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ECONOMICS WORKING PAPER SERIES
Working Paper 2024–10–A

U.S. INTERNATIONAL TRADE COMMISSION
500 E Street SW
Washington, DC 20436

October 2024

The authors would like to thank Nicholas Pairolero, Mike Teodorescu, Theodorus Alysandratos, Alexander Gizcy, Julio Raffo, and the participants at the 19th annual EPIP conference for their valuable feedback. Charles de Grazia and Hwansung Ju would like to thank Ecole de Management Leonard de Vinci for research funding that contributed to this project.

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Abstract

Technology diffusion and spillovers are key drivers of both innovation and economic growth. This paper examines the role of obtaining initial intellectual property rights on international knowledge flows, specifically through technological entrants into the United States. We find causal evidence that a foreign technological entrant's initial patent grant in a host country increases the likelihood of cross-border knowledge flows, measured using forward patent citations, to local U.S. firms and other patenting entities by 29.4 percent. Initial intellectual property rights appear to mitigate impediments to cross-border knowledge flows, the benefits of which outweigh frictions arising from the exclusionary nature of the patents. Consistent with the prior literature on the determinants of international knowledge flows, an initial patent grant leads to an entrant's sustained technological presence in the host country, increasing the probability of at least one subsequent local patent filing at the USPTO by up to thirty percent within five years. These effects, however, do not appear to be driven by an appropriation mechanism for existing technologies—or inventions already filed in other countries at the time of the initial decision. Finally, we find that the effects of an initial patent grant are heterogeneous based on the entrant's country of origin and the invention type.

Keywords: Patents, intellectual property rights, knowledge diffusion, innovation
JEL Codes: O31, O33, O34, F19

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1 Introduction

Sources of innovation, a main driver of domestic economic growth (Romer, 1990), extend beyond national boundaries to knowledge and to technologies created abroad (Grossman and Helpman, 1991; Mudambi, 2008; Keller, 2021). However, the "international diffusion of technology is neither inevitable nor automatic," (Keller, 2004, p. 753). Geographical distance and national borders are impediments to international knowledge flows, even with increased global economic integration and the ubiquity of ICT technologies (Jaffe et al., 1993; von Hippel, 1998; Jensen and Szulanski, 2004; Funk, 2014; Singh and Marx, 2013). Prior studies have identified several determinants of international knowledge diffusion. MacGarvie (2005) finds that technological distance, common language, geographic distance, and FDI have a significant impact on knowledge flows between countries. Research from the international trade literature suggests that cross-border diffusion occurs through intermediate and final good imports (Coe and Helpman, 1995; Pavcnik, 2002; Aghion et al., 2023), exports ("learning-by-exporting", Keller (2021)), and also foreign direct investment (Branstetter et al., 2006).

One global source of technical knowledge are patent documents, which are stored at intellectual property (IP) offices and in patent databases (Griliches, 1998). In exchange for an exclusive property right over a claimed technology space for a limited period of time, patent applicants are required to publicly disclose details of the invention under consideration for a patent. Recent studies have found that this disclosure mechanism accelerates knowledge diffusion (Baruffaldi and Simeth, 2020; Büttner et al., 2022; Hegde et al., 2022). However, increased invention visibility through patent publication alone is not a sufficient condition for the use of codified technical information (Baruffaldi and Simeth, 2020). The proliferation of patent documents and the increased burden of knowledge — the educational burden and knowledge accumulation requires to innovate — limit the dissemination of all relevant technological advancements to firms and to inventors (Jones, 2009; Baruffaldi and Simeth, 2020). As an alternative to the disclosure mechanism, cross-border technology diffusion can be fostered by interactions between domestic and foreign parties, widening the available stock of knowledge to domestic parties and increasing international spillovers (Keller, 2021).

This paper explores the role of IP in international knowledge diffusion, looking beyond the disclosure mechanism as a source of diffusion. Specifically, we examine a crucial yet understudied function of the IP system: the role of individual patent rights in facilitating cross-border knowledge flows. First, we explore the impact of intellectual property rights (IPRs) granted to small foreign technological entrants (first-time foreign patent applicants with a small entity status) on sustained technological presence in a host jurisdiction or country.[1] We posit that an initial patent grant should increase the likelihood of the entrant's continued technological presence via appropriation (protection from initiation) and feedback (increased R&D investment) channels, offsetting invention-related market failures (Arrow, 1962) and potentially improving entrant performance (Farre-Mensa et al., 2020). Next, we consider the impact of an initial patent grant awarded to a foreign entrant on knowledge diffusion to local firms and other patenting entities. Patent grants, which increase a foreign entrant's market (de Rassenfosse et al., 2022) and technological presence, should increase opportunities for knowledge flows to occur between the foreign entrants and local patenting entities (Keller, 2021). Absent licensing frictions, the benefits of sustained geographic proximity (via the market and technological presence channels) should increase diffusion of the focal invention in a host country.

Using a sample of 44,548 new technological entrants into the United States from 2006 to 2017, we first estimate the causal effect of an initial patent grant on a foreign technological entrant's continued technological presence in a host country. Continued presence is measured via subsequent patent applications filed by the focal foreign entrant in the U.S. patent system. Second, we estimate the effects of an initial patent grant on international knowledge flows to local U.S. entities using forward patent citations (Jaffe, 1986) to an entrant's initial application to measure spillovers. Empirically, we compare the outcomes of foreign firms that applied for a patent in the United States for the first time and had it granted with firms for whom that initial patent application was rejected. As part of our identification strategy, we exploit the quasi-random assignment of patent applications to examiners and instrument for the endogenous patent grant decision using the assigned examiner's prior grant rate (Lemley and Sampat, 2012; Sampat and Williams, 2019; Farre-Mensa et al., 2020).[2] Our instrumental variable (IV) framework allows us to disentangle the effects of the patent grant

[1] Our study focuses on small technological entrants for two reasons. First, small firms—especially start-ups—play an important role in economic and innovative activities, are associated with higher net job creation (Haltiwanger et al., 2013; Heyman et al., 2018), and tend to exhibit discontinuous innovation (Mansfield et al., 1968). The second reason is practical: small firms tend to be younger and have far less complex firm structures than large entities, allowing us to determine the timing of technological entry with greater accuracy.

[2] The prior grant rate instrument has origins in the labor economics literature, where researchers instrument for criminal court case decisions using assigned judge's prior tendencies (Kling, 2006).

from the underlying unobserved characteristics of the invention (e.g., invention value) and of the applicant (Farre-Mensa et al., 2020).

Our main results show that when a small technological entrant's initial patent application is granted, it increases the probability of sustained technological presence in the United States by over 27 percent within three to seven years compared to firms for whom their first application was rejected. Sustained technological presence not only represents the introduction of additional foreign inventions into the U.S. patent system and increased visibility of these inventions for U.S. patenting entities (through the local disclosure mechanism), it also at least partially captures an entrant's engagement with the U.S. innovation ecosystem. As evidence of direct knowledge flows to local U.S. entities, we find that the granting of an initial patent increases both the probability that the technology is cited (26 percent) and the frequency with which it is cited (7.9 percent) by U.S. entities within seven years. This finding implies that initial patent grants increase the frequency with which local inventors draw on these newly-introduced foreign technologies, suggesting greater knowledge flows into the United States. Taken together, our findings suggest that the granting of an initial patent is an important source of technology growth and, therefore, has strong implications for economic growth.

Extensions to our baseline framework allow us to provide a richer understanding of the patent grant effects across a number of dimensions. First, we explore prospective channels through which sustained technological presence might occur. We do not find a statistically significant, causal relationship between the initial patent grant decision and subsequent patent filing for other existing inventions from the entrant's portfolio within three years. This suggests that an entrant's initial patent experience does not affect their decisions regarding whether or not to apply for patents for their other existing technologies. We therefore speculate that the increase in sustained technological presence is driven primarily by appropriation and feedback effects related to *new* inventions. Next, following the receipt of an initial patent grant, foreign technological entrants are more likely to file at least one subsequent product-related patent but not process-related patents within 5 years—consistent with the findings of Ganglmair et al. (2022). An initial patent grant in a foreign jurisdiction, therefore, does not offset the perceived high costs of monitoring for process patents in that jurisdiction. Finally, we determine if the estimated patent grant effects differ by the entrant's country of origin—or more specifically, if the country is part of the IP5, or a member of one the five largest IP offices in the world,[3] We find that an initial patent grant significantly affects local innovation outcomes for non-IP5 countries, but generally not for IP5 countries.

This paper contributes to several areas of the innovation economics literature. The first is the literature examining cross-border knowledge flows, IPRs, and technological growth. Knowledge sharing largely remains constrained by geographical distance and national borders (Jaffe et al., 1993; von Hippel, 1998; Singh and Marx, 2013; Funk, 2014), and direct cross-border economic activity via trade and FDI continues to be a crucial channel through which knowledge is diffused (Park, 2001; MacGarvie, 2005; Byun et al., 2021; Keller, 2021). The prior literature has primarily focused on the determinants of the cross-border diffusion of technology, including IPR regime strength (Branstetter et al., 2006; Ivus, 2010). Our work, however, is the first to examine the causal relationship between individual patent rights granted to a foreign entrant in a host country and the local diffusion of foreign technology. Because of the out-sized role that technology plays in most models of economic growth (Romer, 1994; Grossman and Helpman, 1991), policy instruments such as patents and other IPR protections can be a key factor in economic development and welfare (Park and Ginarte, 1997; Branstetter et al., 2011). Our estimates of short- and longer-term impacts on international knowledge spread have clear implications for both economic growth and welfare.

Our study also contributes to the literature examining the effects of obtaining IP protection on firm, inventor, innovative outcomes. Numerous studies have identified the ways in which patent rights have improved firm performance across key metrics, such as sales and growth (Farre-Mensa et al., 2020; Gaule, 2018), as well as exports (de Rassenfosse et al., 2022). Others have found that patent rights hinder follow-on innovation efforts, (Scotchmer, 1991; Galasso and Schankerman, 2015; Williams, 2013), although the effects are not uniform across all technologies (Sampat and Williams, 2019) and are U-shaped in the focal patent's value (Gaessler et al., 2024). A separate literature finds that patent rights significantly affect inventor outcomes, but are heterogeneous depending on the inventor's affiliation status. Melero et al. (2020) finds that patent protection decreases an affiliated inventor's mobility (i.e., changing jobs) while de Grazia et al. (2022) finds that patent rights increase an independent inventor's subsequent inventive activity and participation in the markets for technology. Independent inventors who receive a patent are also more likely to

[3] The IP5 consists of China National Intellectual Property Administration (China), European Patent Office (Europe), Japanese Patent Office (Japan), Korean Patent Office (South Korea), and the U.S. Patent and Trademark Office (USA).

maintain their independent status while pursuing subsequent inventive activity. Our study adds to the literature on the effects of patent protection itself by extending the analysis to foreign technological entrants into a host country and their respective inventive and patenting outcomes in that jurisdiction.

Finally, this paper helps to better understand the consequences of discrimination—intentional or unintentional—against foreign applicants by local patent offices. de Rassenfosse et al. (2019) finds evidence of systematic bias against foreign applicants within the IP5 while de Rassenfosse and Hosseini (2020) shows that unintentional discrimination is the driving force behind the estimated ten percentage point difference in allowance rates between local and foreign applicants at the USPTO. In light of our results, discriminatory treatment of a foreign patent application could hinder the transmission of that technology and could also negatively impact the longer-term spread of future technologies. As such, this type of IPR discrimination can have potentially large and long-lasting impacts on economic growth.

Our paper is organized as follows: In Section 2.1, we provide background information on patent examination process. Section 2.2 presents and discusses the theoretical motivations that underpin our analysis. In Section 3, we introduce our empirical methodology and identification strategy. Section 4 describes the data construction process and discusses our sample. We present our main results in Section 5 and extensions and robustness checks to our baseline results in Section 6. Finally, Section 7 concludes.

