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Patent disclosure and the diffusion of knowledge

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Abstract

Knowledge disclosure is regarded as crucial for cumulative innovation, technological progress and social welfare. In addition, it is also an important dimension concerning firm?s innovation strategies. However, there is still limited empirical evidence on the impact of disclosure on follow-on inventions. We address this gap and exploit a policy change in the US patent legislation (?American Inventors Protection Act?), which had an impact on the disclosure timing of patent documents. Applying a difference-in-difference methodology, we analyze how ?early? disclosure affects the diffusion of knowledge with regard to the geographical dimension. Relying on patent citation data to approximate knowledge flows, our econometric analysis suggests that early disclosure is particularly valuable for geographically distant inventors.

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ABSTRACT

Knowledge disclosure is regarded as crucial for cumulative innovation, technological progress and social welfare. In addition, it is also an important dimension concerning firm's innovation strategies. However, there is still limited empirical evidence on the impact of disclosure on follow-on inventions. We address this gap and exploit a policy change in the US patent legislation ("American Inventors Protection Act"), which had an impact on the disclosure timing of patent documents. Applying a difference-in-difference methodology, we analyze how "early" disclosure affects the diffusion of knowledge with regard to the geographical dimension. Relying on patent citation data to approximate knowledge flows, our econometric analysis suggests that early disclosure is particularly valuable for geographically distant inventors.

Keywords:

Patent disclosure, Geography of Innovation, Cumulative Innovation

1 Introduction

The economics and management of knowledge disclosure are increasingly receiving attention by innovation scholars. Whereas the disclosure of R&D outcomes is regarded as potentially harmful for the creators of this knowledge due to unintended spillovers to competitors (Arrow, 1962; Horstmann et al., 1985; Modigliani, 1999), knowledge disclosure is also considered as a potential strategic instrument for firms to shape the companies' environment and its expectations, resulting in second-order benefits (Alexy et al., 2013). In addition, the importance of disclosure for cumulative innovation, technological progress and social welfare is widely accepted (Furman and Stern, 2011; Murray and O'Mahony, 2007; Scotchmer and Green, 1990). Disclosure may avoid wasteful duplication of R&D efforts, fosters cumulative innovation (Bessen and Meurer, 2008), reduce information asymmetries and support licensing and collaboration opportunities (Johnson and Popp, 2003; Hegde and Luo, 2013).

The disclosure of knowledge can occur via different channels, for instance informal communications between R&D scientists, scientific publications or through the patent system where the patent application process imposes a mandatory disclosure of the technical characteristics of an invention. The disclosure within the patent application process is an important component of the patent system since it potentially balances the negative competitive effects of granting an exclusivity right to an inventor (Denicolo and Franzoni, 2003). As a consequence, patent disclosure has already received some interest both in theoretical (Aoki and Spiegel, 2009; Bessen, 2005; Bloch and Markowitz, 1996) and empirical contributions (Hegde and Luo, 2013; Johnson and Popp, 2003). However, there is no general consensus on the effectiveness of patents as a tool of knowledge disclosure and the empirical evidence is mixed. On the one hand, some studies have found that inventors rarely resort directly to patent literature as a source of information and knowledge (Atal and Bar, 2010; Jaffe et al., 2000; Walsh et al., 2007). Similarly, several authors pointed out that knowledge spillovers occur among geographically close inventors (Audretsch and Feldman, 1996; Jaffe et al., 1993), despite the existence of patent documents which in principle should allow for a wider geographical diffusion of knowledge. On the other hand, some authors argue that patent literature can be an effective source of information and knowledge for inventors, at least in certain sectors (Cohen et al., 2002; Graham et al., 2009). Similarly, Moser (2011) finds evidence for the chemistry sector that the increase in the propensity to patent reduced the localization of innovative activities.

In this paper, we contribute to this line of research by providing evidence on the impact of patent disclosure on the geography of follow-on inventions. Specifically, we investigate whether the effect of an "early" disclosure of patent documents is heterogeneous for citations at different geographic distances. This analysis is informative on the potential effectiveness of patents as a means to weaken or strengthen the localization of innovations. Moreover, there are also important managerial implications, for instance concerning the use of patents as an appropriation instrument. Any differences would point to heterogeneous spillover risks depending on the main competitors' location. In order to provide a more fine-grained view, we also analyze whether the effect of early disclosure differs by technological area, since learning from patents is possibly not equally important throughout all technological fields. Finally, we also assess the role of timely disclosure for the effectiveness of the patent examination process. It is possible that early disclosure does not only inform inventors but also patent examiners, which may have implications for policy makers.

In order to address our research question, we exploit an exogenous shock to the timing of disclosure of patent applications provided by a policy change at the USPTO. The American Inventors Protection Act (AIPA) leads to an "early disclosure" of the patent information as a part of the search report of the examiner, starting from applications filed after the 29th of November 2000. Before this policy change, the patent information was only disclosed at the grant of the patent, therefore with a delay at the median of around 36 months from the application filing (Graham and Hegde, 2012). In the new regime, patent information is disclosed after 18 months with the initial search report of the patent examiner. This shift in the disclosure timing is an ideal setting to investigate the effects of patent disclosure on cumulative innovation and knowledge diffusion. In practical terms, we consider the total number of forward citations and the average time lag from the citing and cited patent filing dates. In this respect, we distinguish the effects of the policy change by the geographic location of the citing patent (abroad and within the same country). Following our interest to identify a potentially different role of disclosure for inventors and patent examiners, we distinguish citations accordingly (Alcacer and Gittelman, 2006).

The econometric analysis relies on a difference-in-difference methodology. The results suggest that timely disclosure reduces the localization of subsequent inventions. Thus, geographically distant inventors benefit more from early disclosure of the codified patent information, particularly when considering the total rate follow-on inventions. Furthermore, we find evidence for some heterogeneity across sectors, and that additional knowledge flows imposed by the early disclosure are not restricted to inventors but also examiners.

The paper is organized as follows: In the next session, we discuss the rationale behind a disclosure function in the patent system. In section 3, we discuss the potential impacts of an "early" disclosure regime on the geography of follow-on inventions. In section 4, we describe the data and econometric design. In section 5, we present and discuss the results of the econometric analysis. We conclude in Section 6.

2 Patent disclosure, spillovers and cumulative innovation

The creation of new knowledge can hardly be accomplished in isolation but typically builds strongly on existing knowledge and research findings. Consequently, knowledge disclosure is regarded as a crucial antecedent for cumulative innovation (Murray and O'Mahony, 2007). Among several other channels, one core medium for the disclosure of knowledge with respect to new inventions is the patent system.

