Innovation quality and global collaborations

Insights from Japan

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Introduction

Even if the post-COVID-19 recovery seems already underway—despite that millions are still hurting due to the loss of loved ones, record-high unemployment levels, and despair and uncertainty that might last until after a vaccine is effectively distributed—some of the secular trends that preceded COVID-19 will likely still accompany us, namely, the global productivity slowdown.

The productivity dynamics of Japan, in particular, are quite intriguing. Most developed nations have seen sharp slowdowns in their productivity growth since 2004, but the Japanese case is puzzling because productivity growth decelerated just as sharply there, even though productivity levels continue to lag well behind countries such as the U.S. and Germany (see Bahar and Strauss, 2020; Baily, Bosworth, and Doshi, 2020)

In light of this, Bahar and Strauss (2020) suggest a possible explanation for this phenomenon, backed by the evidence at hand: an important dichotomy between the quantity and quality of Japanese innovation. In particular, they find that while Japan allocates more resources on research and development (R&D) and files more patent applications than the U.S. and Germany, the quality of Japanese innovation severely lags compared to these two nations.

This paper digs deeper into this finding to identify possible policy actions that could tackle this reality. Specifically, we identify an aspect of Japanese innovation—compared to that of countries like the U.S. and Germany—that could play a role in explaining the lower-quality inventions hindering the creative-destruction process. This aspect is the extent to which Japanese inventors engage in Global Collaborative Patents (GCPs). GCPs are patents where the team of inventors includes individuals residing in two or more countries. As Kerr and Kerr (2018) show, GCPs tend to be higher-quality innovations than entirely domestic patents.

In this context, our study uses patent-level data and document two important stylized facts. First, Japanese inventors tend to engage much less in GCPs as compared to other comparable countries; and second, even if fewer, GCPs by Japanese inventors tend to be of higher measurable quality, consistent with the evidence. Having established these facts, we then find that Japanese firms dominate the production of patents in Japan, with very little innovative activity by foreign firms, where most of the GCPs typically would occur. Thus, based on this, we offer some thoughts about possible directions using policy to facilitate the integration of Japanese inventors into the global stage by (1) pursuing the establishment of foreign R&D centers in Japan and (2) opening the country's doors to more immigration.

The paper is divided as follows. The next section describes the data sources used in our analysis. The following section characterizes Japanese innovation using patent-level data, such as the quantity and quality of innovation, its geographic distribution within Japan, and the most active firms (also referred to as assignees) patenting in the country. After that, we document the relatively low intensity with which Japanese inventors participate in GCPs and establish the fact that Japanese GCPs tend to be of much higher quality than patents filed by all-local inventors. Finally, we present some broad policy guidelines to promote the participation of Japanese inventors in global collaborations before offering concluding remarks.

Data sources

Following the observation made by Bahar and Strauss (2020) on the existing gap between the quantity and quality of Japanese innovation, we start by looking at some comparative patenting trends for the United States, Japan, and Germany. We particularly focus on GCPs, which are patents filed by inventors residing in two or more different countries.[1] Kerr and Kerr (2018) noted that GCPs tend to be of higher quality than purely domestic patents in the U.S. (e.g., patents filed by inventors who all reside in a single country).

Our analysis is based on the *PatentsView* dataset compiled by the U.S. Patent and Trademark Office (USPTO, 2018). This newly-released patent-level dataset stands out from other sources (such as patents from other offices) such that it allows us to track both inventors and assignees across time and space through unique identifiers already built-in into the dataset.

Our complete sample contains above 6.1 million granted patents filed between 1970 to 2015, out of which 1.2 million patents have at least one inventor residing in Japan.[2] Our goal is to exploit the point of time where the innovation happens, consistently with the standards in this literature, and thus we rely on the filing date, as opposed to the granting date. To be more precise, we define the patent date through the earliest date between the application and the priority date. For patents that only have been filed in the USPTO, the application and priority date are the same. For patents that have been filed in another patent office (such as the Japanese Patent Office, for example), the priority date refers to the date in which the patent was filed for the first time in any patent office.

Here it is appropriate to explain why we focus on patents filed in the USPTO and not in other patent offices (such as the European Patent Office or Japan Patent Office). There

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[1] Thus, by definition, this excludes all sole-inventor patents.
[2] Our results are robust to including later years in the dataset, yet as we include recent years quality measures in our data suffer from more pronounced right-censoring (e.g., there is naturally less citations for patents filed in later years as compared to earlier years) which might be misleading.

are three main reasons. First, as the numbers reveal, there is a large enough representation of patents with Japanese inventors in our data (almost 20 percent of all patents), and thus, we believe it is quite ample when it comes to Japanese innovation. In addition, since our focus is on GCPs, the USPTO likely has a more extensive representation of GCPs (for Japan and any other country) than local patent offices. Second, we are trying to identify patterns on innovation that have the potential to boost productivity —which typically corresponds to innovations the most productive inventors and the most productive assignees (e.g., firms or universities)—and these patents are likely filed in several offices, with the USPTO being one of them. Consequently, if we find a gap in quality using these data, we would probably be underestimating the magnitude of the problem, and thus our conclusions would still be valid. Third, the *PatentsView* dataset, as alluded above, contains a unique identifier per inventor and assignee, which allows us to track the same inventor and assignee (e.g., firm) across time as well as when the inventors move locations, giving us an additional dimension to analyze the quality of patents as part of our ongoing broader research agenda.