2 Background and theoretical motivations

2.1 The Patent Application Process

A patent application, after submission to the USPTO, is first assigned a technology classification and is then routed to the small administrative unit of patent examiners, called a group art unit (GAU), responsible for the assigned technology area. A supervisory patent examiner (SPE) assigns the focal application to an examiner within the GAU. The examiner then reviews the application and determines if the patent application meets the conditions for patentability described in Section 35 of the U.S. Code. To meet the threshold for patentability, the focal invention must be subject matter eligible (35 U.S.C. § 101), novel (35 U.S.C. § 102), and non-obvious (35 U.S.C. § 103), among other requirements. Initial application fees entitle the applicant to two rounds of examination at the USPTO. If the application satisfies each patentability requirement, the application will be allowed, and after the applicant pays the appropriate fees, a patent is issued. However, if the application does not satisfy all statutory requirements, the examiner typically issues a non-final rejection after the first round of examination, which details the reasons for rejection, and a final rejection after the second.

Foreign applicants may file patent applications at the USPTO via three distinct routes: (1) directly; (2) the Paris Convention; or (3) the Patent Cooperate Treaty (PCT). Applicants may file an application directly with the USPTO regardless of their country of origin. Applicants wishing to establish priority in a foreign jurisdiction before seeking patent protection at the USPTO may do so via the Paris Convention and PCT routes. The Paris Convention allows applicants to claim priority to an original patent filing in other participating jurisdictions if the subsequent applications are filed within twelve months of the original application's filing date.[4] The Paris Convention route requires applicants to file applications directly in each jurisdiction of interest. The PCT route permits applicants more flexibility and streamlines the application process across countries. This process requires applicants to file an international patent application, or a PCT application, within twelve months of the original filing date. The applicants then have until thirty months after the original application's filing date to enter the national stage phase for each designated jurisdiction.[5]

2.2 Theoretical motivations

A patent grant at least partially offsets the public good nature of invention, awarding an exclusionary right to the claimed technology for a limited period of time. These property rights are not limited to local applicants and may be sought for inventions created outside of the awarding jurisdiction. In this subsection, we consider entrant-level effects of obtaining initial IPRs on subsequent patent filings and continued technological presence within the host country. The channels

[4]Claiming priority to a foreign patent application that covers the same invention establishes the application's priority date at the USPTO as the filing date for the original application in the foreign jurisdiction (MPEP 213). In first-to-file patent systems, the right to seek patent protection on an invention is established by the priority date, not the date of invention.

[5]In the United States, the filing date for direct and Paris Convention route applications reflect the date of filing at the USPTO. For the PCT route, the "date of entry is dependent upon receipt of certain items required under 35 U.S.C. § 371(c)" (1893.03(b)). This date is referred to as the "371(c)" date and begins the national phase (MPEP 1893.03(b)). We do not consider provisional applications in our analysis.

through which IPRs may affect subsequent patenting for small foreign entrants are complex and often interrelated. Therefore, we consolidate these channels into two main sets of mechanisms: appropriation and feedback effects.

First, an awarded patent functions as an appropriation mechanism, allowing the patent holder to seek legal remedies to prevent imitation or patent infringement in the awarding jurisdiction. This exclusionary right could lead to quasi-rents, which may prolong market presence (de Rassenfosse et al., 2022) and may increase the expected profitability from the host market. The IPR might also decrease the severity of a firm's liability of foreignness and increase the patent holder's confidence that they can secure exclusionary rights on future applications (Lu et al., 2022; Benischke et al., 2023).

Second, securing a monopoly position over a claimed product or technology space could improve the financial performance of the small foreign entrant, which may be re-invested in R&D and spur feedback effects. For example, increased R&D investment could prompt the firm to conduct subsequent inventive activities and file new patent applications. Feedback effects may also occur when a small firm uses a patent grant as a signaling device to obtain external funding, subsequently reinvesting those funds in inventive activities (Farre-Mensa et al., 2020). Collectively, the appropriation and feedback effects should lead to increased follow-on applications and thus continued technological presence in the host country. Therefore,

Hypothesis 1. *An initial patent grant, conditional on application, awarded to a foreign technological entrant should increase subsequent patenting by the entrant in the host country*

Technological entrants, in exchange for the opportunity to seek a temporary monopoly right, are required to provide a written description of the invention. This description should enable any person skilled in the art to make and use the claimed technology.[6] The pre-grant publication of foreign inventions represents an indirect knowledge flow into the host country, which may increase visibility of the invention in the host country. However, pre-grant publication is not dependent on the ultimate outcome of the entrant's initial application in the host patent office. How then

[6]This requirement applies to countries that are party to the TRIPS agreement (Article 29 of the TRIPS agreement). In the U.S., this stipulation is stated by 35 USC § 112(a)). Since the enactment of the American Inventor's Protection Act of 1999, claimed inventions are disclosed via pre-grant publications, or the publication of the patent application eighteen months after filing at the USPTO. Applicants who submit a non-publication request may not seek international patent protection for the invention.

might an initial patent grant, conditional on application, impact local diffusion of the protected invention relative to those technologies for which the corresponding applications were rejected? On one hand, the granting of the patent might provide sufficient conditions for prolonged market and technological presence, or might encourage firms to increase foreign direct investment inflows. Both outcomes would likely increase local diffusion. On the other hand, the exclusionary nature of patent rights could impose additional costs on the technology's external use, limiting its local adoption and diffusion (Galasso and Schankerman, 2015; Gaessler et al., 2024).

Much of the existing literature suggests that proximity can be a critical factor in knowledge sharing, suggesting the potential value of the local disclosure requirement. Even with increased global economic integration and improved ICTs, geographic proximity and national borders continue to affect technology diffusion and knowledge flows (Porter et al., 1998; Storper and Venables, 2004; Singh and Marx, 2013; Funk, 2014). The international trade literature suggests that interactions between domestic and foreign agents widen the available stock of knowledge to domestic agents, increasing international spillovers (Keller, 2021). These interactions may take the form of exports to the host country through intermediate and final goods (Coe and Helpman, 1995; Pavcnik, 2002; Aghion et al., 2023) as well as foreign direct investment inflows (Branstetter, 2006). A local patent grant should increase a technological entrant's continued commercial (de Rassenfosse et al., 2022) or technological presence (Hypothesis 1) in the host country, increasing opportunities for local technology diffusion and spillovers to occur.[7]

By contrast, the exclusionary nature of patent rights may limit knowledge diffusion and use of the technology as the basis for follow-on inventive activity by local firms (Galasso and Schankerman, 2015; Spulber, 2015; Gaessler et al., 2024). The establishment of a property right permits patent holders "to exclude others from making, using, or selling their inventions" (Spulber, 2015, p. 274) through the use of legal remedies (e.g. patent infringement lawsuits or injunctive relief). A patent can increase the cost of follow-on inventive activity through the cost of licensing or—absent a licensing agreement—an increase in expected litigation costs. Therefore, the spread of patented technologies requires that these costs not become too expensive.

Although IPRs impose additional costs on third-parties for the use of technology, the entrant's

[7] A patent grant also acts a certification device for the invention, reducing informational asymmetry surrounding the invention (Spulber, 2015). This informational asymmetry may be especially acute for foreign technological entrants.

continued technological and market presence in the host country should increase spillover opportunities to local firms provided that the licensing costs and negotiating frictions are not prohibitively high. Therefore,

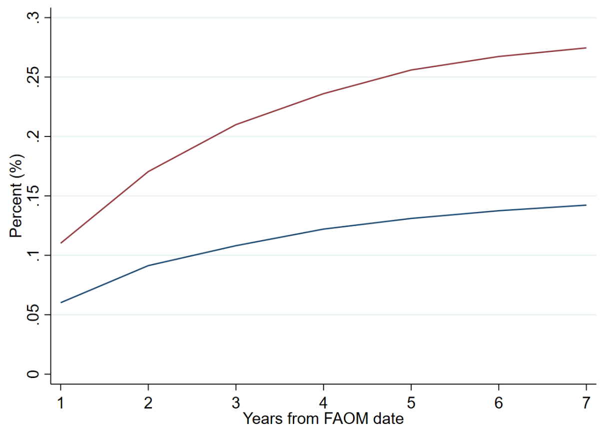
Hypothesis 2. *An initial patent grant in an external jurisdiction should increase diffusion and spillovers of the focal invention to local patenting entities in the host country*

2.3 Graphical evidence

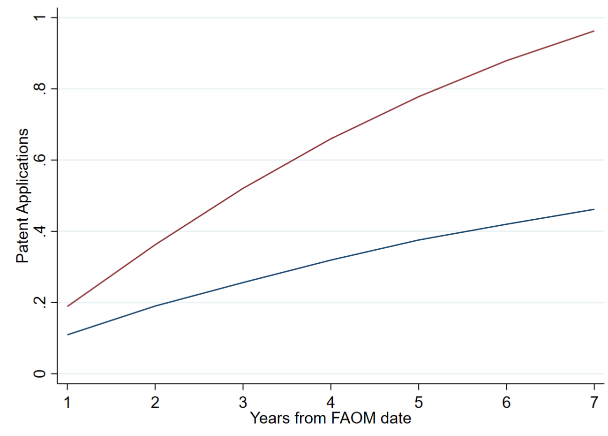
Data on patenting activities over a seven-year time horizon provide strong (non-causal) graphical support for Hypotheses 1 and 2. First, figures 1(a) and 1(b) compare subsequent patenting outcomes for foreign technological entrants whose initial applications were granted versus those that were not. The data suggest that obtaining initial IPRs may spur firms to file again and do so repeatedly. In Figure 1(a), technological entrants whose initial patent applications were granted were five percentage points (pp) more likely to file at least one follow-on application within the first year following the first-action decision compared to those whose initial application was rejected. This difference grows to 10.2 pp by year three and 13.2 by year seven. These trends are consistent with the mean number of follow-on applications by initial application status, shown in Figure 1(b). Both trends are consistent with the prediction of Hypothesis 1.

Second, we consider the effects of the patent grant decision on local knowledge diffusion, measured by external forward citations by local entities. The data suggest that the granting of a patent accelerates the external citations from local entities it receives. Figures 1(c) and 1(d) show the share of focal applications with at least one forward citation by a U.S. assignee and the average number of citations by U.S. assignees to the initial application, respectively, within one to seven years after the first-action on the merits (FAOM) date. For both forward citation variables, we observe an upward trend in citation activity over time, regardless of the grant decision outcome. However, granted applications receive more overall U.S. forward citations on average, and the magnitude of the difference between granted and rejected applications reaches 10.7 percentage points by year seven. Overall, Figure 1 indicates the presence of potentially significant patent grant effects for technological entrants across several dimensions. These trends are consistent with the predictions of Hypothesis 2. In the sections that follow, we turn to formal econometric methods to estimate the

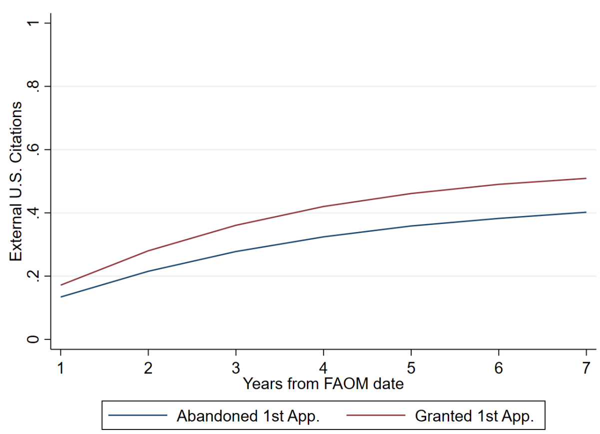
Figure 1: Firm and application outcomes by focal patent disposal status (grant or abandonment)



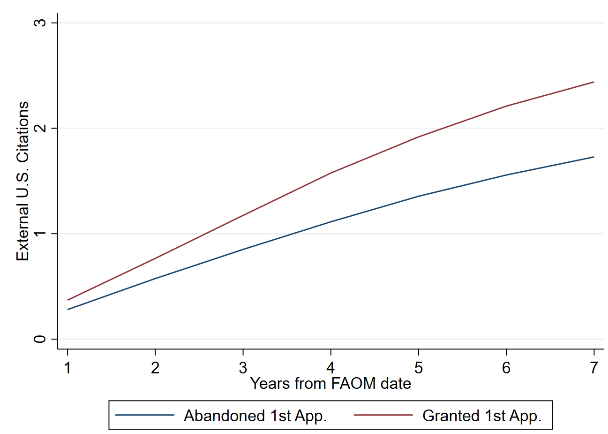
(a) Follow-on Percentage



(b) Follow-on Count



(c) External U.S. citations percentage



(d) External U.S. citations count

Notes: Follow-on percentage is the percent of firms that file at least one non-continuation patent application a specified period of time. Follow-on count is the number of subsequent one non-continuation patent applications filed by the focal assignee within a specified period of time. External U.S. citations refers to forward citations by patents owned by external U.S. firms to the focal patent application, measured both by the percentage of focal applications with at least one external U.S. citation and by the cumulative total of external U.S. citations.

causal effect of receiving an initial patent grant. The results largely confirm these initial empirical observations.