In order to provide incentives to potential inventors to engage in research and development, the patents grant exclusivity rights to inventors of novel technologies. However, providing an inventor a monopolistic position hampers competition and thus leads to increasing prices. The disclosure requirement is meant to counterbalance such negative effects. Through the disclosure of the technical invention, other inventors are informed about the state of the art which potentially enables them to adapt their strategy and behavior in order to maximize their benefits from R&D investments (Scotchmer and Green, 1990). In addition, knowledge disclosure in patent documents is also a crucial component for the patent examination process. The disclosure of the relevant technical information allows the patent examiners to identify relevant prior art for the evaluation of the novelty of new inventions and the claims regarding the desired protection scope (Lampe, 2007; Malva and Hussinger, 2012; Michel and Bettels, 2001; Tan and Roberts, 2010). In this sense, knowledge disclosure in patent documents is supposed to decrease the probability that other inventors step on the same inventions, at least involuntarily, and, in case they do, it allows patent examiners to limit the scope of the second coming patents in view of the previous existing patent documents (Bessen and Meurer, 2008).

The disclosure in the patent system has received some attention by scholars. Theoretical contributions analyze particularly the incentive structure for inventors to rely on patent protection as opposed to other mechanism like trade secrecy since disclosure potentially affects the ex-ante profitability of research (Aoki and Spiegel, 2009; Scotchmer and Green, 1990; Zaby, 2010). In some contexts, the disclosure of knowledge might be perceived as so harmful that the disclosure requirement outweighs the effect of the protection offered by the patent. Bloch and Markowitz (1996) develop a theoretical model that analyzes the impact of the disclosure timing on the discovery of new products and the competitive positioning of firms in an R&D race. One of their key findings is that intermediate research outcomes should not become disclosed too early in highly uncertain R&D activities in order to sustain a sufficiently high investment level. Bessen (2005) argues with a theoretical model that the patent system is not enhancing the diffusion of technical information.

With regard to empirical literature specifically taking into account the effects of an early disclosure, the amount of studies remains scarce with a few exceptions. Recent work analyzes potential positive effects of disclosure for inventors as a mean to improve the efficiency of markets for technology. Pre-grant disclosure may reduce information asymmetries on markets for technology and thus enhance the licensing opportunities for firms. Hegde and Luo (2013) examine the effect of pre-grant disclosure on the licensing revenues. The authors found a positive effect of "early" disclosure on the probability and timing of licensing which is attributed to a reduction of information-asymmetries determined by early disclosure Motivated by the discussion about the potential negative effects of disclosure particularly for smaller inventors, Graham and Hegde (2013) analyzed this aspect explicitly and found that small inventors "opt out" less frequently from the disclosure requirement, challenging conventional wisdom. Johnson and Popp (2003) observe that a policy of earlier disclosure (18 months publication instead of publication at grant) would constitute a more significant change for inventions of higher quality, since quality is found to be associated with longer grant time lags.

3 Patent disclosure and the geography of follow-on inventions

A distinct but related stream of literature investigates the localization of knowledge using patent citation data. The majority of these empirical studies found that knowledge flows, when measured with patent citations, are significantly geographically localized (Audretsch and Feldman, 1996; Belenzon and Schankerman, 2009; Breschi and Lissoni, 2001; Jaffe et al., 1993; Singh and Marx, 2013). These findings support the hypothesis that the transfer of tacit knowledge requires physical proximity and cannot be substituted by codified sources of knowledge. Consequently, codified knowledge, and patent documents in particular, may have a limited impact on diffusion of knowledge (Feldman and Kogler, 2010).

However, there are very little direct empirical insights on whether the existence of a patent document impacts the geographical diffusion of knowledge. Some evidence on historical data regarding the chemical industry in the 19th century suggests that an increase in the propensity to patent weakened the localization of inventive activity (Moser, 2011). Precisely, a 1% increase in patenting rates was associated with a 1.3 decrease in localization. On the other hand, the assumption that patent disclosure may lead to substantial knowledge flows caused intensive discussion around the legislative procedure of the American Inventors Protection Act (AIPA). An important concern was that the policy change could allow faster imitation, particularly from distant foreign inventors, and harm domestic inventors in US (Johnson and Popp, 2003). In other words, geographic proximity may not only allow for the exchange of tacit knowledge but also enables the substitution of valuable codified knowledge. However, inventors located further away cannot substitute informal interaction and learning mechanism (like local job mobility) but have to rely to a stronger extent on codified knowledge. Therefore, we expect earlier disclosure to have a stronger effect for citations from different countries than for citations within the same country (both in terms of total number of forward citations and reduction of the citation time lag).

It has to be stressed that arguments suggesting an opposite conclusion do exist, too. To the extent that patent disclosure is a complement rather than substitute of informal information networks, earlier disclosure may actually increase the localization of innovations. Patent documents might turn to be an effective source of knowledge only in the presence of complementary sources of tacit and uncodified knowledge, enabling a better understanding of the technical knowledge disclosed or simply notifying other inventors about the existence of the patent document (Cowan et al., 2000). In a similar vein, Hedge and Luo (2013) notice that earlier disclosure might push inventors and applicants to actively promote their inventions earlier to potential partners and collaborators. This appears particularly plausible based on the fact that AIPA also grants provisional property rights to inventors. As such, if earlier disclosure (and patent protection) has an effect on knowledge diffusion only through the active promotion of the invention by inventors and applicants within their existent social networks, a higher localization of follow-on inventions, rather than lower, might follow the policy change.

4 Data and Methodology

4.1 Data and sampling

The main data source is the EPO's Worldwide Patent Statistical Database 2014 ("PATSTAT") that contains information about the patent applications at all major patent offices, including the USPTO. The policy change of interest came into effect on the 29th of November 2000. From this point in time, patent applications at the USPTO are published after 18 months with the "search report" of the patent examiner. However, there are some exceptions to be considered in our analysis. Patent applications that are going through the PCT procedure in order to also obtain protection outside US were always subject to the "early disclosure" requirements. Furthermore, the patent legislation also offers inventors the possibility to "opt out" to inventors not extending their patents abroad, implying that the disclosure takes place only with the grant event, as it has been the usual practice before the change.

In order to conduct the analysis on a sample that has been exposed to the AIPA policy change, we have limited the sample to (i) Patents filed in a time window of one and a half years before and after the 29th of November 2000, (ii) Only first filing patents at the corresponding patent office (USPTO), therefore excluding patents with previous filings in the same patent family (iii) Patents having a grant lag greater than 18 months. Overall, we obtain a sample of 149,019 USPTO patents that satisfy these filter criteria. In addition to USPTO patents we include in our sample patent applications from Germany and UK at their respective patent offices and at the European patent office (EPO), with the same criteria mentioned above. This latter group of patents where not affected by the policy change and will serve as a control group in our empirical analysis (see Section 4.3). The control group consists of 41,981 observations.

4.2 Variables

This study analyzes the impact of early disclosure on the diffusion of inventions, and following our discussion above, we have a particular interest in determining the effect of the policy change on the localization of follow-on inventions. To measure the impact of the policy change on knowledge diffusion in general and spatial pattern in particular, we use indicators that are based on forward citation data.