Stylized facts about Japanese innovation

In this section, we establish some basic facts on Japanese innovation exploiting data on about 1.2 million patents filed by at least one inventor residing in Japan between 1970 to 2015, complemented when appropriate with patents filed in other countries.

We start with a basic comparison inspired by Bahar and Strauss (2020), summarized in Figure 1. The left panel of the figure presents the total number of patents filed in the USPTO based on the country of residence of the inventor, comparing the trend for the United States (thin dashed line), Germany (thick dashed line), and Japan (thick continuous line).[3] As can be seen, there is an upward trend in the number of patents filed per year by inventors in all three nations. By the end of the period (and throughout, too) the United States leads in terms of the number of patents filed per year, as expected, followed by Japan and then by Germany.[4]

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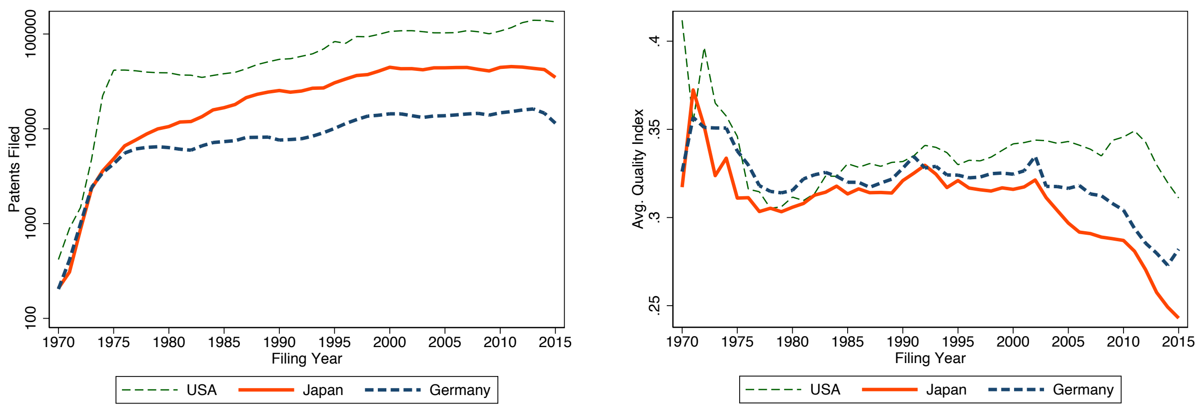
[3] Note that in this calculation, if a patent is filed by two inventors residing in, say, Germany and Japan, it will be counted once for each country.

[4] Note that this graph differs from Figure 12 in Bahar and Strauss (2020) given the source of the data. This figure uses USPTO patents, whereas Bahar and Strauss (2020) focuses on triadic patent families obtained from the OECD Patent Statistics.

Figure 1. Quantity and quality of patents

Panel A: Quantity of patents **Panel B: Quality of patents**



The right panel of the same figure reinforces the findings of Bahar and Strauss (2020): patents by Japanese inventors tend to be of lower quality than peers from the United States and Germany. The figure uses the composite index Quality-6 suggested by Squicciarini, Dernis, and Criscuolo (2013) as a quality measure.[5] Bahar and Strauss (2020) pose a plausible explanation for this differential in terms of R&D policy: Japan's over-reliance on R&D tax incentives in contrast with the U.S. and Germany, where direct subsidies to targeted innovation projects is a more common policy.[6]

Yet, in this paper, we pose an additional, non-competing, explanation for this difference: the intensity with which Japanese inventors interact and collaborate with inventors in other parts of the globe, which we explore in detail in the next section.