3 Empirical Methodology

Our primary objective is to estimate the effects of an initial patent grant on (a) subsequent patenting behavior by foreign technological entrants at the USPTO and (b) the technology diffusion of these inventions to local firms and other local patenting entities. We first estimate the relationship between a foreign technological entrant's initial patent grant decision in a host country and our outcomes of interest using the following regression equation:

$$y_{i,t+k} = \beta' Grant_{ijat} + \Gamma' X_{ijat} + \epsilon_{ijat}. \tag{1}$$

Here, $y_{i,t+k}$ denotes our economic outcomes of interest for foreign entrant i. These outcomes include various measures of subsequent patent filings and technology diffusion measured in year $t+k$, where k represents elapsed time (in years) since the focal application's initial uncertainty is resolved. Additional details about the variables and time intervals are provided in the next section. $Grant_{ija}$ represents the examiner j's patent grant decision on foreign entrant i's initial USPTO patent filing a at time t. The matrix, X_{ijat} contains control variables that vary by specification, including GAU-FAOM-year and technology classification fixed effects. Finally, we cluster our heteroskedasticity-robust standard errors at the GAU-FAOM-year level.

In an ideal experiment to test these effects, a researcher would randomly assign patent rights across first-time foreign applicants.[8] The researcher could then compare local patenting and diffusion outcomes across those entrants that received a patent grant compared to those that did not, cleanly identifying and measuring the effects of obtaining patent rights on the specified outcomes of interest. However, in practice, the patent grant decision is endogenous and ultimately depends on whether the application meets the standard for patentability described in Section 2.1. For the estimated coefficient on the grant decision ($\hat{\beta}$) to be interpreted causally, receiving a patent—conditional on application—must be uncorrelated with ϵ_{ijat}. It is clear, however, that the grant decision will be correlated with unobserved invention, application, and/or applicant characteris-

[8] Farre-Mensa et al. (2020) first proposed a similar hypothetical in the context of start-up outcomes.

tics, biasing the estimated ordinary least squares (OLS) coefficients (Sampat and Williams, 2019; Farre-Mensa et al., 2020).

We overcome this empirical issue by instrumenting for the patent grant decision using the focal examiner's prior grant rate (Sampat and Williams, 2019; Farre-Mensa et al., 2020; de Grazia et al., 2021, 2022), the origins of which can be traced to studies that use the prior tendencies of judges to instrument for legal decisions (Kling, 2006). We define the instrumental variable ($GrantRate_{ija}$) as the granted share of applications out of total applications disposed by the focal patent examiner before the focal application's FAOM date ($GrantRate_{ijat} = \frac{allowed_{ijat}}{disposed_{ijat}}$). In other words, the instrumental variable captures a patent examiner's idiosyncratic propensity to grant applications prior to their initial decision on the focal application. The prior grant rate instrument is a backward-looking metric that is measured the day immediately preceding the focal application's first-action decision and is calculated using only non-continuation applications that were disposed by that date.[9]

As with any instrumental variables framework, identification requires instrument relevance and validity (Cameron and Trivedi, 2005). For instrument validity, we rely on the pseudo-random assignment of applications to examiners within GAUs (Lemley and Sampat, 2012; Farre-Mensa et al., 2020; de Grazia et al., 2021). Lemley and Sampat (2012) interviews several supervisory patent examiners at the USPTO, finding that the assignment mechanisms used in practice are consistent with pseudo-random assignment of application to patent examiners.[10] Under this assumption, application and applicant characteristics should be uncorrelated with examiner attributes, including a focal examiner's prior grant rate (Farre-Mensa et al., 2020). We test the exclusion restriction, or the assumption that the instrument only affects outcomes through the grant decision, in Section 5. The results of the tests, in addition to the quasi-random assignment assumption, support the exclusion restriction assumption. The first-stage regression equation in our empirical setting is as follows:

[9]Continuations are generally docketed to the same examiner who examined the parent applications, violating pseudo-random assignment. These applications are therefore removed from the measurement of the prior grant rate. To ensure that the prior grant rate accurately reflects the examiners prior allowance tendencies, we drop applications for which the examiner had previously examined, through disposal, fewer than ten applications.

[10]More recent work (Righi and Simcoe 2019; Feng and Jaravel 2020), test this assumption empirically, identifying administrative unit-years (e.g., technology centers and art units) where the assumption is more likely to hold. Righi and Simcoe (2019), which finds evidence of examiner specialization within art units, suggests that researchers instrumenting for the patent grant decision using an examiner's prior grant rate should control for the focal application's technology classifications. In Section 6.2, we test the robustness of our results to these considerations.

$$Grant_{ija} = \pi' GrantRate_{ija} + \Psi' X_{ijat} + \mu_{ijat}. \quad (2)$$

The dependent variable, $Grant_{ija}$, is the grant decision from Equation 1 and X_{ijat} reflects the same set of controls. While the standard instrumental variables framework assumes that treatment effects are homogeneous across sub-populations, this assumption is clearly violated in our setting if the initial patent grant decision is unaffected by the prior grant rate for certain sub-populations. We relax this assumption by estimating local average treatment effects (Imbens and Angrist, 1994), or LATEs, which requires an addition assumption for identification: monotonicity. In order words, a patent grant (the treatment) is affected by the prior grant rate in a monotonic way (Imbens and Angrist, 1994).

4 Data and descriptive statistics

Our primary sample contains all initial patent applications at the USPTO with an FAOM date between 2006 and 2017 that meet the conditions for small or micro entity status and are assigned to foreign technological entrants. Thus, the data are comprised of small, first-time, foreign applicants. Small entities pay discounted fees throughout the examination process but are limited in size to five hundred or fewer employees.[11] To construct our sample, we first link application-level data from the Patent Examination Research Dataset (PatEx)—including technology classification, entity size, patent examiner, examination milestone dates (filing date, FAOM date, etc.), and application outcomes—to patent assignee data from PatentsView.[12] We exploit the assignee disambiguation algorithm from PatentsView to construct patent application portfolios for each disambiguated assignee (including pre-grant publications and granted patents), allowing us to identify the foreign technological entrant's initial and subsequent patent filings.[13] A technological entrant is designated as foreign if the raw assignee country from PatentsView is populated in the data for the assignee's first application and is not listed as the United States.

[11] Non-profits, universities, and individuals also qualify as small entities, but these assignees, or owners, are dropped from our sample.

[12] We use an early-release version of the 2022 PatEx data product released by the USPTO, retrieved on February 15, 2024. PatentsView version released on February 13, 2024. Both databases were accessed on February 15, 2024.

[13] We define a technological entrant's initial application to be the earliest filed patent application at the USPTO. Foreign technological entrants whose initial applications are filed outside of the 2006 to 2017 time horizon are dropped from our sample.

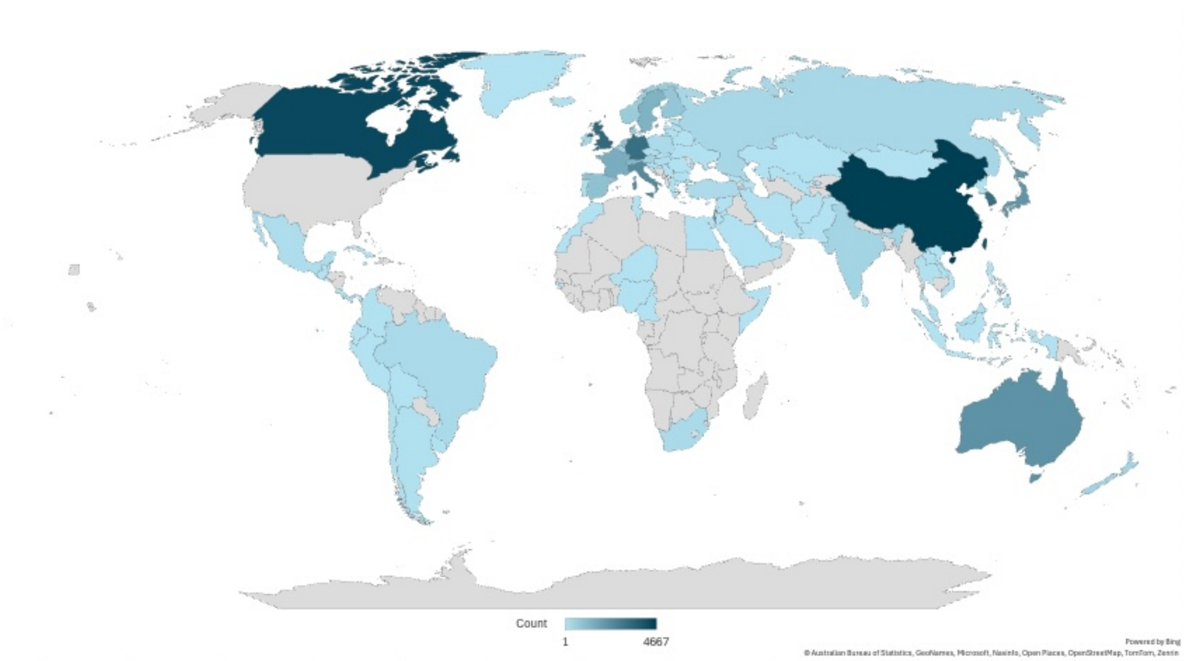
According to the Manual of Patent Examining Procedure (MPEP), there are four types of U.S. national applications (MPEP 1893): provisional, regular domestic, national stage entry, and international design applications. Our study only focuses on utility patent applications filed via the regular domestic or national stage entry pathways. Filing dates recorded by the USPTO differ based on application type. For example, the filing date for a regular domestic application is the date that the USPTO receives the complete application and reflects the date of entry into the U.S. patent system. The filing date for a national stage entry application at the USPTO, however, corresponds to the application's international filing date. Therefore, for these applications, we use the 371(c) date, or the date of entry into the U.S. national phase.[14] The foreign priority date, defined only if an application claims priority to an earlier patent application filed abroad, is the earliest filing date for foreign applications to which the focal application claims priority. While PCT applications and applications filed via the Paris convention will normally have a priority date that differs from the filing date at the USPTO, applications filed directly at the USPTO without a foreign priority will not. Finally, we note that some applications in our sample are labelled as continuations. While continuations are generally removed from the types of empirical analyses conducted in this study, applicants may file what is called a "bypass continuation", or a direct continuation of a PCT application (MPEP 1895-6). These applications do not claim priority to an existing U.S. application and are therefore included in our sample.