Patents receive a forward citation by a follow-on patent in case the former represents a relevant prior-art for the latter. Despite some limitations, patent citation data is frequently used in the academic literature and in particular also for analyzing spatial patterns of spillovers and knowledge flows (Breschi and Lissoni, 2001; Jaffe et al., 1993; Thompson and Fox-Kean, 2005). In order to address our research question on the geography of follow-on inventions, we exploited the address information regarding the inventors and constructed indicators on whether at least one inventor of the citing patent is located in the same geographical unit (country) of at least one inventor of the cited patent. In the econometric analysis, we consider two dimensions of knowledge flows with indicators that capture the amount of follow-on citations (citation counts) and the diffusion speed (citation time lags). In order to avoid double counting of the same follow-on knowledge, we consider patent-forward citations at the family level. Moreover, to keep the citation indicators comparable over time, we consider citations within a time window of 10 years starting from the priority date of the cited patent.

Furthermore, as an extension, we also distinguish citations by their institutional origin, namely if the inventor or the patent examiner has added them (Alcacer and Gittelman, 2006; Criscuolo and Verspagen, 2008; Michel and Bettels, 2001). With some degree of approximation, we can argue that inventor citations point to documents which are taken into account by the inventor during the development of the invention and the patent application process (Lampe, 2007; Singh and Marx, 2013; Thompson, 2006). On the contrary, examiner citations are to a large extent included in order to reduce the scope of a patent protection in view of the existing prior art (see Tan and Roberts, 2010). Therefore, as far as earlier patent disclosure has an effect on inventor citations, it can be argued that patent disclosure is beneficial for following on inventors and correspond to a knowledge flow enabling them to develop a new technology. On the contrary, in the case that the effect is restricted to examiner citations, we would conclude that earlier disclosure is mainly beneficial to the applicant of the cited patents since it reduces the risk that similar patents are granted to potential competitors.

The core independent variable *NEW REGIME* is a dichotomous measure that receives the value 1 if the patent has been filed after the policy change came into effect (November 29, 2000), otherwise 0. The variable *TREATED* reflects on whether a patent belongs to the treatment group (US patents) or the control group (see following section 4.3). For interpreting the effects of the policy change, the interaction effect between the two abovementioned variables *NEW REGIME x TREATED* is of central interest since it shows the actual effect of the policy change in the difference-in-difference setting. In order to control for patent heterogeneity like the scope of patents, we include as additional independent variables the logarithm of the number of claims (*LOG CLAIMS*), the logarithm of the number of applicants (*LOG APPLICANTS*) and logarithm of the number of inventors (*LOG INVENTORS*), the logarithm of the number of backward references (*LOG BWDREF*), the science-orientation of the patent – measured as the logarithm of the number of non-patent literature citations (*LOG NPLREF*)[2], as well as the grant time lag (*GRANT LAG*). We control for the filing date by introducing year quarter dummies for the time window that captures one and a half years before and after the policy change. Finally, we control for the technology sector of the patent including sector dummies: we assign patents to sectors following the World Intellectual Property Organization (WIPO) IPC-technological field concordance table (WIPO, 2013). Since the time trends between the treatment and the control group may not perfectly coincide, we additionally interact the period variable with the treatment status.

4.3 Econometric design

The econometric analysis relies on a difference-in-difference setup. The AIPA policy change can be interpreted as a discontinuity in the disclosure timing of patents. This implies that patents filed right before and right after the policy change are comparable. Consequently, differences between patents before and after AIPA should be only attributed to observable characteristics or time trends. Having controlled for patents' observable characteristics and any existing time trend, AIPA constitutes an exogenous shock. Since we compare similar patents in a rather narrow time window, the comparison of patents before and after the policy change might already be informative with regard to differences in follow-on citations. However, it cannot be excluded that time trends or macro-economic shocks simultaneous to the policy change may bias the results. To mitigate this concern we adopt patent applications from Germany and UK at their respective patent offices and at the EPO as control group. In the following we discuss. We consider the entire sample of USPTO patents as the treated group. The unit of analysis is the patent-level and we count (i) the number of forward citations within the 10 years window, as well as (ii) the average citation lag of the citations received. Consequently, we rely on Quasi Maximum Likelihood Poisson models (QML-P), Tobit and OLS regression models reflecting the nature of our dependent variables. In the following we discuss a series of challenges to our approach.

A first concern is that applicants might behave strategically, accelerating the filing of patents before AIPA, or renouncing to file patents for certain inventions after AIPA came into effect. However, the existence of an opt-out option for applicants reduces this concern since inventors also have the option to avoid disclosure in the new regime. In other words, the existence of this option mitigates potential doubts on selection into early or late regime if an inventor has the required application material ready around the threshold date. In order to gain further insights on this possibility, we looked at the number of patent filings in the days and weeks just before and after AIPA. If applicants select strategically in the period either before or after the policy change we might observe a concentration of filings on one of

[2] In alternative to the total number of non-patent literature references we considered the subsample of non-patent literature references pointing to scientific articles, with identical results.

the two sides, most likely before AIPA. However, we did not find any evidence supporting this hypothesis.

A second concern derives by the fact that the possibility to opt-out implies that not the entire population of patents in our treatment group will be affected by the policy change. However, this only implies that our estimates can be interpreted as a local average treatment effect (LATE), rather than as an average treatment effect (ATE). In other words, as far as the populations of patents just before and just after the policy change are comparable (applicants do not strategically select in one or the other), our estimates will correspond to a causal effect on the sub-population of patents complying with the new earlier disclosure requirements (Angrist and Pischke, 2008). In any case, we observe that the share of post-AIPA patents that is published at the moment of the grant event is significant but relatively small.[3] If anything, including these cases should give conservative estimates.

Similarly, we also consider US patents that seek protection via the PCT procedure subsequently to the first filing at the USPTO as being treated. Since the PCT procedure already required disclosure after 18 months, these patents were not or only marginally affected by the policy change. These patents are influenced by the policy change to the extent that the publication of the USPTO search report anticipates the subsequent publication of the PCT search report. In addition, the earlier publication of the USPTO document might have an effect regardless of the existence of PCT filing. This is the case if the USPTO document is more accessible to inventors than patent documents in local patent offices of other countries, for example due to language barriers (Hedge and Luo, 2013).

Finally, an obvious challenge is the selection of an appropriate control group and we acknowledge that cross country comparisons might not provide the ideal counterfactual. However, we tested several options with similar results. We decided to use patent applications from Germany, UK and EPO because a considerable number of patent applications originate from these patent offices. In particular, Germany and UK countries are like the United States known as countries with many innovative companies and are highly R&D intensive. In the following section, we present and discuss figures that compare the time trends between our treatment and the control group, which support the view that the control group is a reasonable benchmark for implementing the difference-in-difference setup.