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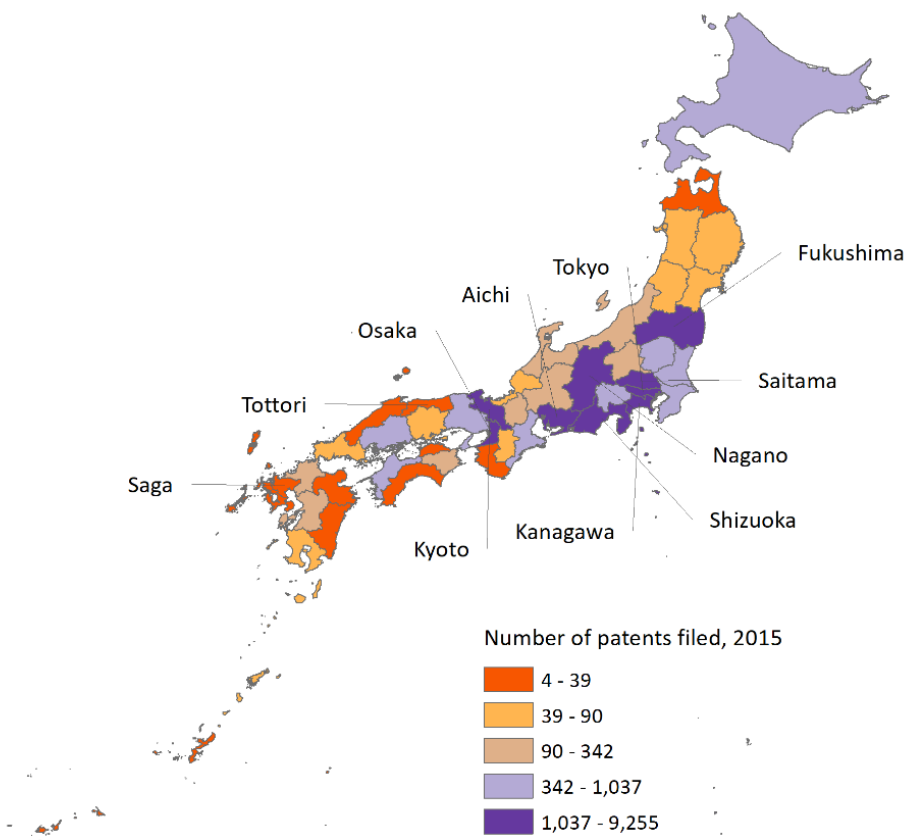
[5] The patent Quality-6 index includes six components: number of forward citations (up to 5 years after publication); patent family size; corrected claims; generality index; backward citations; and the grant lag index. The index is computed only for granted patents. For more information see Squicciarini, Dernis, and Criscuolo (2013). Note that the drop in quality that is common to all three countries in most recent years is due to right censoring of the variable due to forward citations and others.

[6] Another angle to explore the quality of innovation is by examining the receipts in U.S. dollars (in constant prices based on 2010 USD) for the use of intellectual property reported in the balance of payments per capita, using data from the World Development Indicators and authors' calculations. This number proxies for the value of the intellectual property produced by a country normalized by its population, which could be perceived as another measure of quality (another option is to normalized it by number of patents produced per year, but receipts corresponds for the stock of patents produced in all previous years, so this would not be a proper normalization). This exercise reveals a similar result: for the entirety of the period from 1995 until 2015, Japan underperforms compared to the United States, while its performance with respect to Germany is larger, though the gap is reduced in recent years. For instance, in 2000 Japan's IP receipts per capita were about U.S. $90.45 per capita, whereas the same figure was $149.15 for the United States and $27.67 for Germany. In the year 2015, the figures are $289.98, $424.12 and $213.25 for Japan, U.S. and Germany, respectively. While Japan outperforms Germany based on this measure, if the same trends continue, Germany would outpace Japan in just a few years.

Before that, however, we explore some basic facts on Japanese innovation. Our data is rich in terms of the location of inventors, even within Japan. Figure 2, for example, maps the number of patents filed in 2015 by inventors residing in different prefectures—Japan's first level of administrative division (GADM, 2018). The color-coding of the map divides prefectures into five quintiles and highlights the within-country variation in the number of patents filed within Japan. We observe that Tokyo had the largest number of patents filed in 2015, reaching almost 10,000, which accounts for nearly 25 percent of all patents filed in Japan that year. Kanagawa and Aichi follow with around 4,000 patents each. On the other end, Saga and Tottori are the least productive prefectures when it comes to innovation, producing only 4 patents each in 2015.

Figure 2. Number of patents filed by prefecture, 2015



The geographic distribution should come as no surprise. After all, patenting activity is quite geographically clustered, as is the location of large firms with R&D centers where most innovation happens. In the case of Japan, for instance, the 10 largest firms in terms of patent production account for about 30 percent of all patent filings in Japan from 2010 to 2015. These firms are presented in Table 1. Note that all these assignees are Japanese firms, and there are no foreign multinationals in the list, a finding that has important implications which we discuss below.