Our final sample contains 44,548 first-time, foreign applicants with U.S. filing years ranging from 2006 to 2017.[15] 64.6 percent of applicants in our sample are located in non-U.S., IP5 countries and 42.3 percent of which are located in European Patent Office (EPO) member countries. Figure 2 shows the global distribution of foreign applicants in our sample by country. Figure 3 presents the top-ten countries by total count of entrants during the observed period. China hosts the largest number of first-time applicants in our sample with 4,667 firms, followed closely by Canada—a fellow member of the North American Free Trade Agreement (NAFTA)—with 4,390 firms. The initial patent application filings in our sample represent a diverse set of technology areas, as shown in Figure 4. These applications are distributed across Technology Centers (TCs),

[14]PatEx records the filing date or 371(c) date depending on the application type. Please see 35 U.S.C. 371 for more information on the commencement of the national stage.

[15]Tables containing variable definitions (Table A1) and data summary statistics (Table A2) can be found in the Appendix.

Figure 2: Distribution of foreign technological entrant count by country



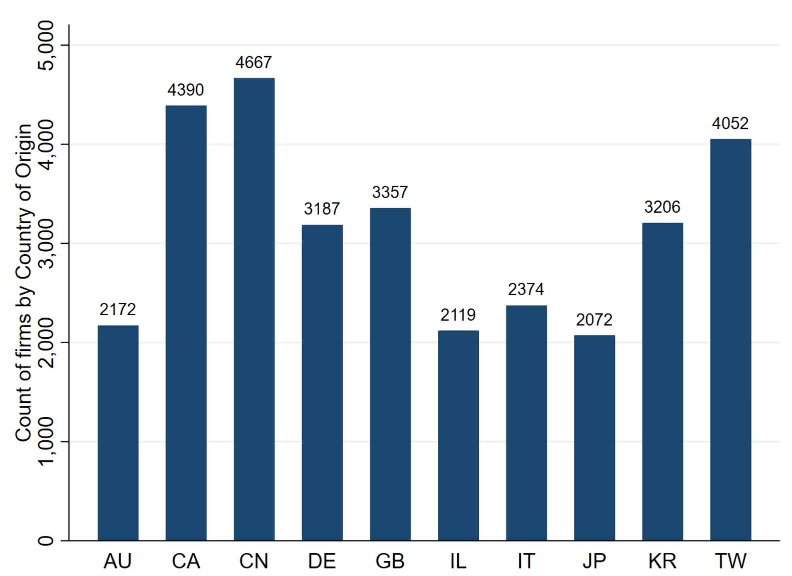
Notes: The unit of observation is a foreign technological entrant to the United States and its respective country of origin.

or large administrative units with jurisdiction over broad technology areas within the USPTO. The largest concentration of firms (22.8%) appears in TC 3700, which covers mechanical engineering, manufacturing and products. Over 25% of firms are concentrated in biochemistry TCs, located in TCs 1600 (biotechnology and organic fields) and 1700 (chemical and materials engineering fields). Finally, nearly 32% of initial applications are related to information technology, or computer architecture, information security, computer networks, communications, and semiconductors (TCs 2100, 2400, 2600, and 2800).

To estimate patent grant effects on subsequent patenting and diffusion outcomes, we construct several firm-level and application-level outcomes. To test Hypothesis 1, we track subsequent USPTO filings at the entrant level by leveraging disambiguated assignee information from PatentsView to collect all publicly-available USPTO applications filed by a given firm. To capture the occurrence of subsequent patenting events, we create three separate binary indicators equal to one if the firm files at least one non-continuation application at the USPTO within three, five, and seven years, respectively, from the FAOM date (time t in our regression framework).[16] Following

[16]Continuation applications may represent strategic behavior by technological entrants and not reflect inventive

Figure 3: Foreign technological entrant count by Country (10 largest countries)



Notes: The unit of observation is a foreign technological entrant to the United States and its respective country of origin. This graph contains the ten countries with the largest number of technological entrants to the United States during the observed time-frame (2006 to 2017). Countries are presented in alphabetical order along the X-axis.

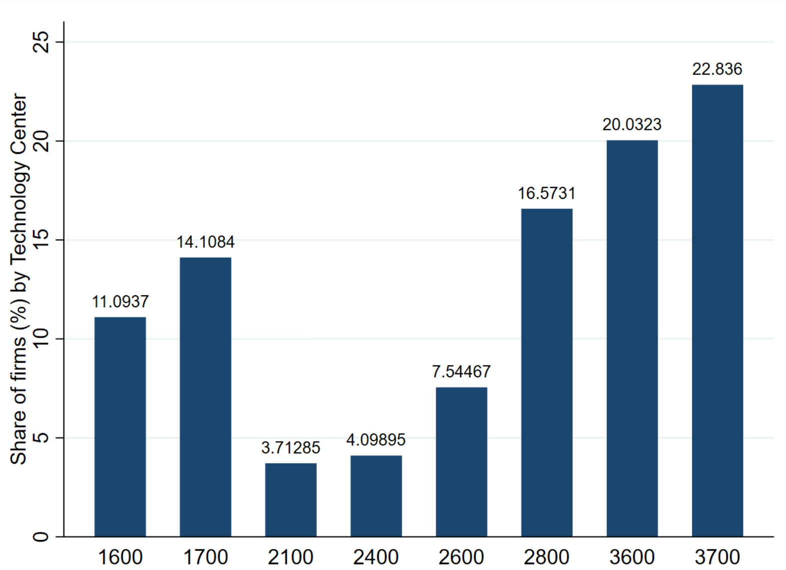
Farre-Mensa et al. (2020), we track outcomes from the FAOM for two reasons. First, the timing of the final disposal date is likely endogenous. Second, the information contained in the first-action decision and accompanying Office action greatly reduces the degree of uncertainty regarding the ultimate allowability of a focal application.

To test Hypothesis 2, we proxy technology and knowledge diffusion using a focal patent's forward citations (Jaffe et al., 1993; Hegde et al., 2023).[17] During the application and examination process, applicants and patent examiners may cite any existing patent document, or prior art, that is relevant to the determination of patentability of an application under examination (35 USC 301). According to Jaffe et al. (1993, p. 580), "[i]n principle, a citation of Patent X by Patent Y means that X represents a piece of previously existing knowledge upon which Y builds". Existing literature suggests that forward citations not only capture technology diffusion or knowledge spillovers (Jaffe

activity (Hegde et al., 2009; Righi and Simcoe, 2023). Applications of this type allow applicants to introduce new claims after existing technological uncertainty has been resolved, tailoring the continuation patent's scope to include newly-developed technologies excluded from the original patent (Righi and Simcoe, 2023). These applications are not necessarily indicative of inventive activity and are therefore removed from the baseline set of subsequent filing variables.

[17]Patent applications may cite relevant background art from granted patents, pre-grant publications, and non-patent literature. These references are included on information disclosure statements (IDS) submitted by the applicant (document code PTO-1449) or by the examiner (document code PTO-892). The pre-grant publication of a rejected application may also be considered as relevant background art to future applications and cited on an IDS.

Figure 4: Foreign technological entrant count by Technology Center

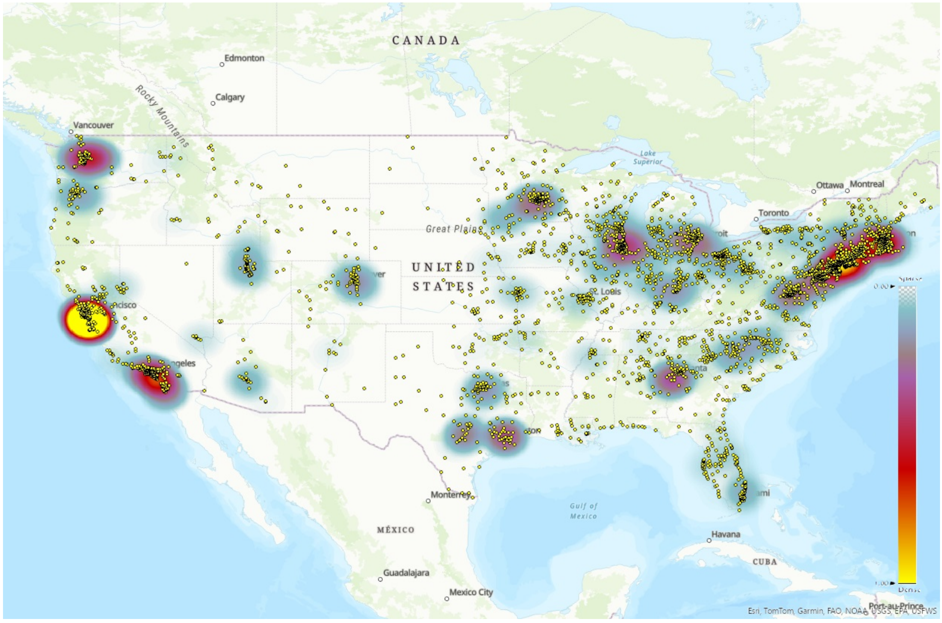


Notes: Technology Centers are administrative units within the USPTO that cover a broad range of technologies, including Biotechnology and Organic fields (TC 1660); Chemical and Materials Engineering field (TC 1700); Computer Architecture Software and Information Security (TC 2100); Computer Networks, Multiplex, Cable and Cryptography/Security (TC 2400); Communications (TC 2600); Semiconductors, Electrical and Optical Systems and Components (TC 2800); Transportation, Electronic Commerce, Construction, Agriculture, Licensing and Review (TC 3600); and Mechanical Engineering, Manufacturing and Products (TC 3700).

et al., 1993), but also a proxy for technological importance (Squicciarini et al., 2013) and patent value (Harhoff et al., 1999). We operationalize our measure of technology diffusion by creating a series of binary outcome variables, equal to one if the focal patent application is cited by a patent granted to a U.S.-based firm or other entity within three, five, and seven years, respectively, and zero otherwise.[18] Figure 5 shows the geographic distribution and intensity of citations by U.S. assignees to foreign technological entrants' initial patent applications, limited to those citations occurring within five years of the FAOM date. There are two key takeaways from Figure 5. First, the diffusion of focal foreign technologies are distributed across the United States. Unsurprisingly, however, these flows occur most frequently in areas of high population and economic activity, with the largest concentration of citations by U.S. patenting entities located near or in Silicon Valley.

[18]The use of patent citations as a measure of technology diffusion is imperfect and has been subject to some criticism in recent years. Kuhn et al. (2020) notes a significant uptick in the total number of citations since the 1990s, driven by a small number of patents with a high number of citations. This change in how citations are included in patents renders them less useful as an empirical measure of direct knowledge inheritance and diffusion over time. Kuhn et al. (2020) also argues that uncorrected patent citation variables may not be appropriate to capture information flows across inventors and firms. For our main diffusion outcomes, we therefore remove forward citations to the focal applications from patent documents with more than twenty backward citations. In our robustness checks, we also remove examiner-cited citations (Alcacer and Gittelman, 2006; Kuhn et al., 2020), and find consistent results.

Figure 5: Distribution of citations by U.S. assignee to initial applications by tech. foreign entrants



Notes: A yellow dot represents at least one forward citation to the focal set of applications by a U.S. patenting entity located at that latitude and longitude within five years of the application's first-action (FAOM) date. 5-year citation intensity is shown in red at lower levels and bright yellow at greater levels of intensity.

Finally, to explore the intensity of the patent grant effects across our outcomes of interest, we construct logged subsequent application count variables for each outcome described in this section, defined as $ln(1 + y_{i,t+k})$, where k represents the length of time since the focal application's FAOM date, as defined above.[19]

5 Impacts of patents on subsequent filings and technology diffusion

5.1 First stage IV estimates

We begin by examining the results of the first stage IV regression, which considers the relationship between the likelihood that a patent is granted and the examiner's prior grant rate (Equation 2). The results of these regressions are presented in Columns (1) and (2) of Table 1. The estimated coefficient on the grant rate instrument ($\hat{\pi}$) is positive and statistically significant at the one percent

[19]While we acknowledge the limitations of logged dependent variables in this context, demands of our empirical framework require several thousand fixed effects, rendering the estimation of IV count models impractical.

level. The impact of the IV is economically large; a one standard deviation increase in the prior grant rate (s.d. = 0.22) increases the probability of that a patent is granted by 11.1 percentage points. In Column (2), we introduce application and applicant characteristics as additional controls. We specifically include a control for application scope (independent claim count); an indicator for if the applicant is from an IP5 country; the EPO worldwide bibliographic data (DOCDB) patent family size—a commonly-used measure of the patent's private value (Putnam, 1996; Harhoff et al., 2003) and contemporaneous country-level measures of economic activity, high-technology exports, and residential patenting experience from the applicant's country of origin. The introduction of these controls does not significantly change the magnitude nor the significance of the coefficient on the grant rate instrument, only decreasing the prior grant rate coefficient's magnitude by approximately two percentage points.