4.4 Descriptive statistics and figures

In Table 1, we present descriptive statistics of the sampled patents. Around 51% of all observations are in the new regime. This even distribution across regimes is a further indication that there was likely no active strategic behavior of the patent applicants with respect to a self-selection into one of the two

[3] The opt-out cases represent 19.4% of all USPTO sample patents with application date after the policy change.

regimes. Although the patents in the treatment group are partially significantly different across regime status, the mean values are in absolute terms very similar and our control variables take such heterogeneity in the subsequent regression analysis into account. When comparing the patents on their treatment status, we see – not surprisingly due to the different nature of citations between the patent offices – much larger differences.[4]

-- Insert Table 1 about here --

The first assessment concerns the effect of the policy change on the publication (=disclosure) time lags of the patents in the treatment and control group, depending on the regime status, as displayed in Figure 1. Indeed, we can observe a sharp drop of the average publication lag after the policy change came into effect while the control group stays stable over time at a lower level. The remaining difference between the treatment and control group after the regime change is due to the "opt-out" cases. This difference of about 4 months indicates that these "opt-out" cases represent a considerable and rather stable share of patents, weakening down the overall effect of early disclosure if one considers the entire patent population.

-- Insert Figure 1 about here –

The Figure 2 displays the overall citation frequency between treatment and control group with regard to within-country and foreign citations. While we observe a very stable and flat citation propensity for the control group, we detect a decline over time for the treatment group. However, around the policy change date, we detect an evident upward shift, particularly sharp for citations from inventors abroad. This result is in line with our priors that particularly inventors located abroad may benefit from an early disclosure policy.

-- Insert Figure 2 about here --

A third interesting prima-facie inspection (Figure 3) is the citation-lag of follow-on patents for the treatment and control group depending on the regime change. The general trends are similar with decreasing citation lags both for the treatment and control group, and for both within-country and abroad

[4] USPTO requires an exhaustive list of references from the applicant whereas EPO inventors are not obliged to do so.

citations. Interestingly, there is no apparent difference for within-country citations between the treatment and the control group, whereas we obtain a different picture for citations from abroad. While we observe a slight increase of the citation lag for the control group, we notice a sharp decline of the citation lag for the treatment group.

-- Insert Figure 3 about here –

5 Econometric results and discussion

5.1 Impact of policy change on citation counts and citation lags

First, we examine the total amount of citations depending on the regime status, using a difference-in-difference methodology. As discussed in the methodology section, the chosen control group are patent applications filed at the European Patent office, Germany, and United Kingdom. We construct different citation counts depending on the geographic origin of follow-on citations (domestic or abroad) and consider the forward citations within a 10 years window starting from the priority date of our sampled patents. Since the dependent variable is a count measure, we use Quasi-Maximum-Likelihood-Poisson (QML-Poisson) and complementary Tobit regressions models where we estimate the share of abroad citations on all citations. The results are reported in Table 2.

-- Insert Table 2 here –

We detect a positive and significant effect of the policy change on the amount of forward citations as indicated by the interaction term *NEW REGIME x TREATED*, and we also observe some differences by geography. The magnitude of the effect is slightly stronger for follow-on citations from abroad. The complementary Tobit regression model (4) which explains the share of abroad citation on total forward citations obtained, reflect the same tendency, although the coefficient is not significant. Second, we quantify the impact of the policy change on the adoption speed as reflected by the citation time lags. This analysis uses subsamples where the citation counts are larger or equal than one. Not surprisingly, the average forward citation lag of patents in the new regime is considerably shorter throughout all estimations. We again detect stronger magnitudes for citations originating abroad with even more pronounced differences between abroad and within-country citations than in the case of the absolute citation counts. Taking both the result on citation counts and citation lags jointly into consideration, it can be concluded that the policy change has some impact on follow-on inventions and that the early disclosure moderates spatial pattern of innovation diffusion.

Whereas from a theoretical viewpoint it would also have been possible that the policy change contributes and reinforces the localization of knowledge flows, our results support more strongly the view that geographical distance is associated with reduced possibilities to substitute codified knowledge as a source of learning. Whereas inventors in technological clusters like Silicon Valley may learn through informal mechanism and personal interactions, it is more important for distant inventors to rely on codified knowledge. In other words, patents as a disclosure mechanism are more valuable for competitors located at greater distance. Thus, our results in terms of geography provide also some support that patent documents can be a valuable source of information. In order to obtain a more detailed picture, we split the forward citations by inventor and examiner in the next subsection.

5.2 Inventor vs. examiner citations

As mentioned in the methodology section, a citation can be distinguished on whether the inventor or the patent examiner has added it. This distinction reflects if the follow-on inventors benefit from a timely disclosure of knowledge or if the disclosed information is informative for patent examiners, potentially increasing the quality of the examination process. The results of the corresponding regressions are reported in the Tables 3a (citation counts) and 3b (citation lags).

-- Insert Table 3a & 3b about here –

Starting with the citation counts, we observe that the effect of the policy change is significant for both inventor-added citations and examiner-added citations. The coefficients between examiner and inventor citations are very similar, and for both groups the magnitudes are stronger for citations originating from abroad. Regarding the citation lags, we obtain a similar result concerning the role of citations from abroad, while the magnitudes are weaker for examiner-added citations compared to the case of inventor-added ones. The results on examiner citations suggests that earlier disclosure increases the probability that patent examiners include a citation to a patent, potentially increasing the efficacy of the patent protection on the cited invention. Therefore, both abovementioned mechanism seems to be at place. While our results indicate a knowledge flow that is beneficial for follow-on inventors, also examiners become informed, with potentially higher rejection likelihood and lower scope of the follow-on patents, thus enabling additional protection for inventors.

5.3 Heterogeneity by technological area

Since the importance of codified patent documents as source of knowledge may vary by sector and thus presumably also by technological domain (Heger and Zaby, 2013), we investigate this aspect in greater depth. We estimate subsample regressions using the broad technological fields Chemistry and Biology, Electrical engineering, Instruments, and Mechanical engineering (see WIPO, 2013). The regression results are reported in Tables 4a (citation counts) and 4b (citation lags).

-- Insert Table 4a & 4b about here --

Throughout all sector subsamples, we detect a rather consistent pattern concerning the differences between citations from abroad and within-country citations. The coefficients between the two citation groups are very similar, but we observe slightly larger ones for abroad citations. For the instruments sector, the early disclosure even has a strong positive impact on the amount of citations from abroad, whereas we detect a negative but not significant sign for within-country citations. The analysis of citation lags reveals a non-uniform picture. Interestingly, the policy change does in some sectors (like in Electrical Engineering) not lead to a reduction in citation lags. The results on the geographical dimension is similarly mixed with sectors where the policy change leads to stronger decreases in the time lags for within-country citations (Instruments), and others where we obtain the opposite finding (Mechanical Engineering).

Overall, the sector analysis suggests that the technological area is to some extent influential in determining the effects of the policy change. Our findings are in line with complementary observations that the use of patent literature is heterogeneous depending on sectors and findings that patents have a non-uniform impact on the direction of inventive activity in an industry (Graham et al., 2009; Moser, 2005). From this point of view, it is plausible that we observe a particularly strong impact of the policy change in Electrical Engineering where technologies are heavily interrelated and technological progress is strongly cumulative. Since it is challenging to provide more detailed evidence concerning the underlying drivers of these differences across sectors, our results are not conclusive. Nonetheless, the observed differences might offer managerial implications for firms in these sectors in order to assess benefit-cost rationale of patent protection.