Table 1. Top assignees in terms of patent filings, from 2010 to 2015

Assignee	Patents	%
Canon Kabushiki Kaisha	17,076	6.33
Kabushiki Kaisha Toshiba	9,450	3.50
Sony Corporation	8,972	3.33
Toyota Jidosha Kabushiki Kaisha	7,881	2.92
Seiko Epson Corporation	7,757	2.88
Panasonic Intellectual Property Management	6,949	2.58
Fujitsu Limited	6,840	2.54
Ricoh Company, Ltd.	6,412	2.38
Mitsubishi Electric Corporation	5,662	2.10
Denso Corporation	4,792	1.78

Global collaboration and quality of innovation

Considering the observation by Kerr and Kerr (2018) that higher-quality patents result from global collaborations (e.g., inventors from two different countries working together), we turn to explore the breakdown of patents in Japan by the locality of its inventors. We categorize patents in our sample into domestic and GCPs. As the name suggests, domestic patents are patents that only have inventors residing in Japan (please note that this group also includes patents with only one inventor) [7]. GCPs, on the other hand, are patents with at least two inventors living in at least two different countries at the time of application.

Figure 3 depicts the number of patents filed over time, reaching less than 50,000 patents filed per year during the early 2010s, up from roughly 10,000 patents in the 1980s. Due to the data incompleteness, we observe a steep decline in the number of patents filed for more recent years (as can be seen in Figure 1 above). Despite the steady growth from 1970 to 2000, the annual number of patents stagnates, roughly around 45,000 every year after 2000.

Note that the share of GCPs has grown from around 0.4 percent of all patents in the early 1970s to over 3 percent in the early 2010s—nearly a 10-fold growth. This is consistent with the findings of Kerr and Kerr (2018), who show that the number of GCPs

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[7] Our results regarding quality differences are robust to using only domestic patents with two or more inventors as the comparison group for GCPs.

has also increased significantly in the past decades in the U.S., likely a result of globalization. Our data also shows that the share of GCPs start to stagnate after the 2000s.

While GCPs have increased sharply in terms of their share of all patents in Japan in the past decades, it remains significantly low compared to countries like the United States and Germany. Figure 4 plots the share of all patents that classify as GCP in these three countries. The figure shows that, as compared to these two countries, Japan clearly lags behind in terms of the intensity with which its inventors collaborate with inventors in other countries. While about 25 percent of all patents in Germany classify as a GCP and nearly 10 percent do so in the United States in 2015, the share of GCPs in Japan remains significantly low at about 3 percent.