Next, we implement a test for weak instruments introduced by Olea and Pflueger (2013), which calculates effective F-statistics for our entire sample that are robust to heteroscedasticity, auto-correlation, and clustering (Olea and Pflueger, 2013; Andrews et al., 2019). For our main sample (N=44,548), the effective F-statistic is 1081.46, suggesting a strong instrument based on the threshold of 10 proposed by Stock and Yogo (2005). A potential concern is that the dependent variable (grant likelihood) measured at seven years post-FAOM date may be right-censored for applications filed at the end of our sample. To mitigate this concern, we drop applications from from the 7-year regression samples if the FAOM date occurs after 2015 (N=34,559). For these subsamples, the reported effective F-statistic lowers slightly to 869.03 but remains relatively large. Based on these effective F-statistics, we are confident in the strength of the IV.[20]

Finally, we test for possible violations of the exclusion restriction through a series of empirical exercises that the check for correlations between the instrument and the different controls described above. The results of these tests are presented in Columns (3) through (8) of Table 1. We find no significant relationship between our controls and the assigned examiner's prior grant rate, providing credibility to the exclusion restriction assumption.

[20]Regression estimates for Equation 2 using the 7-year sample subset are consistent with the estimates presented in Table 1 and are available on request.

Table 1: 1st Stage Estimates and Falsification Test Results

Variables	(1) Pat. Grant	(2) Pat. Grant	(3) Grant Rate	(4) Grant Rate	(5) Grant Rate	(6) Grant Rate	(7) Grant Rate	(8) Grant Rate
Prior grant rate	0.516***	0.504***						
	(0.0159)	(0.0171)						
DOCDB family size		0.0130***	-0.000147				-3.93e-05	-5.84e-05
		(0.00196)	(0.000143)				(0.000160)	(0.000173)
Appl. scope (logged ICC)		0.00234		-0.00101			-0.000938	-0.00108
		(0.00429)		(0.00133)			(0.00135)	(0.00149)
IP5 country ind.		-0.0325***			-0.000771		0.000336	0.00193
		(0.00763)			(0.00163)		(0.00170)	(0.00230)
Log GDP		-0.00647				-0.000754		-0.000756
		(0.00400)				(0.00143)		(0.00143)
Logged high-tech exports		0.0122***				-0.00100		-0.00122
		(0.00270)				(0.000949)		(0.000963)
Logged annual patents by local firms		0.000109				0.000552		0.000453
		(0.00231)				(0.000768)		(0.000771)
Constant	0.647***	0.372***	0.594***	0.591***	0.594***	0.612***	0.591***	0.616***
	(0.0637)	(0.0922)	(0.000763)	(0.000807)	(0.00105)	(0.0212)	(0.00174)	(0.0227)
Observations	44,548	37,302	44,546	43,536	44,548	37,894	43,534	37,302
R-squared	0.051	0.073	0.000	0.000	0.000	0.000	0.000	0.000
Number of gau_faom_yr	5,334	4,891	5,334	5,306	5,334	4,911	5,306	4,891
Uncond. Mean DV	0.709	0.701	0.593	0.591	0.593	0.584	0.591	0.583
GAU x Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
USPC FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Significant at *** $p<0.01$, ** $p<0.05$, * $p<0.10$. Each regression contains GAU-by-year fixed effects. ICC, or independent claim count, is measured by the number of independent claims in the focal application's pre-grant publication (PGPub). DOCDB simple patent family is the total number of patent documents worldwide that represent the same invention (source: PATSTAT). IP5 Country is equal to one if the assignee is located in any non-U.S. IP5 country. Gross Domestic Product (GDP) per capita is measured in constant 2015 U.S. dollars (USD). High-technology exports are measured in current USD and resident patent applications are the number of patent applications filed at the local patent office by the local assignees.

5.2 Main results

In this section, we first test Hypothesis 1, using OLS to estimate Equation (1) as an empirical benchmark. Next, we use the IV derived in the previous section to conduct a series of second stage regressions designed to identify a causal impact of patent grants on subsequent patent applications. The results of these regressions are presented in Table 2. Odd-numbered columns contain the OLS estimates and even-numbered columns contain the two-stage IV estimates. In Panel A, the OLS estimates show that the initial patent grant decision appears to have a positive and significant ($p<0.01$) effect on the subsequent filing status of foreign technological entrants over time. In the three-year interval following the FAOM date, an initial grant increases the probability of at least one subsequent, non-continuation filing by 9.5 percentage points, or 52.8 percent relative to the unconditional mean of the dependent variable. The effect is monotonic in time, increasing to 11.8 and 12.5 percentage points at five and seven years post-FAOM date, respectively. The even-numbered columns in Table 2 contain the IV estimates, which mitigate biases in the OLS estimate by instrumenting for the patent grant decision. The IV estimates are similarly positive and statistically significant at conventional levels ($p<0.05$). The estimate values suggest that patent grants increase the likelihood of subsequent applications by 4.9 to 6.5 percentage points. We prefer the 5-year IV estimate ($\hat{\beta_{IV}} = 0.0653$) because it captures longer term causal impacts of patenting without a reduction in sample size. Finally, we note that the IV coefficient estimates are smaller in magnitude than the corresponding OLS estimates, indicating either an upward bias of the OLS coefficients or that the LATEs estimated using the IV approach are smaller in magnitude than the average treatment effects (ATEs) estimated using OLS.[21]

In Panel B of Table 2, we re-estimate Equation 1, replacing the dependent variable with logged counts of subsequent filings within each specified time interval (3, 5, and 7 years, respectively). The OLS and IV estimates are generally consistent in sign and significance with those presented in Panel A. This suggests that the extensive and intensive effects of patent grants on subsequent filings are generally consistent.

[21] Keane and Neal (2023) notes that second-stage t-tests suffer from power asymmetry, where the size of the 2SLS standard errors artificially fluctuates depending on the relative distance between the estimated OLS and 2SLS coefficients. Following practical suggestions from Keane and Neal (2024), we re-evaluate each of our main 2SLS estimates using the Anderson-Rubin test (Anderson and Rubin, 1949), which avoids the power asymmetry issue but does not calculate asymptotically-valid standard errors. The results are shown in the Appendix and are consistent with our main results.

Table 2: Subsequent Patenting Results - Full Sample (OLS & IV)

Variables	(1) 3 years	(2) 3 years	(3) 5 years	(4) 5 years	(5) 7 years	(6) 7 years
Panel A - Patent indicator						
Patent Grant	0.0950***	0.0485**	0.118***	0.0653**	0.125***	0.0648**
	(0.00407)	(0.0237)	(0.00441)	(0.0257)	(0.00510)	(0.0304)
Constant	0.113***	0.146***	0.136***	0.173***	0.153***	0.194***
	(0.00289)	(0.0168)	(0.00313)	(0.0182)	(0.00347)	(0.0207)
Observations	44,548	44,548	44,548	44,548	34,559	34,559
R-squared	0.011		0.015		0.018	
Uncond. Mean DV	0.180	0.180	0.220	0.220	0.238	0.238
Panel B - Patent count						
Patent Grant	0.103***	0.0615**	0.139***	0.0875***	0.160***	0.0890**
	(0.00472)	(0.0277)	(0.00562)	(0.0330)	(0.00693)	(0.0414)
Constant	0.115***	0.145***	0.149***	0.186***	0.178***	0.226***
	(0.00335)	(0.0197)	(0.00398)	(0.0234)	(0.00471)	(0.0282)
Observations	44,548	44,548	44,548	44,548	34,559	34,559
R-squared	0.010		0.013		0.015	
Number of gau_faom_yr	5,334	5,334	5,334	5,334	4,307	4,307
Uncond. Mean DV	0.188	0.188	0.248	0.248	0.286	0.286
Reg. Type	OLS	IV	OLS	IV	OLS	IV

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year fixed effects and heteroskedastic-robust standard errors. For Columns (1) to (6) in Panel A, the subsequent application indicator is equal to one if the focal assignee files at least one non-continuation application within a three, five, or seven years, respectively after the first-action date. Subsequent application - existing invention indicator (Columns 7 and 8 of Panel A) is equal to one if the focal assignee files at least one non-continuation application within three years after the first-action date and the PCT filing or priority date for the subsequent application precedes the first-action date of the focal application. For Panel B, we replace the indicator variables with the logged count of subsequent patent applications, specifically $ln(1 + y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. Our main sample (Columns 1 through 4, 7, and 8) contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. Due to potential right-censoring for the seen-year interval, we limit the sample for these regressions, shown Columns (5) and (6), to those applications with first-action year between 2006 and 2015. We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications are dropped from our sample.

Overall, our results demonstrate the *causal* effect of an initial patent grant in a host country on subsequent local patent filings, confirming Hypothesis 1. While several past studies identify which factors influence a firm's propensity to seek international patent protection,[22] our results demonstrate that continued technological presence in a host country is driven, at least in part, by securing local patent rights. Situating this result within the broader international trade literature, obtaining a patent grant in a country plays an important role in facilitating not only the export of innovative goods to that country (Palangkaraya et al., 2017; de Rassenfosse et al., 2022) but also the introduction of subsequent foreign inventions into its innovation ecosystem.

We next turn to the effects of an initial patent grant on international knowledge diffusion to local U.S. firms and other patenting entities (Hypothesis 2). To do so, we re-estimate Equation 1 with two sets of variables reflecting diffusion outcomes: The occurrence (0/1) and logged count of forward citations by an external U.S. entity within 3, 5, and 7 years of the initial application's FAOM date. The results of these regression are presented in Table 3. Using OLS (Columns 1, 3, and 5), we find a strong positive relationship between a foreign technological entrant's initial patent outcome and local knowledge diffusion across all observed years, using both measures of local diffusion. For the occurrence of at least one forward citation (Panel A), OLS estimates range from a 5.9 percent points by year three to 10.4 percentage points by year seven. The IV estimates for this outcome are smaller in magnitude and not statistically significant at year 3 (Column 2). At year 5 (Column 4), however, a patent grant increases the occurrence of at least one forward citation by a U.S. entity by 7.1 percentage points (our preferred estimate), and by 7.6 percentage point at year 7 ($p<0.05$). Relative to the mean of the dependent variable, receiving a patent increases the likelihood of at least one citation by up to 30 percent. The results of the IV regressions using the logged count of forward citations are similar (Panel B). The causal effects appear to be increasing over time but are only statistically significant for 5 and 7 years ($p<0.05$). We take these results as strong evidence that obtaining an initial patent grant, conditional on technological entry, increases the diffusion of the technology to local U.S. firms—confirming Hypothesis 2.[23]

[22]These factors include host country IPR regime strength, market size, firm-specific advantages, and the firm's strategy regarding trade and FDI (Allred and Park, 2007; Yang and Kuo, 2008; Huang and Jacob, 2014; Lin and Lincoln, 2017; Cui et al., 2022).