5.4 Robustness tests

Relying on a difference-in-difference methodology implies the choice of an appropriate control group. Although our graphical analysis of time trends suggests that our chosen control group of German, UK, and EPO patents represents a fair benchmark for the patents in the treatment group, we executed further tests to gain evidence on the robustness of our results. First, we focused on the differences within the treated patents before and after the policy change using a reduced sampling window around the policy change (180 days before and after AIPA came into effect). In the absence of a control group, a reduced sampling window ensures the comparability of patents on each side the policy change event and minimized the bias from time trends. The regression results, as reported in Appendices A.1. and A.2. were in line with our difference-in-difference estimation results. As a further variation, we additionally imposed placebo-policy changes by moving the policy change date 180 days forward and backward in the timeline. Moving the sampling date forward (A.3), it can be seen that the significant coefficient of the variable *NEW REGIME* vanished. When the policy change is moved backwards in time, *NEW REGIME* is in some specifications significant, although there is little evidence that there is a significant difference by geography of the follow-on citations. In summary, these robustness tests support our interpretations gained from our main regression models.

6 Conclusion

This study is one of the first empirical contributions that investigate the dynamics of knowledge disclosure in the patent system. Our analysis suggests that early disclosure indeed has an impact on the speed of follow-on developments both with regard to the total amount of follow-on knowledge and the adoption speed. Importantly, we find that early patent disclosure informs relatively more frequently inventors located abroad. In other words, the timing of disclosure moderates spatial pattern of knowledge diffusion, which was found to be rather localized in previous work (e.g. Jaffe et al., 1993). As such we provide micro-level evidence that the disclosure of codified knowledge informs and potentially stimulates follow-on research and patenting activity.

From a managerial viewpoint, our findings offer several interpretations. Starting from a traditional view on the negative effects of knowledge spillovers, the policy change may shift incentives toward secrecy if firms suspect that competitors benefit from codified knowledge despite the protection that a patent offers. On the other hand, one has to keep in mind that spillovers are not necessarily negative but rather stimulate external follow-on research that can be incorporated again by a focal firm, or is in other ways beneficial (Alexy et al., 2013; Belenzon, 2012). Firms that have more strategic approaches regarding knowledge disclosure may feel encouraged by our findings to continue relying on the patent system. Moreover, the observation that examiners likewise benefit from the policy change has managerial implications, too. Since the policy change improves the possibilities for examiners to detect relevant prior art, a focal inventor should receive increasing protection since follow-on patents likely receive restrictions. Subsequent patents that overlap with a focal invention should be less likely granted or have a reduced number of claims. This in turn may reduce the need for firms to monitor and pursue infringement by competing firms since the examiner detect such patents earlier on.

Our results are also interesting for policy-makers since they provide support for the assumed positive effects of disclosure on cumulative innovation, potentially supporting innovation and economic growth also at the macro-level. Our findings are not necessarily restricted to means of patent disclosure, but may apply similarly to other disclosure instruments like scientific publications or technical reports. Moreover, the result that patent examiners benefit from knowledge disclosure is not only worth mentioning from a managerial viewpoint but is also an important observation for policy makers that are concerned with the optimal design of the patent system. The reduction of information asymmetry allows patent examiners to detect non-novel follow-on patents, which should decrease the social costs like litigation since "problematic" patents are detected earlier.

This study also has limitations that should be kept in mind. As we acknowledge in the paper, the use of citation data to capture knowledge flows is controversial. Obviously, not every follow-on invention is patented, and even if it is patented, this does not imply the observation of a citation. The observation of a citation does also not necessarily represent a causal knowledge flow to the inventor caused by the disclosure of the patent document. For instance, it is possible that we observe increasing citation numbers since a certain piece of knowledge – that was already transmitted by informal mechanisms – became only cited as the codified equivalent was earlier visible in the new regime. However, while the increase of total citation counts in the new regime might be partially explained by construction of the policy change, there is little reason why the geographic dimension should be systematically affected. In addition, more generally speaking, patent citation data is the best measure that can be obtained with regard to technological knowledge and some studies provide support that it is a fair proxy of knowledge flows.

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FIGURES & TABLES

TABLE 1 – Descriptive statistics

Variable	Obs.	Mean	S.D.	Min	Max	MEAN NEW R	MEAN OLD R	*t-test*
Treatment group								
NEW REGIME	149019	0.51	0.50	0.00	1.00	1.00	0.00	
LOG CLAIMS	149019	2.89	0.72	0.00	6.27	2.91	2.86	***
LOG INVENTORS	149019	0.69	0.60	0.00	4.33	0.69	0.70	-
LOG APPLICANTS	149019	0.04	0.18	0.00	4.34	0.04	0.04	-
LOG BWDCITES	149019	2.57	0.83	0.00	5.25	2.60	2.55	***
LOG NPLCITES	149019	1.19	0.79	0.00	5.11	1.20	1.18	***
GRANT LAG	149019	3.17	1.39	1.56	8.00	3.25	3.08	***
Control group								
NEW REGIME	41981	0.50	0.50	0.00	1.00	1.00	0.00	
LOG CLAIMS	41981	0.33	0.85	0.00	4.52	0.38	0.29	***
LOG INVENTORS	41981	0.53	0.57	0.00	3.00	0.54	0.52	***
LOG APPLICANTS	41981	0.07	0.23	0.00	2.30	0.07	0.07	-
LOG BWDCITES	41981	1.53	0.49	0.00	3.87	1.55	1.52	***
LOG NPLCITES	41981	0.81	0.28	0.00	3.04	0.81	0.81	-
GRANT LAG	41981	3.71	1.60	1.56	8.00	3.66	3.76	***

