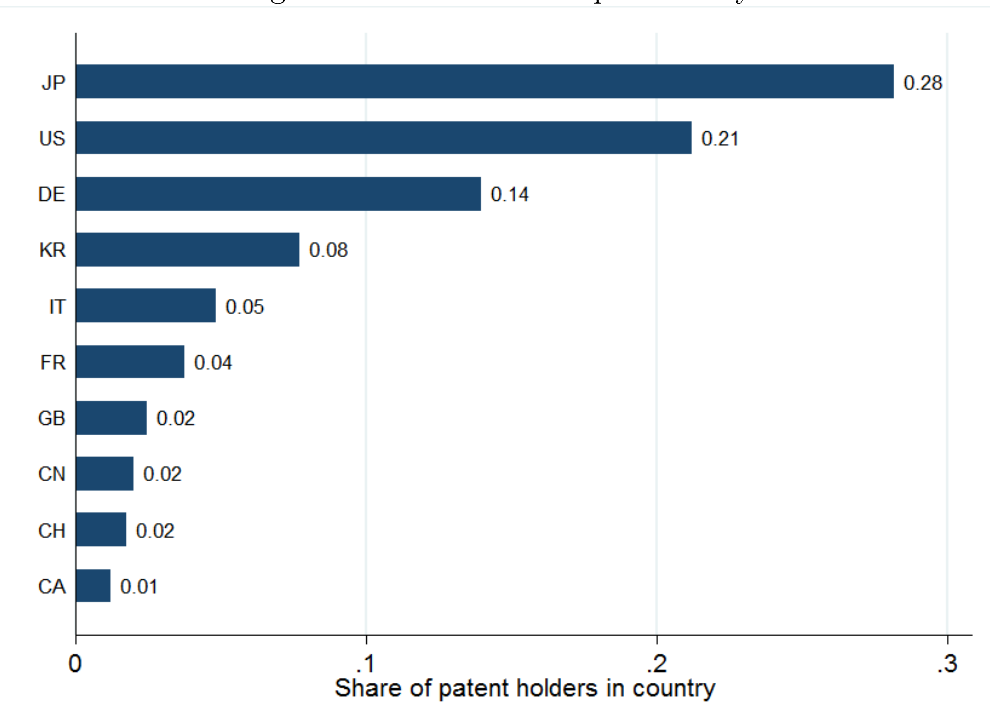
Notes: The table only shows the top 15 countries where patents are filed. A patent refers to an innovation/patent family. Patents in the dataset are those owned by firms or individuals identified in the pre-sample period and surviving until 2010. The total number of patents is 9,234,557.

Table 8: 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.