[23]In a systematic review of international knowledge flow measures, Dubbert et al. (2022) notes that patent citation linkages may result from strategic behavior from citing assignees and might not reflect knowledge flows that aide the inventive process. In our setting, U.S. assignees may respond to a foreign technological entrant's patent grant by filing strategic patent applications of their own that cite the focal patent, creating non-exposure channel through which

Table 3: External U.S. Forward Citations (OLS & IV)

Variables	(1) 3 years	(2) 3 years	(3) 5 years	(4) 5 years	(5) 7 years	(6) 7 years
Panel A - Citation indicator						
Patent Grant	0.0586***	0.0320	0.0866***	0.0706***	0.104***	0.0762**
	(0.00394)	(0.0220)	(0.00462)	(0.0253)	(0.00545)	(0.0302)
Constant	0.131***	0.150***	0.178***	0.190***	0.222***	0.241***
	(0.00279)	(0.0156)	(0.00328)	(0.0180)	(0.00371)	(0.0205)
Observations	44,548	44,548	44,548	44,548	34,559	34,559
R-squared	0.005		0.008		0.011	
Uncond. Mean DV	0.172	0.172	0.240	0.240	0.293	0.293
Panel B - Citation count						
Patent Grant	0.0552***	0.0317	0.0873***	0.0667***	0.110***	0.0760**
	(0.00353)	(0.0197)	(0.00437)	(0.0244)	(0.00540)	(0.0306)
Constant	0.110***	0.126***	0.155***	0.169***	0.200***	0.223***
	(0.00251)	(0.0140)	(0.00310)	(0.0173)	(0.00367)	(0.0208)
Observations	44,548	44,548	44,548	44,548	34,559	34,559
R-squared	0.005		0.009		0.012	
Number of gau_faom_yr	5,334	5,334	5,334	5,334	4,307	4,307
Uncond. Mean DV	0.149	0.149	0.217	0.217	0.275	0.275
Reg. Type	OLS	IV	OLS	IV	OLS	IV

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year fixed effects and heteroskedastic-robust standard errors. The external U.S. citation indicator (Panel A) is equal to one if the focal application receives at least one forward patent citation by a different U.S. assignee within three (Columns 1 and 2), five (Columns 3 and 4), and seven years (Columns 5 and 6) after the focal application's first-decision date. For Panel B, we replace the indicator variables with the logged count of subsequent patent applications, specifically $ln(1 + y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. Our main sample (Columns 1 through 4) contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. Due to potential right-censoring for the seen-year interval, we limit the sample for these regressions, shown Columns (5) and (6), to those applications with first-action year between 2006 and 2015. We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications are dropped from our sample.

Several factors may be driving the effect of the initial patent grant decision on local knowledge spillovers estimated above. An initial patent grant increases continued technological presence through subsequent patenting (Hypothesis 1) or local market participation (de Rassenfosse et al., 2022), either of which may create opportunities for knowledge flows via closer, sustained proximity. For example, continued market presence might lead to increased technological adoption and exposure to the invention (Coe and Helpman, 1995; Pavcnik, 2002; Aghion et al., 2023) —leading to the observed increase in international knowledge flows related to granted patents. The exclusionary nature of patents grant the assignee control over the invention's use while the patent is in-force (Spulber, 2015). Explicit control over the IP and other frictions in the markets for technology might inhibit follow-on invention and knowledge spillovers by external entities, especially if the nature of the invention is cumulative (Scotchmer, 1991). Given the positive effects of patenting on forward patent citations shown in Table 3, however, these frictions do not appear to be a limiting factor for local knowledge spillovers, or at least that the patent grant effects outweigh frictions introduced by the creation of the property right itself. Another consideration is that an invention covered by a rejected patent application may be used without fear of patent infringement litigation or securing licensing agreements. The lower use of freely available technologies (i.e., not protected by a patent) by external entities relative to patented ones suggests that the attainment of IPRs clearly plays a positive role in local knowledge diffusion, as estimated above.

Overall, our results show that an initial patent grant causally increases both the introduction of foreign inventions into the U.S. patent system and the diffusion of the protected technologies to local assignees. Similar to the literature on trade and patenting, an initial patent grant increases the probability that the focal technological entrant remains in the U.S. patent system, which has implications for the knowledge flows to U.S. inventors, firms, and other entities. In contrast to the prior literature on follow-on patenting and IPRs, the initial patent grants lead to more external forward citations, not fewer (Galasso and Schankerman, 2015; Williams, 2013). Our results suggest a trade-off between frictions that arise from the exclusionary nature of the property right and relative proximity through continued technological and market presence in the United States. An important implication is that initial patent grants—by spurring technological diffusion—can

an initial patent grant might effect forward patent citations. Although we cannot fully rule out this mechanism, this issue is at least partially mitigated by removing continuations when calculating our forward patent citation-based dependent variables.

improve consumer welfare and economic growth.

6 Extensions and robustness checks

6.1 Extensions

In this section, we explore several extensions to our baseline analysis. First, we examine the extent to which the impacts of initial patent grants on subsequent applications are driven by appropriation or feedback effects. We do so by looking at the effects of the patent grant on firms' *existing* versus *new* inventions. Improved market conditions and viability, via the appropriation channel, may incentivize foreign technological entrants to seek patent protection at the USPTO for existing inventions (and corresponding IP filings) within their portfolio. That is, it may induce them to seek patent protection for other inventions that had already been filed in other jurisdictions but not yet in the United States. Meanwhile, feedback effects might raise the entrant's invention rate, leading the entrant to seek patent protection in the host country for new inventions.

To assess the appropriation channel as an explanation for entrant-level changes in subsequent application filings, we turn to information on applications for existing inventions. We consider a subsequent application an existing invention if (i) the subsequent application is filed at the USPTO after the initial applications FAOM date and (ii) the subsequent application's priority date occurs before the initial application's FAOM date.[24] In other words, the entrant filed for patent protection for an invention in another jurisdiction prior to the initial U.S. application's FAOM date but filed the U.S. equivalent after the FAOM date. To capture this outcome, we redefine our 3-year technological presence outcome variable to equal one only if the entrant files at least one subsequent application at the USPTO for an existing technology, and zero otherwise. This variable reflects a firm's willingness to bring existing inventions to the United States after the focal application's initial uncertainty is successfully resolved while removing new inventions (and patent applications) that might arise from feedback effects. Notably, PCT and Paris filing routes limit the amount of time between initial filing in the original jurisdiction and filing at the USPTO. Therefore, we limit the interval to three-years post-FAOM date. We also redefine a second dependent variable equal to the logged count of

[24] The priority date was obtained through the Worldwide Patent Statistical Database (PATSTAT) – Global edition, Autumn 2023 version. Accessed June 10, 2024.

Table 4: Subsequent Patenting Results - Existing IP - Full Sample (OLS & IV)

VARIABLES	(1) 3 years	(2) 3 years	(3) 3 years	(4) 3 years
Patent grant	0.0590***	0.0201	0.0577***	0.0247
	(0.00340)	(0.0199)	(0.00346)	(0.0207)
Constant	0.0790***	0.107***	0.0727***	0.0960***
	(0.00241)	(0.0141)	(0.00246)	(0.0147)
Observations	44,548	44,548	44,548	44,548
R-squared	0.006		0.006	
Number of gau_faom_yr	5,334	5,334	5,334	5,334
Reg. Type	OLS	IV	OLS	IV
Uncond. Mean DV	0.121	0.121	0.114	0.114
GAU x Year FE	Yes	Yes	Yes	Yes
USPC FE	Yes	Yes	Yes	Yes

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year fixed effects and heteroskedastic-robust standard errors. Subsequent application - existing invention indicator (Columns 1 and 2) is equal to one if the focal assignee files at least one non-continuation application within three years after the first-action date and the priority date for the subsequent application precedes the first-action date of the focal application. In Columns (3) and (4), we replace the indicator variables with the logged count of subsequent patent applications (existing inventions), specifically $ln(1+y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. the sample for these regressions contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications are dropped from our sample.

existing inventions filed at the USPTO within three years. We re-estimate Equation 1, regressing the re-defined dependent variables on the patent grant decision.

The results are shown in Table 4. For existing inventions, OLS estimates (Columns 1 and 3) demonstrate a strong and positive relationship ($p<0.01$) between the initial patent grant and subsequent filing of existing inventions, regardless of the specific form of the dependent variable. However, corresponding IV estimates (Columns 2 and 4) are smaller in magnitude and are statistically insignificant. Given our preference towards the IV specifications, we interpret these results as indicating that the appropriation mechanism for existing inventions is not driving the overall impacts of initial patent grants. Several considerations might explain this lack of a significant effect. First, invention portfolios for foreign technological entrants at the time of the first-action decision date may be limited in size. Second, we only observe the priority date of the patent application and not the date of the underlying inventive activity. Therefore, we may be missing inventions that were created before the FAOM dates but have priority dates after the FAOM date.

Next, we separately analyze the subsequent patenting outcomes by invention type, which can be either product or process innovations. Ganglmair et al. (2022) find evidence that U.S. patents granted to foreign assignees are more likely to contain product-related claims than process-related claims. The authors argue that this difference is consistent with the survey evidence on patenting propensities by claim type and may be driven by high monitoring costs of process-related patents. Using the publicly-available claim classification data provided by the authors, we can determine the degree to which the effects of initial patent grants extend to subsequent product and process patents. We define a patent as a "process" ("product") patent if it contains at least one process (product) claim, according to the Ganglmair et al. (2022).[25] We then create two binary outcome variables that are equal to one if the focal technological entrant files at least one product (process) application that is later granted within five years of the initial application's FAOM date. We re-estimate Equation 1, regressing these indicators on the initial patent grant decision.[26]

The estimates for invention type are presented in Table 5. The OLS estimates, shown in Columns (1) and (3) from , are positive and statistically significant ($p<0.01$) for both product and process patents. The instrumental variable estimates, shown in Columns (2) and (4), indicate that an initial patent grant increases the probability of at least one additional follow-on *product* patent ($p<0.05$) but has no statistically significant effect on subsequent *process* patents. This extension complements that of Ganglmair et al. (2022), demonstrating that obtaining an initial patent grant does not offset the high monitoring costs of process-related patents for foreign assignees. These estimates also have significant implications for consumer welfare and economic growth. It is likely that increased product patenting by technological foreign entrant at least partially represents the introduction of new products into the United States, though this relationship is not one-to-one.[27] de Rassenfosse et al. (2022), for example, notes that initial exports often follow the initiation of a patent application in a host market and not vice-versa, conditional on observed patenting activity. Patent protection, when applicable, leads to the introduction and sustained presence of goods into a host market, benefiting consumers through additional choice. If these product introductions

[25] The authors assigns classifications at the claim level, therefore some patents include both patent and process claims.

[26] Publicly-available data associated with Ganglmair et al. (2022) only contains claim classifications for patents *granted* by the end of 2020. Therefore, these dependent variables will likely be right-censored.

[27] According to Cohen et al. (2000), technologies in discrete product areas may be covered by a single or few patents, whereas technologies in complex product areas may require hundreds of patents to cover a new technology.

Table 5: Follow-on Product and Process Patents - 5 years (OLS & IV)

Variables	(1) Sub. product patent	(2) Sub. product patent	(3) Sub. process patent	(4) Sub. process patent
Patent grant	0.0869***	0.0516**	0.0482***	0.0123
	(0.00358)	(0.0216)	(0.00282)	(0.0161)
Constant	0.0776***	0.103***	0.0436***	0.0692***
	(0.00254)	(0.0153)	(0.00200)	(0.0115)
Observations	44,548	44,548	44,548	44,548
R-squared	0.012		0.006	
Number of gau_faom_yr	5,334	5,334	5,334	5,334
Uncond. Mean DV	0.139	0.139	0.078	0.078
Reg. Type	OLS	IV	OLS	IV

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year fixed effects and heteroskedastic-robust standard errors. The subsequent product patent indicator is equal to one if the focal assignee files at least one application, which is later granted, with at least one product claim within five years after the first-action date (Columns 1 and 2). The subsequent product patent indicator is equal to one if the focal assignee files at least one application, which is later granted, with at least one process claim within five years after the first-action date (Columns 3 and 4). Our sample contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications are dropped from our sample.

are imports, then associated transactions will not enter directly into conventional measures of economic growth. However, technology diffusion from technological entrants to local U.S. firms could positively affect economic growth (Romer, 1990; Grossman and Helpman, 1991).