TABLE 2: Difference-in-difference analysis of citation counts

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CITATION COUNTS				CITATION LAGS		
	QML-P	QML-P	QML-P	TOBIT	OLS	OLS	OLS
	ALL GEO	ABROAD	CTRY	% ABROAD	ALL GEO	ABROAD	CTRY
NEW REGIME	-0.079*	0.415***	0.034	0.112***	-2.450***	-2.175***	-15.104***
	(0.042)	(0.070)	(0.059)	(0.016)	(0.542)	(0.824)	(0.768)
TREATED	-0.254***	-0.080	0.475***	0.241***	1.907***	3.759***	-0.235
	(0.036)	(0.074)	(0.046)	(0.011)	(0.392)	(0.568)	(0.572)
NEW REGIME x TREATED	0.207***	0.415***	0.307***	0.017	-1.968***	-2.522***	-1.432*
	(0.048)	(0.101)	(0.062)	(0.016)	(0.543)	(0.805)	(0.785)
LOG CLAIMS	0.222***	0.210***	0.227***	-0.000	-0.478***	-0.563***	-0.481***
	(0.006)	(0.009)	(0.008)	(0.002)	(0.064)	(0.088)	(0.097)
LOG NO INVENTORS	0.180***	0.078***	0.181***	-0.033***	-0.577***	-0.859***	-1.237***
	(0.008)	(0.008)	(0.009)	(0.002)	(0.077)	(0.107)	(0.111)
LOG NO APPLICANTS	-0.036	0.039	-0.045	0.072***	0.160	0.378	1.339***
	(0.024)	(0.027)	(0.038)	(0.007)	(0.248)	(0.341)	(0.367)
LOG BWDCITES	0.216***	0.143***	0.237***	-0.020***	0.947***	0.540***	1.020***
	(0.006)	(0.007)	(0.008)	(0.002)	(0.063)	(0.089)	(0.093)
LOG NPLCITS	0.143***	0.077***	0.167***	-0.032***	-0.375***	-0.246***	-0.880***
	(0.006)	(0.007)	(0.008)	(0.002)	(0.064)	(0.092)	(0.093)
GRANT LAG	-0.044***	-0.061***	-0.053***	-0.011***	1.206***	1.469***	1.462***
	(0.003)	(0.004)	(0.004)	(0.001)	(0.037)	(0.051)	(0.052)
PERIOD X TREATED	-0.058***	-0.107***	-0.083***	-0.006**	0.004	0.110	-0.100
	(0.009)	(0.016)	(0.012)	(0.003)	(0.103)	(0.155)	(0.149)
TECH FIELD CONTROLS	YES	YES	YES	YES	YES	YES	YES
PERIOD CONTROLS	YES	YES	YES	YES	YES	YES	YES
Observations	191,000	191,000	191,000	173,229	173,237	136,150	160,319
Pseudo-R^2	0.1746	0.102	0.1967	0.0345	0.041	0.024	0.081

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

TABLE 3A: Citation counts differentiated between examiner and inventor citations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		EXAMINER CITS				INVENTOR CITES		
	QML-P	QML-P	QML-P	TOBIT	QML-P	QML-P	QML-P	TOBIT
	ALL GEO	ABROAD	CTRY	ABROAD	ALL GEO	ABROAD	CTRY	ABROAD
NEW REGIME	-0.067*	0.400***	-0.047	0.112***	-0.095*	0.438***	0.258***	0.199***
	(0.040)	(0.069)	(0.053)	(0.017)	(0.057)	(0.091)	(0.100)	(0.028)
TREATED	-0.318***	0.043	0.149***	0.287***	-0.120***	-0.308***	1.027***	0.070***
	(0.034)	(0.077)	(0.047)	(0.012)	(0.046)	(0.088)	(0.061)	(0.020)
NEW REGIME x TREATED	0.196***	0.413***	0.291***	0.030*	0.228***	0.421***	0.334***	0.049*
	(0.047)	(0.108)	(0.066)	(0.017)	(0.062)	(0.118)	(0.083)	(0.029)
PATENT-LEVEL CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES
TECH FIELD CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES
PERIOD CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES
Observations	191,000	191,000	191,000	166,985	191,000	191,000	191,000	135,929
Pseudo-R^2	0.1271	0.0985	0.1478	0.0434	0.1744	0.0752	0.1978	0.0089

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

TABLE 3B: Citation lags differentiated between examiner and inventor citations

	(1)	(2)	(3)	(5)	(6)	(7)
		EXAMINER CITS			INVENTOR CITES	
	OLS	OLS	OLS	OLS	OLS	OLS
	ALL GEO	ABROAD	CTRY	ALL GEO	ABROAD	CTRY
NEW REGIME	-1.902***	-2.064**	-1.672**	-5.085***	-5.293***	-4.213***
	(0.565)	(0.867)	(0.662)	(0.768)	(1.170)	(0.915)
TREATED	1.327***	3.508***	-0.175	2.910***	5.259***	1.806***
	(0.415)	(0.600)	(0.494)	(0.546)	(0.819)	(0.654)
NEW REGIME x TREATED	-1.438**	-2.312***	-1.150*	-3.160***	-4.032***	-3.308***
	(0.568)	(0.847)	(0.668)	(0.776)	(1.167)	(0.930)
PATENT-LEVEL CONTROLS	YES	YES	YES	YES	YES	YES
TECH FIELD CONTROLS	YES	YES	YES	YES	YES	YES
PERIOD CONTROLS	YES	YES	YES	YES	YES	YES
Observations	166,994	129,511	142,811	135,931	73,050	114,357
Pseudo-R^2	0.039	0.023	0.035	0.037	0.025	0.034

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

TABLE 4A: Citation counts using sector subsamples

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
		BIO & CHEM			ELEC. ENGIN			INSTRUMENTS			MECHAN. ENGIN.	
	ALL GEO	ABROAD	CTRY	ALL GEO	ABROAD	CTRY	ALL GEO	ABROAD	CTRY	ALL GEO	ABROAD	CTRY
NEW REGIME	-0.338***	0.207	-0.192	0.138	0.890***	0.307**	-0.174*	0.402**	-0.047	-0.062	0.381***	0.067
	(0.108)	(0.157)	(0.143)	(0.120)	(0.186)	(0.147)	(0.096)	(0.190)	(0.156)	(0.057)	(0.100)	(0.083)
TREATED	-0.813***	-1.109***	0.387***	0.101	0.323**	0.905***	-0.035	-0.088	1.015***	-0.093*	0.376***	0.184**
	(0.098)	(0.190)	(0.107)	(0.078)	(0.141)	(0.110)	(0.073)	(0.135)	(0.107)	(0.054)	(0.121)	(0.078)
NEW REGIME x TREATED	0.130	0.370*	0.305**	0.374***	0.703***	0.630***	0.126	0.648***	-0.013	0.122*	0.307*	0.234**
	(0.126)	(0.223)	(0.148)	(0.115)	(0.206)	(0.169)	(0.105)	(0.200)	(0.147)	(0.066)	(0.169)	(0.097)
PATENT-LEVEL CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
PERIOD CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	26,253	26,253	26,253	77,575	77,575	77,575	31,770	31,770	31,770	39,675	39,675	39,675
R2	0.101	0.041	0.170	0.108	0.047	0.104	0.174	0.083	0.176	0.100	0.089	0.1001

QML-Poisson estimation models. Robust standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1

TABLE 4B: Citation lags using sector subsamples

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
		BIO & CHEM			ELEC. ENGIN			INSTRUMENTS			MECHAN. ENGIN.	
	ALL GEO	ABROAD	CTRY	ALL GEO	ABROAD	CTRY	ALL GEO	ABROAD	CTRY	ALL GEO	ABROAD	CTRY
NEW REGIME	-2.898**	-2.352	-12.936***	-0.596	1.143	-12.501***	-2.930**	-2.158	-15.254***	-2.668***	-2.276	-16.175***
	(1.181)	(1.796)	(1.759)	(1.624)	(2.597)	(2.233)	(1.374)	(2.064)	(1.903)	(0.924)	(1.422)	(1.272)
TREATED	8.417***	9.474***	8.278***	-6.171***	-5.211***	-9.783***	-0.098	1.562	-3.236**	1.702**	4.277***	-1.446
	(0.911)	(1.304)	(1.387)	(1.001)	(1.512)	(1.457)	(0.983)	(1.476)	(1.395)	(0.749)	(1.081)	(1.085)
NEW REGIME x TREATED	-2.669**	-0.961	-2.442	0.752	1.978	1.336	-3.148**	-2.345	-3.541*	-0.852	-3.542**	0.372
	(1.236)	(1.815)	(1.877)	(1.515)	(2.271)	(2.149)	(1.391)	(2.112)	(1.943)	(0.949)	(1.417)	(1.363)
PATENT-LEVEL CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
PERIOD CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	22,120	15,502	20,180	73,994	63,122	69,024	29,250	23,235	27,317	34,461	24,577	31,533
R2	0.024	0.015	0.045	0.027	0.015	0.055	0.032	0.016	0.069	0.007	0.007	0.045