Figure 3. Number of patents filed

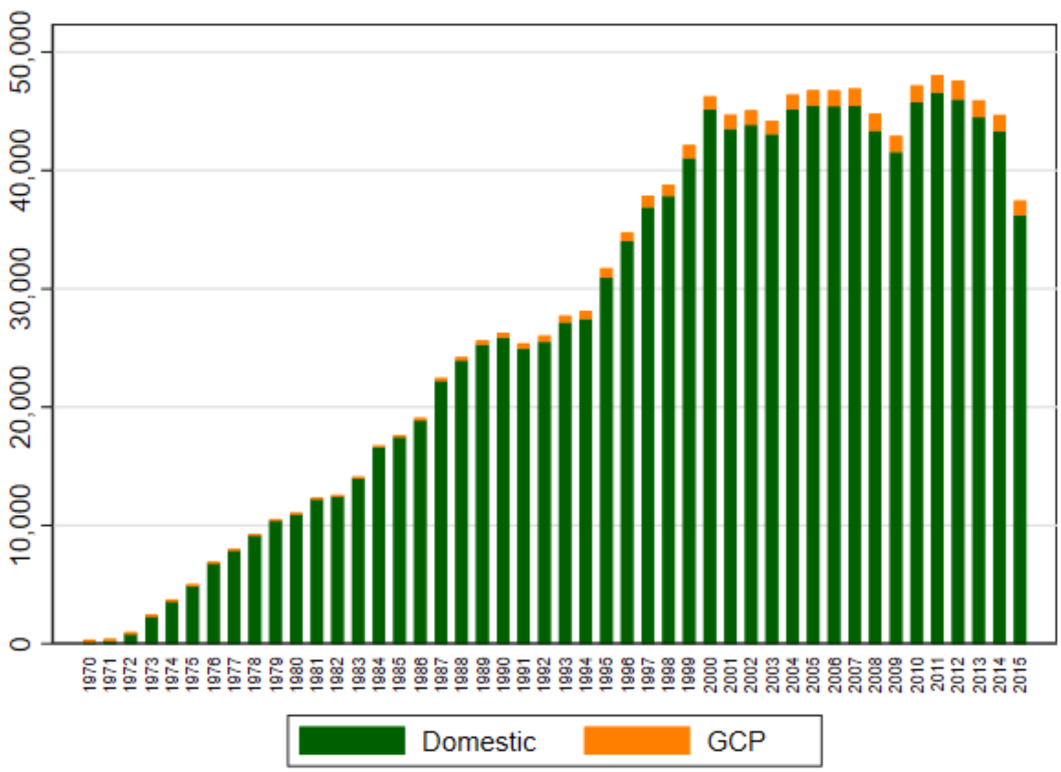
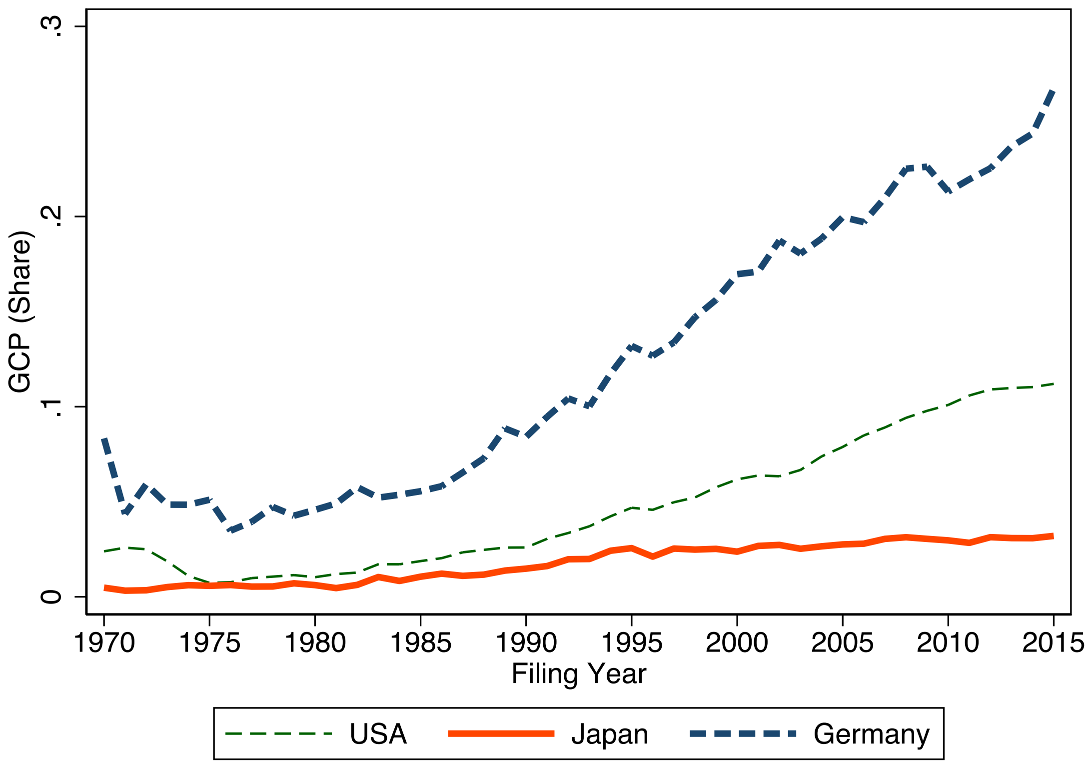


Figure 4. Share of GCPs in all patents



This distinction matters because the GCPs being of higher average quality is also a fact for Japanese innovation. Figure 5 contrasts four measures of patent quality over the years for both GCPs and domestic patents. The figure suggests that indeed GCPs with at least one inventor located in Japan tend to be significantly of higher quality than purely domestic Japanese patents. Figure 6 presents the average quality of patents between 2010 and 2015 by technology classes using an aggregated measure of quality, the "Quality-6 index" showing that GCPs have higher average quality across all the technology classes. Overall, the difference in the index is a little over 0.03, over 10 percent, and we find this difference to be statistically significant.