Finally, patent grant effects may differ depending on the assignee's country of origin and, in particular, the global reach of the country of origin's patent office. We therefore split our main sample by the country of origin's IP5 status. Using each subsample, we re-estimate Equation 1 for each of the subsequent patenting and diffusion outcomes in our main analysis, where the outcome measured are calculated at 5 years post-FAOM date (tables are presented in the Appendix). The patent grant effects for non-IP5 countries, results of which are presented in the Appendix, are positive and statistically significant for both the subsequent patenting and diffusion outcomes, consistent with our main results. By comparison, IP5-based technological entrants appear to benefit less from an initial patent grant. Grants for IP5 countries do not significantly affect subsequent patent filings at the USPTO and only weakly affects ($p<0.1$) local technology diffusion status. The difference in results by IP5 status may be driven by a number of factors. For example, weaker diffusion effects may result from higher overall visibility of and exposure to patent documents from

IP5 countries compared to those from non-member countries, offsetting the benefits of receiving a local U.S. patent. However, a full accounting of these factors is beyond the scope of this paper and we therefore leave it to future research.

6.2 Robustness Checks

To further validate our main findings, we test the robustness of our results across different sub-samples, alternative formulations of the main outcome variables, and the inclusion of additional controls. For the sake of parsimony, the results of these robustness tests are described here and presented in full in the Appendix.

First, Righi and Simcoe (2019) find evidence of examiner specialization within GAU-year and that more specialized examiners have a lower allowance rate. To account for this examiner specialization, we conduct two robustness checks. First, we add controls in the form of U.S. patent classification (USPC) fixed effects (at the class level) to our main regression equations. When controlling for USPC class, the estimates are generally consistent with our main results. However, Righi and Simcoe (2019) also note that controlling for technology class may not be sufficient to account for specialization. The prior literature on the random assignment of examiners has provided a framework to identify administrative unit-year combinations within the USPTO where the quasi-random assignment is more plausible (Righi and Simcoe, 2019; Feng and Jaravel, 2020). As a second approach, we re-estimate our main regressions using only those applications that are docketed to examiners within these plausibly random administrative unit-years. The estimates are generally larger in magnitude than those from our main results. For example, the estimated effect of a patent grant on the probability of at least one subsequent patent within five years of the FAOM date is 49.5 percent ($\hat{\beta_{IV}} = 0.0976$) larger for this sub-sample than the main estimate in Table 2.

Second, considerations for technological entry, subsequent patenting, and knowledge diffusion may be different for firms from Canada and Mexico compared to rest of the world. Both countries have long maintained strong bilateral trade relationships and increased technology flows with the United States because of their close geographic proximity and the significant preferential trade advantages established under NAFTA. In 2017, over a quarter of U.S. imports came from Canada and Mexico alone (USITC 2018). As a robustness test, we remove Canadian and Mexican firms from our sample and re-estimate our main regressions using the non-NAFTA subsample. The OLS and IV estimates for the non-NAFTA sub-sample are generally consistent with our main results.

Third, while all of the firms in our main sample are small entities, they are not necessarily start-ups. To test for the effects on start-ups only, we derive a sub sample that removes non-start-ups. We do so by linking our data to Orbis Intellectual Property (Orbis IP), a proprietary database containing firm-level information, and dropping any firms that were incorporated before 1990.[28] The resulting subsample better differentiates between foreign technological entrants based on their age at the point of technological entry by removing firms for which there was a significant delay between incorporation and technological entry. The estimates for this robustness check are consistent with our main results, suggesting that delayed technological entry into the United States is not a main driver the estimated effects of patent grants.

Fourth, the use of patent citations as a measure of knowledge flows and spillovers is imperfect and has been subject to criticism in recent years (Kuhn et al., 2020; Lampe, 2012; Alcacer and Gittelman, 2006). When constructing our main local diffusion outcome variables, we partially account for this issue by removing forward citations from patents for which the number of backwards citations exceeds 20 (Kuhn et al., 2020), but other limitations likely remain. Alcacer and Gittelman (2006) finds that examiner-added citations, which do not reflect the knowledge flows or spillovers, account for roughly forty percent of citations. Kuhn et al. (2020) notes, however, if both the applicant and the examiner cite the same prior art, the reference is noted as an examiner-added citation on the face of the patent, potentially undercounting highly-relevant applicant-to-applicant knowledge flows. As a robustness check, we re-define our external U.S. citation outcome variables to only include applicant-added forward citations from patents with twenty or fewer backward citations. Unsurprisingly, the resulting estimates are smaller in magnitude and slightly less statistically significant than our main estimates.

Fifth, as a separate robustness check on the diffusion outcome variables, we address concerns that the effect of patent grants on local diffusion may be driven artificially by a change in citation patterns after application uncertainty is resolved. When citing a relevant invention as prior art, U.S. assignees could plausibly substitute references from the foreign priority document to the U.S. application, especially once the uncertainty is resolved. We may, therefore, observe a spurious increase

[28]The Orbis IP data does not contain a complete record of assignments and incorporation years. For this robustness check, we do not drop observations that are missing incorporation years.

in forward citations to the granted application without any corresponding increase in knowledge flows or spillovers from foreign technological entrants to U.S. entities. To mitigate this issue, we redefine our external U.S. citation indicators by replacing citation linkages between patents granted to U.S. assignees and a foreign technological entrant's first application at the USPTO with U.S. patent-to-DOCDB-family linkages.[29] A DOCDB family, or simple patent family, refers to the set of patent documents within and across jurisdictions that represent the same invention. Using the family-level patent citation data from the Worldwide Statistical Patent Database (PATSTAT), we regress a binary indicator, equal to one if at least one granted U.S. patent assigned to a U.S. entity cites the focal patent family within a specified timeframe and zero otherwise, on the patent grant indicator. We account for multiple citations from the granted patent to the focal patent family by only considering the earliest-filed cited document within the DOCDB family. The estimated patent grant effects are generally consistent with our main results ruling out the possibility that our results are driven by a change in citation patterns.

Finally, we show that our IV estimates are robust to certain plausible identification issues. One potential issue is that the prior grant rate may be correlated with omitted examiner characteristics that also might affect the outcome variables of interest, such as review speed. Following Farre-Mensa et al. (2020), we address this by conditioning on the length of administrative delay from application date to first-action date, or first-action pendency. Due to the likely endogeneity of this initial review speed, we instrument for the focal application's first-action pendency using the examiner's average first-action pendency from prior applications. The inclusion of first-action pendency has minimal impact on the estimated effect of patent grants on our main subsequent patenting and local knowledge diffusion. The OLS and IV estimates of the effect of a patent grant are consistent with our main regression estimates across all years. Meanwhile, there is some evidence that first-action pendency can affect subsequent patenting and knowledge diffusion. The OLS estimates for first-action pendency are negative and significant for both subsequent patenting outcome variables (status and count), suggesting that additional delays in review speed lead to a lower probability of at least one follow-on filing. The IV estimates for the effect of initial review speed are not statistically significant at conventional levels. Interestingly, first-action pendency has

[29] We not not remove any citations based on citing document characteristics or the nature of the citation (e.g. applicant or examiner).

a positive and generally significant effect on the knowledge diffusion to local U.S. patent assignees. Most importantly, this robustness check demonstrates that controlling for first-action pendency does not affect our main results.

7 Conclusion

Knowledge flows, domestic and international, are key components of economic growth. While prior studies have focused on the relationship between invention disclosure and knowledge diffusion, this paper explores a previously-understudied determinant of international knowledge diffusion and patenting—the IPR itself. We estimate the causal effect of an initial patent grant on sustained technological presence and cross-border technology diffusion, conditional on technological entry into the United States. Successful technological entrants, whose initial application at the USPTO was granted, are 26.9 percent more likely to sustain technological presence in the United States through subsequent patent filings within three years. These follow-on filings demonstrate the role of IP protection in bringing new and existing foreign inventions into the U.S. patent system. These findings complement the literature on international trade and IP, demonstrating that initial IP protection allows entrants to maintain not only a market presence via imports to the host country (de Rassenfosse et al., 2022) but also a technological presence in the host country via re-engagement with the local patent office (this study). Individual patent rights also play a key role in facilitating international knowledge diffusion. An initial patent grant increases the probability of cross-border knowledge flows to local U.S. patenting entities by 29.4 percent within 5 years, a result that highlights the trade-off between bargaining frictions and sustained technological and market presence in facilitating spillovers.

There are several implications of our study. First, obtaining IPRs in a host country fosters international knowledge flows, increasing the stock of knowledge available to local firms and inventors, which has clear implications for the economic growth literature. Second, the benefits of initial IPRs in a host country extend beyond local applicants (Gaule, 2018; Farre-Mensa et al., 2020) to foreign applicants, especially in maintaining a foreign firm's technological presence in the host country. Third, discrimination against foreign applicants by local patent offices (de Rassenfosse et al., 2019), regardless of intent, likely limits both immediate and long-term international knowledge flows originating from foreign applicants that were denied a patent. For this reason, policies that aim to level the playing field for foreign applicants, which are consistent with the national treatment principle, may have significant impacts on technological and economic growth.

Although our sample is representative of all small technological entrants with a first-action decision between 2006 and 2017, we note some limitations and their implications on external validity. First, our results may not extend to large entrants, which are omitted from our sample and may not benefit from an initial patent grant to the extent of small technological entrants. For example, larger entities may have complementary resources that lessen the importance of an initial grant on subsequent direct knowledge flows. These firms may have different sensitivities to rent dissipation and may therefore prevent spillovers through litigation or impeding licensing agreements. Second, our analysis only focuses on technological entrants to the United States. Given the market size and placement on the technological frontier, the importance of an initial grant may differ across host countries. This additional analysis is beyond the scope of this paper and we leave it to further research. Finally, this study accentuates the importance of IP on innovation outcomes and cross-border knowledge flows, suggesting that a higher patent allowance rate might lead to increased knowledge spillovers in the host country. In line with prior studies on patent grant effects, we refrain from commenting on the optimal allowance rate.