OLS estimation models. Robust standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1

FIGURE 1: Time-lag between priority and patent publication

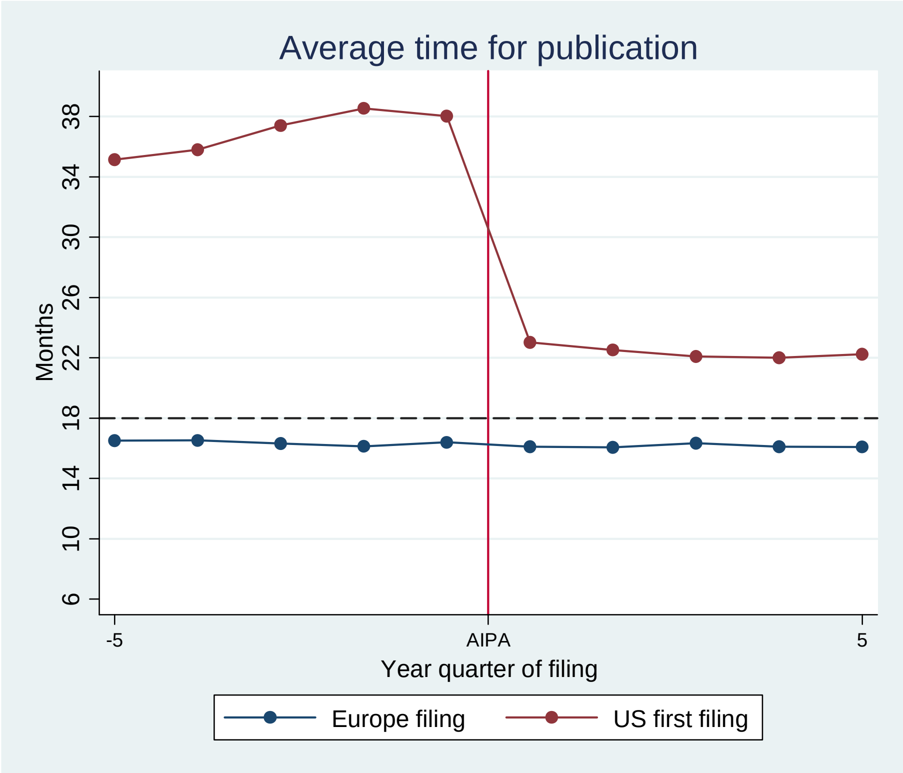


FIGURE 2: Citations counts of treatment vs. control group

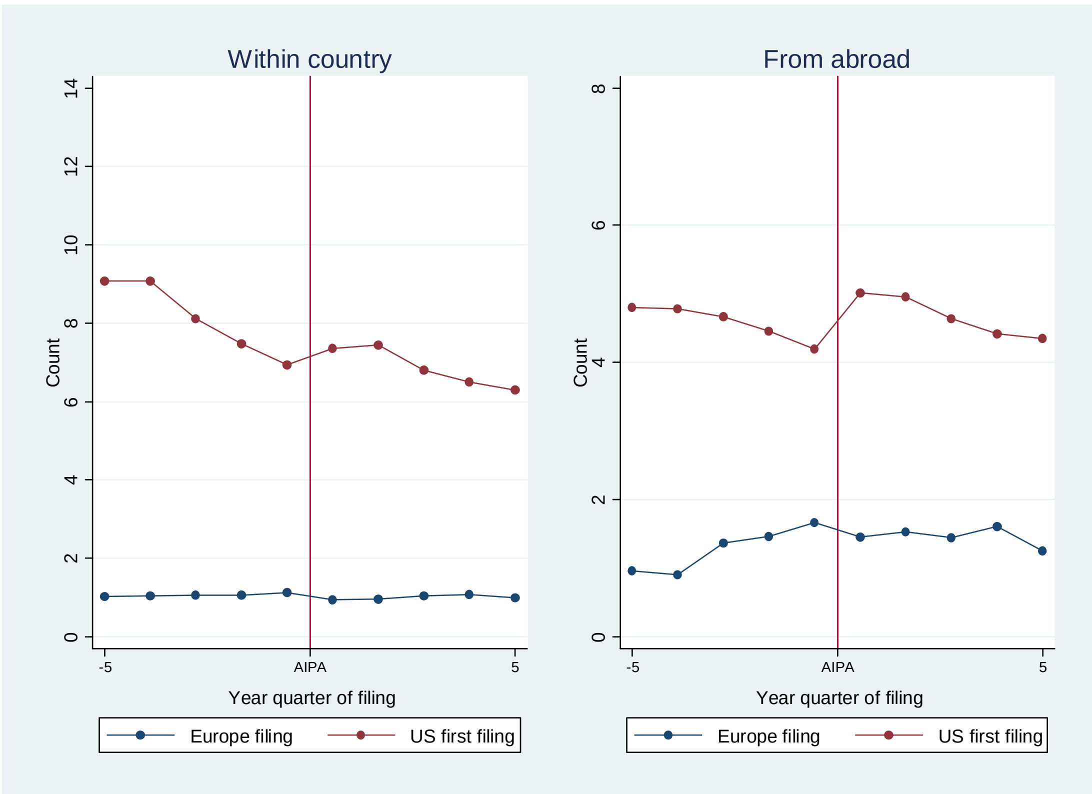
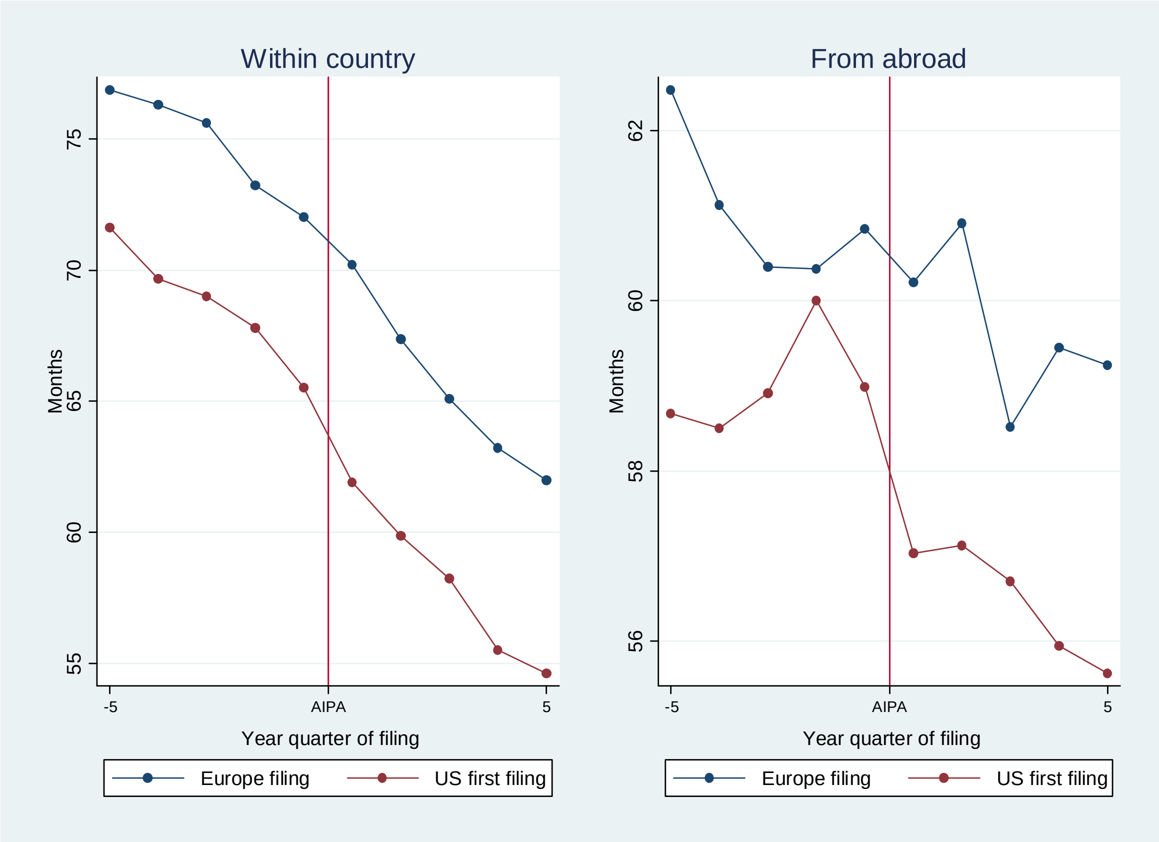