Figure 5. Selected patent quality indicators

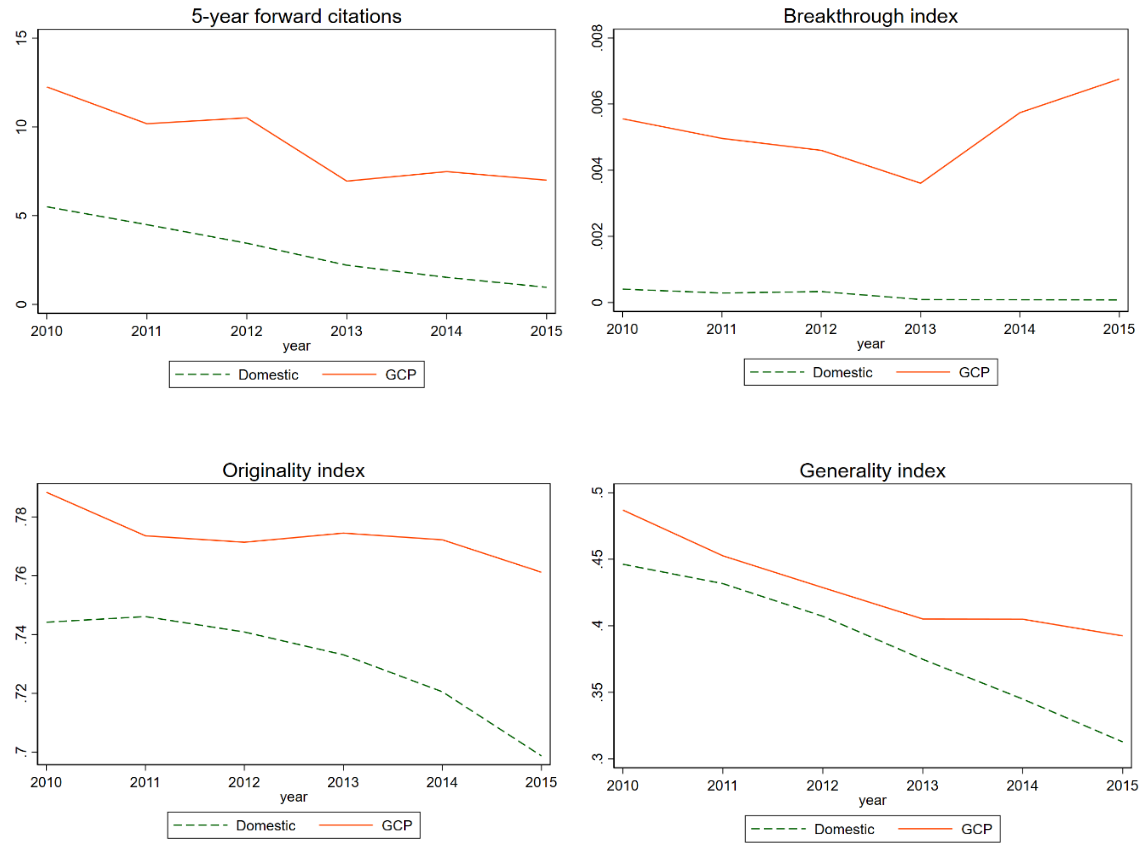
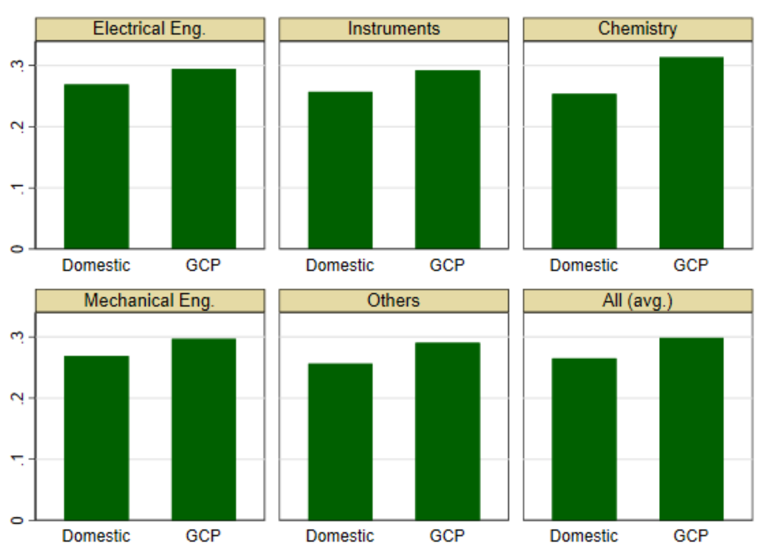


Figure 6. Patent quality by technology



In this context, two important facts are relevant to Japan: GCPs tend to be of higher quality, and Japan lags behind other developed nations in terms of global collaborations. These two facts together likely account for at least part of the dichotomy briefly discussed above—and discussed at length by Bahar and Strauss (2020)—on the quantity versus quality of Japanese innovation, which is a crucial determinant of productivity dynamics. In the next section, we outline policy recommendations that can serve as a basis to address this issue.

Integrating Japanese inventors in the global stage

Naturally, the choice of inventors in a given location, such as Japan, to work with inventors in other countries is an organic process. Yet, to the extent that market failures hinder this process, including lack of public goods that could facilitate collaborations, there is a role for public policy.

Are there any identifiable market failures behind the fact that there are very few GCPs in Japan compared to other countries? To answer this, we first must rule out some obvious possible explanations that might not relate to market failures per se. In particular, Japan being geographically far away from other countries where innovation happens more intensively, such as the United States and European nations, makes it harder for inventors to collaborate with peers in other countries. This reality certainly plays a role, but according to our dataset, the evidence suggests that such is not necessarily a binding constraint. There are two main reasons for this. First, with only 3 percent of patents classifying as GCPs in Japan, the same figure is nearly 4.5 percent in Korea and 18 percent in China, all countries in the same geographic neighborhood, suggesting that geography alone cannot explain the gap. Second, perhaps more importantly, as Table 2 shows, the top three nations of inventors with which Japanese inventors collaborate in terms of GCPs are the United States, Germany, and China. While it is fair to assume that the number of collaborations with U.S.-based inventors is significantly greater given the nature of our dataset of USPTO patents, the data reveals that there are many more global collaborations with countries further apart, such as Germany, the United Kingdom, and Canada, than with neighboring countries, such as China and South Korea, even when ignoring the United States.

Table 2. Main collaborators from 2010 to 2015

	Number of co-inventors	Percent
United States	11,848	56.1
Germany	1,551	7.3
China	1,538	7.3
South Korea	1,087	5.2
United Kingdom	973	4.7
Singapore	667	3.2
Taiwan	439	2.1
France	396	1.9
Canada	316	1.5
Switzerland	244	1.2

Thus, while the geographic reality might be playing a role, there seems to be important room for growth in collaborations, particularly with inventors in countries with which links have already been established. It is important to keep this list of countries in mind when thinking about particular policies that could facilitate more interactions between inventors.

Regardless of geographic determinants, we believe there is a role for policy in achieving higher integration when it comes to innovation. Given that GCPs have significantly higher patent quality, Japan needs to craft and implement policies to lift the roadblocks inhibiting local inventors from collaborating internationally. We focus on two particular aspects to achieve this: incentives for international R&D centers and migratory reforms.

Attracting foreign R&D-related investment

The fact is that any economic activity that crosses a border is more costly. We know, for example, that trade and investment across borders are challenging for firms because of persistent information asymmetries, as well as monitoring and coordination costs. This phenomenon holds even more so for multi-country R&D efforts, where typical externalities related to innovation are common. Hence, major economies allocate considerable resources to incentivize innovation through direct grants or tax subsidies.

However, these incentives do not always result in countries' ability to attract foreign firms with productive R&D centers. The case of Japan constitutes a good example, where most of the patenting production is done by domestic firms (see Table 1), suggesting there is space to grow in terms of attracting highly productive foreign firms to establish local R&D centers.

Some evidence suggests that foreign firms are less likely to choose Japan as a preferred location for R&D activities, as documented by a recent report by McKinsey & Company (Chokki et al., 2020). In the study, the authors present results from a survey with chief technology officers (CTOs) and heads of R&D centers for 18 Japanese companies and find that just 24 percent of respondents who work in a multinational corporation (MNC) believed their companies would prefer Japan when deciding on an R&D location. The combination of the aging population and the challenges of attracting high-skilled young talents to Japan were listed as the main inhibitors.

While some of the factors named in the report are structural, there are ways to address this by revising the existing set of incentives aimed at attracting large foreign MNCs to choose Japan as a home for their R&D activities through targeted incentives.

In Japan, this task mainly falls on Japan's External Trade Organization (JETRO), which has the national mandate of attracting foreign investment into the country, operating under the Ministry of Economy, Trade and Industry (METI). A recent report by the OECD and the Interamerican Development Bank examining several Investment Promotion Agencies (IPAs) among OECD and Latin-American countries (Volpe Martincus and Sztajerowska, 2018), including JETRO, gives us some insights about the main differences between several IPAs active around the globe. In such a report, Japan's IPA stands out as being one of the largest in terms of budget, personnel, and the number of offices in the world.

However, a few aspects called our attention when focusing on the ability of JETRO to attract foreign R&D centers. First, JETRO is one of the few agencies among OECD countries that did not undergo any considerable structural reform recently. In contrast, the average of IPA in OECD was reformed more than once during the period 2007-2017. Reforms might be crucial in a fast-changing world. There is an opportunity to make sure that in a forthcoming structural reform, the agency can include focused activities in attracting foreign R&D centers.

Second, in light of the above, we noticed a few essential aspects that might be taken into account if and when a major reform is enacted. One of them is that JETRO stands out by having many mandates, thus not being specialized enough compared to other leading OECD countries. Another one is that, according to the aforementioned report, the focus of Japan's IPA is not on investment generation, which entails identifying and approaching potential investors, and is a common function for many other IPAs in leading OECD nations. Instead, JETRO's budget is focused on investment facilitation and retention (providing assistance to investors), image-building, and policy advocacy, with very little to none targeting particular industries. In that sense, given the importance of focusing on R&D centers, there is an important opportunity for a paradigm shift of how the agency typically works. Another important distinction is that Japan's IPA has a board of directors only composed of individuals from the private sector, with no seat at the table for individuals representing the research and academic community, which might provide substantial weight towards the agency focusing on foreign R&D activities.