FIGURE 3: Citation time lag from follow-on patents abroad



APPENDIX

A1: Citation counts by regime for treated group with +/- 180 days sampling window

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	ALL CITATION COUNTS				EXAMINER CITATION COUNTS				APPLICANT CITATION COUNTS			
	QML-P	QML-P	QML-P	TOBIT	QML-P	QML-P	QML-P	TOBIT	QML-P	QML-P	QML-P	TOBIT
	ALL GEO	ABROAD	CTRY	% ABROAD	ALL GEO	ABROAD	CTRY	% ABROAD	ALL GEO	ABROAD	CTRY	% ABROAD
NEW REGIME	0.011	0.106***	0.027	0.040***	0.039*	0.143***	0.035	0.044***	-0.020	0.037	0.022	0.060***
	(0.024)	(0.029)	(0.030)	(0.007)	(0.023)	(0.025)	(0.029)	(0.007)	(0.029)	(0.048)	(0.036)	(0.013)
PATENT-LEVEL CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
TECH FIELD CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
PERIOD CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	50,026	50,026	50,026	47,508	50,026	50,026	50,026	45,788	50,026	50,026	50,026	39,395
Pseudo-R^2	0.0746	0.0228	0.0598	0.0049	0.072	0.0287	0.0584	0.0097	0.0746	0.0228	0.0598	0.0049

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

A2: Citation lag by regime for treated group with +/- 180 days sampling window

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	CITATION LAGS			EXAMINER CITATION LAGS			APPLICANT CITATION LAGS		
	ALL GEO	ABROAD	CTRY	ALL GEO	ABROAD	CTRY	ALL GEO	ABROAD	CTRY
NEW REGIME	-2.432***	-2.872***	-6.232***	-1.093***	-2.219***	-0.388	-4.792***	-5.443***	-4.217***
	(0.289)	(0.403)	(0.430)	(0.321)	(0.427)	(0.394)	(0.373)	(0.605)	(0.421)
PATENT-LEVEL CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES
TECH FIELD CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES
PERIOD CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	47,508	39,745	44,471	45,789	37,901	39,543	39,395	21,497	33,610
Pseudo-R^2	0.016	0.011	0.018	0.013	0.010	0.009	0.016	0.012	0.013

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

A3: Citation counts with policy change moved 180 days into the future (placebo test)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	CITATION COUNTS				EXAMINER CITATION COUNTS				APPLICANT CITATION COUNTS			
	QML-P	QML-P	QML-P	TOBIT	QML-P	QML-P	QML-P	TOBIT	QML-P	QML-P	QML-P	TOBIT
	ALL GEO	ABROAD	CTRY	% ABROAD	ALL GEO	ABROAD	CTRY	% ABROAD	ALL GEO	ABROAD	CTRY	% ABROAD
NEW REGIME	-0.025	0.013	-0.024	0.008	-0.017	0.009	-0.000	0.007	-0.035	0.020	-0.041	0.008
	(0.022)	(0.028)	(0.028)	(0.007)	(0.020)	(0.024)	(0.026)	(0.007)	(0.028)	(0.047)	(0.035)	(0.012)
PATENT-LEVEL CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
TECH FIELD CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
PERIOD CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	49,639	49,639	49,639	47,402	49,639	49,639	49,639	45,842	49,639	49,639	49,639	39,176
Pseudo-R^2	0.0879	0.0287	0.0653	0.0083	0.0754	0.0281	0.0622	0.0059	0.0746	0.021	0.0554	0.0037

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

A4: Citation counts with policy change moved 180 days into the past (placebo test)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	CITATION COUNTS				EXAMINER CITATION COUNTS				APPLICANT CITATION COUNTS			
	QML-P	QML-P	QML-P	TOBIT	QML-P	QML-P	QML-P	TOBIT	QML-P	QML-P	QML-P	TOBIT
	ALL GEO	ABROAD	CTRY	% ABROAD	ALL GEO	ABROAD	CTRY	% ABROAD	ALL GEO	ABROAD	CTRY	% ABROAD
NEW REGIME	-0.073***	-0.059*	-0.095***	0.002	-0.046*	-0.047*	-0.055*	0.004	-0.101***	-0.081	-0.120***	-0.017
	(0.025)	(0.031)	(0.032)	(0.007)	(0.024)	(0.026)	(0.031)	(0.008)	(0.031)	(0.050)	(0.038)	(0.013)
PATENT-LEVEL CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
TECH FIELD CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
PERIOD CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	49,465	49,465	49,465	46,853	49,465	49,465	49,465	45,095	49,465	49,465	49,465	38,915
Pseudo-R^2	0.0908	0.0264	0.074	0.01	0.068	0.0227	0.0562	0.0088	0.0854	0.0225	0.0733	0.0042

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1