Therefore, in the space of attracting foreign R&D centers, we identify that Japan's principal agency with such mandate might be underperforming given structural limitations, which might be beneficial to revisit.

Finally, it is important to include local governments as part of these efforts. Local conditions can greatly influence the type of incentives that would encourage foreign firms to invest in their cities or regions. Perhaps the most salient example of successfully attracting foreign R&D investments into Japan assisted by joint efforts of both national and local governments is the opening of an Apple R&D center in Yokohama, the second-largest city in Japan, in 2017 (Wuerthele, 2017). This center is reported to devote its research efforts to artificial intelligence technologies with breakthrough innovations in the upcoming years, potentially raising the overall quality of Japanese innovation.

In sum, we believe that the broad policy guidelines to attract R&D-related foreign investment, and with it boosting the quality of innovation in Japan, goes by renewing efforts by stakeholders, under the lead of JETRO. This includes focusing efforts and resources on the promotion of foreign investment particularly for R&D activities, working in conjunction with local authorities. Studying closely the success stories of Japan itself in the past or of other countries in this regard will serve as a crucial input for designing comprehensive policy to achieve these goals, and are a matter for further research (a good starting point, we believe, is the study by Volpe Martincus and Sztajerowska, 2018).

Comprehensive migratory policies to attract foreign workers

Another factor that is known to play a vital role in fostering global cooperation in patenting is migration, based on ongoing background research by Bahar and other coauthors. In essence, the inflow of skilled immigrants—many of them inventors—facilitate global collaborations, resulting in higher quality innovations.[8]

Yet, while Japan has experienced much higher migration flows in the recent past, there's the need for even more. The share of foreigners in Japan's total population strikingly rose from 0.9 percent in 1990 to 1.7 percent in 2015 (UNDESA, 2019), but Japan still significantly lags compared to other developed nations (e.g., the share of immigrants in both the U.S. and Germany is of about 15 percent). The importance of a more flexible migration policy is particularly important for STEM occupations: Chokki et al. (2020) report that Japan has an estimated shortage of 240,000 skilled IT professionals, and that number is expected to rise to almost 600,000 by 2030.

Due to population aging and skilled labor shortage, Japan's Parliament amended their immigration law in late 2018 to ease restrictions on foreign workers. According to reports, following this law, the country expects an intake of more than 300,000 foreign workers (BBC, 2018). This is a step in the right direction, but there's still the need for a

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[8] In ongoing background research by Bahar et al., the authors investigate the effect of dozens of migration reforms across 15 countries on innovation outcomes. The preliminary results suggest that that reforms easing the inflow of foreigners or of returning citizens result in higher patenting, both domestic and cross-border, and higher quality innovation. Analogously, reforms that restrict immigration hinder innovation, both in terms of quantity and of quality.

more aggressive policy besides expanding visas to improve the attractiveness of Japan as a destination for foreign workers that can contribute to the innovation engine of the country. In fact, an OECD working paper by Tuccio (2019) positions Japan much behind Germany and the U.S. in terms of its attractiveness for highly educated workers, entrepreneurs, and university students. Among these talent profiles, the group that finds Japan the least attractive is highly educated workers, who rank Japan in the last place among 35 OECD countries.

Thus, there's an urgent need for policy tools to provide the right set of incentives to foreign workers. The exact design of these policies would require understanding the main obstacles hindering Japan from being perceived as an attractive destination for foreign workers. Yet, whatever the policy tool, there must be an important focus on STEM occupations as foreign workers could fill the gap that is foreseen in the local labor force. Naturally, the presence of more immigrant inventors will likely boost innovation quality through organic global collaborations that will be formed.

Conclusion

As in any other developed nation at the technological frontier, one of the most critical determinants for Japan's productivity growth is its ability to continue to engage in breakthrough innovations. Hence, this brief focuses on documenting stylized facts around the relatively lower quality of Japanese innovation, compared to other nations such as the U.S. and Germany. Consequently, this brief also documents that Japanese inventors tend to collaborate much less with inventors residing in other countries, essentially claiming —based on the evidence—that more global collaborations could be a key element in boosting Japanese innovation.

While achieving higher levels of global collaborations between inventors in Japan and other countries is an organic process, we do identify a role for policy to facilitate this process, particularly in two areas: restructuring Japan's Investment Promotion Agency such that it can target more effectively and attract foreign R&D activities to Japan, as well as making a bigger effort to attract foreign talent through incentivizing inward migration. The specific design of these policies is a matter for further research based on, among many factors, successful experiences of other countries and local political limitations that always come into play.

All in all, with proper policy reforms in the areas identified above, we believe that it is entirely possible for Japan to very quickly reach its full potential in producing breakthrough innovation, ultimately fueling Japan's productivity growth.

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