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A Supplementary Tables

Table A1: Variable Definitions

Variable	Definition	Source
Patent grant	Binary indicator equal to one if the focal application was granted, zero otherwise	PatEx
U.S. ext. citation (fwd.)	Forward patent citation by a *U.S.*-based firm or other patenting entity within a specified period of time. Measured using a binary indicator (=1 if value $>$ 0) and in logs (value plus one)	PatentsView (PV)
Group art unit (GAU)	Administrative unit within the USPTO responsible for a technology area or grouping of technology areas	PatEx
First-action year	Year of the first-action "on the merits" (FAOM) decision on a focal application	PatEx
Sub. pat. filing	Subsequent patent application filed by the same assignee within a specified period of time. Measured using a binary indicator (=1 if value $>$ 0) and in logs (value plus one)	PV & PatEx
Sub. pat. filing - Existing Invention	Subsequent patent application filed by the same assignee within a specified period of time, conditional on foreign priority date occurring prior to the FAOM date of the focal application. Measured using a binary indicator (=1 if value $>$ 0)	PV & PatEx
Sub. product patent	Subsequent product patent filed by the same assignee within a specified period of time, where a product patent is defined as having at least one product claim. Measured using a binary indicator (=1 if value $>$ 0)	PV, PatEx, & Ganglmair et al. (2022)
Sub. process patent	Subsequent process patent filed by the same assignee within a specified period of time, where a process patent is defined as having at least one process claim. Measured using a binary indicator (=1 if value $>$ 0)	PV, PatEx, & Ganglmair et al. (2022)

Notes: PatentsView (PV); Patent Examination Research Dataset (PatEx); (grants & pre-grant publications)

Table A2: Summary Statistics

Variables	N	Mean	Std.Dev.	Min	25%	Median	75%	Max
Patent grant	44,548	0.709	0.454	0	0	1	1	1
Disposal year	44,548	2,014	3.270	2,006	2,012	2,014	2,016	2,023
FAOM year	44,548	2,013	3.153	2,006	2,010	2,013	2,015	2,017
Filing year	44,548	2,011	3.483	2,001	2,008	2,011	2,014	2,017
Prior grant rate	44,548	0.593	0.220	0	0.444	0.628	0.772	1
Subsequent pat. filing ind. (5 years)	44,548	0.220	0.414	0	0	0	0	1
Sub. existing pat. filing ind. (3 years)	44,548	0.121	0.326	0	0	0	0	1
U.S. ext. citation ind. (5 years)	44,548	0.240	0.427	0	0	0	0	1
EPO country	44,548	0.423	0.494	0	0	0	1	1
IP5 country	44,548	0.646	0.478	0	0	1	1	1
Ln. sub. pat. filing count (5 years)	44,548	0.248	0.543	0	0	0	0	5.118
Ln. U.S. ext. citation count (5 years)	44,548	0.217	0.423	0	0	0	0	3.401
Ln. sub. existing pat. filing count (5 years)	44,548	0.114	0.337	0	0	0	0	4.585
DOCDB family size	44,546	5.332	5.116	1	2	4	7	379
Application scope - Logged ICC	43,536	0.608	0.617	0	0	0.693	1.099	6.260

Table A3: Robustness check - IP5 subset (OLS & IV)

Variables	(1) Sub. app. indicator	(2) Sub. app. indicator	(3) ln Subseq. app. ct.	(4) ln Subseq. app. ct.	(5) U.S. ext. cite ind.	(6) U.S. ext. cite ind.	(7) ln U.S. ext. cite ct.	(8) ln U.S. ext. cite ct.
Patent grant	0.111***	0.0389	0.128***	0.0606	0.0746***	0.0625*	0.0725***	0.0455
	(0.00573)	(0.0336)	(0.00718)	(0.0432)	(0.00584)	(0.0323)	(0.00526)	(0.0297)
Constant	0.140***	0.192***	0.154***	0.202***	0.161***	0.170***	0.137***	0.156***
	(0.00411)	(0.0241)	(0.00515)	(0.0310)	(0.00419)	(0.0232)	(0.00377)	(0.0213)
Observations	28,800	28,800	28,800	28,800	28,800	28,800	28,800	28,800
R-squared	0.013		0.011		0.006		0.007	
Number of GAU-years	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800
Reg. Type	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.220	0.220	0.246	0.246	0.215	0.215	0.189	0.189

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year fixed effects and heteroskedastic-robust standard errors, as shown in Equation 1. For Columns (1) and (2), the dependent variable, or subsequent application indicator, is equal to one if the focal assignee files at least one non-continuation application within five years after the first-action date. For Columns (3) and (4), we replace the indicator variables with the logged count of subsequent patent applications, specifically $ln(1 + y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. For Columns (5) and (6), the external U.S. citation indicator is equal to one if the focal application receives at least one forward patent citation by a different U.S. assignee within five years after the focal application's first-decision date. For Columns (7) and (8), we replace the indicator variables with the logged count of forward citations, specifically $ln(1 + y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. Our main sample contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. For this table, we only keep those applications assigned to foreign entrants in IP5 countries (EPO, CNIPA, JPO, KPO). We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications are dropped from our sample.

Table A4: Robustness check - non-IP5 subset (OLS & IV)

Variables	(1) Sub. app. indicator	(2) Sub. app. indicator	(3) ln Subseq. app. ct.	(4) ln Subseq. app. ct.	(5) U.S. ext. cite ind.	(6) U.S. ext. cite ind.	(7) ln U.S. ext. cite ct.	(8) ln U.S. ext. cite ct.
Patent grant	0.125***	0.0918**	0.146***	0.122**	0.106***	0.117**	0.111***	0.129***
	(0.00817)	(0.0444)	(0.0102)	(0.0547)	(0.00896)	(0.0456)	(0.00874)	(0.0457)
Constant	0.133***	0.156***	0.151***	0.168***	0.211***	0.203***	0.191***	0.179***
	(0.00567)	(0.0309)	(0.00711)	(0.0380)	(0.00622)	(0.0317)	(0.00607)	(0.0317)
Observations	15,748	15,748	15,748	15,748	15,748	15,748	15,748	15,748
R-squared	0.018		0.014		0.011		0.012	
Number of GAU-years	4,291	4,291	4,291	4,291	4,291	4,291	4,291	4,291
Reg. Type	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.219	0.219	0.252	0.252	0.285	0.285	0.268	0.268

Significant at *** $p<0.01$, ** $p<0.05$, * $p<0.10$. Each regression contains GAU-by-year fixed effects and heteroskedastic-robust standard errors, as shown in Equation 1. For Columns (1) and (2), the dependent variable, or subsequent application indicator, is equal to one if the focal assignee files at least one non-continuation application within five years after the first-action date. For Columns (3) and (4), we replace the indicator variables with the logged count of subsequent patent applications, specifically $ln(1 + y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. For Columns (5) and (6), the external U.S. citation indicator is equal to one if the focal application receives at least one forward patent citation by a different U.S. assignee within five years after the focal application's first-decision date. For Columns (7) and (8), we replace the indicator variables with the logged count of forward citations, specifically $ln(1 + y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. Our main sample contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. For this table, we only keep those applications assigned to foreign entrants in non-IP5 countries (EPO, CNIPA, JPO, KPO). We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications are dropped from our sample.

Table A5: Follow-on applications - No NAFTA countries (OLS & IV)

Variables	(1) 3 years	(2) 3 years	(3) 5 years	(4) 5 years	(5) 7 years	(6) 7 years
Panel A - Patent indicator						
Patent Grant	0.0958***	0.0483*	0.118***	0.0638**	0.126***	0.0672**
	(0.00429)	(0.0248)	(0.00465)	(0.0271)	(0.00535)	(0.0321)
Constant	0.116***	0.149***	0.139***	0.178***	0.156***	0.196***
	(0.00303)	(0.0175)	(0.00329)	(0.0192)	(0.00362)	(0.0217)
Observations	40,036	40,036	40,036	40,036	31,023	31,023
R-squared	0.012		0.015		0.018	
Uncond. Mean DV	0.183	0.183	0.223	0.223	0.241	0.241
Panel B - Patent count						
Patent Grant	0.106***	0.0679**	0.141***	0.0963***	0.163***	0.101**
	(0.00503)	(0.0294)	(0.00598)	(0.0352)	(0.00735)	(0.0444)
Constant	0.118***	0.145***	0.154***	0.186***	0.183***	0.225***
	(0.00356)	(0.0208)	(0.00423)	(0.0249)	(0.00498)	(0.0300)
Observations	40,036	40,036	40,036	40,036	31,023	31,023
R-squared	0.010		0.013		0.015	
Number of GAU-years	5,225	5,225	5,225	5,225	4,207	4,207
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.193	0.193	0.254	0.254	0.293	0.293

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year fixed effects and heteroskedastic-robust standard errors, as shown in Equation 1. For Panel A, the subsequent application indicator is equal to one if the focal assignee files at least one non-continuation application within a three (Columns 1 and 2), five (Columns 3 and 4), or seven years (Columns 5 and 6), respectively after the first-action date. For Panel B, we replace the indicator variables with the logged count of subsequent patent applications, specifically $ln(1+y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. Our main sample (Columns 1 through 4) contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. Due to potential right-censoring for the seen-year interval, we limit the sample for these regressions, shown Columns (5) and (6), to those applications with first-action year between 2006 and 2015. We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications and applications assigned to entities located in either Canada or Mexico are dropped from our sample.

Table A6: External U.S. citations - No NAFTA countries (OLS & IV)

Variables	(1) 3 years	(2) 3 years	(3) 5 years	(4) 5 years	(5) 7 years	(6) 7 years
Panel A - Citation indicator						
Patent Grant	0.0537***	0.0253	0.0807***	0.0605**	0.0988***	0.0785**
	(0.00409)	(0.0225)	(0.00490)	(0.0261)	(0.00575)	(0.0314)
Constant	0.124***	0.144***	0.170***	0.185***	0.212***	0.226***
	(0.00289)	(0.0159)	(0.00346)	(0.0185)	(0.00389)	(0.0212)
Observations	40,036	40,036	40,036	40,036	31,023	31,023
R-squared	0.004		0.007		0.010	
Number of GAU-years	5,225	5,225	5,225	5,225	4,207	4,207
Uncond. Mean DV	0.162	0.162	0.228	0.228	0.279	0.279
Panel B - Citation count						
Patent Grant	0.0504***	0.0277	0.0805***	0.0585**	0.104***	0.0796***
	(0.00362)	(0.0198)	(0.00455)	(0.0243)	(0.00558)	(0.0308)
Constant	0.103***	0.119***	0.146***	0.162***	0.188***	0.204***
	(0.00256)	(0.0140)	(0.00321)	(0.0172)	(0.00378)	(0.0208)
Observations	40,036	40,036	40,036	40,036	31,023	31,023
R-squared	0.005		0.008		0.012	
Number of GAU-years	5,225	5,225	5,225	5,225	4,207	4,207
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.139	0.139	0.203	0.203	0.258	0.258

Significant at *** $p<0.01$, ** $p<0.05$, * $p<0.10$. Each regression contains GAU-by-year fixed effects and heteroskedastic-robust standard errors, as shown in Equation 1. The external U.S. citation indicator (Panel A) is equal to one if the focal application receives at least one non-continuation forward patent citation by a different U.S. assignee within three (Columns 1 and 2), five (Columns 3 and 4), and seven years (Columns 5 and 6) after the focal application's first-decision date. For Panel B, we replace the indicator variables with the logged count of non-continuation forward citations (by a U.S. assignee), specifically $ln(1 + y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. Our main sample (Columns 1 through 4) contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. Due to potential right-censoring for the seen-year interval, we limit the sample for these regressions, shown Columns (5) and (6), to those applications with first-action year between 2006 and 2015. We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications and applications assigned to entities located in either Canada or Mexico are dropped from our sample.

Table A7: Follow-on applications - Appl. with foreign priority or PCT parent (OLS & IV)

Variables	(1) 3 years	(2) 3 years	(3) 5 years	(4) 5 years	(5) 7 years	(6) 7 years
Panel A - Patent indicator						
Patent Grant	0.0861***	0.0348	0.108***	0.0437	0.115***	0.0352
	(0.00462)	(0.0266)	(0.00502)	(0.0292)	(0.00575)	(0.0345)
Constant	0.115***	0.151***	0.138***	0.184***	0.155***	0.209***
	(0.00327)	(0.0188)	(0.00355)	(0.0206)	(0.00389)	(0.0234)
Observations	34,445	34,445	34,445	34,445	26,384	26,384
R-squared	0.010		0.013		0.015	
Uncond. Mean DV	0.176	0.176	0.215	0.215	0.233	0.233
Panel B - Patent count						
Patent Grant	0.0915***	0.0481	0.124***	0.0747**	0.145***	0.0714
	(0.00524)	(0.0312)	(0.00630)	(0.0370)	(0.00777)	(0.0466)
Constant	0.115***	0.146***	0.151***	0.185***	0.178***	0.228***
	(0.00370)	(0.0221)	(0.00446)	(0.0262)	(0.00526)	(0.0315)
Observations	34,445	34,445	34,445	34,445	26,384	26,384
R-squared	0.008		0.011		0.013	
Number of GAU-years	4,952	4,952	4,952	4,952	3,975	3,975
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.180	0.180	0.238	0.238	0.276	0.276

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year fixed effects and heteroskedastic-robust standard errors, as shown in Equation 1. For Panel A, the subsequent application indicator is equal to one if the focal assignee files at least one non-continuation application within a three (Columns 1 and 2), five (Columns 3 and 4), or seven years (Columns 5 and 6), respectively after the first-action date. For Panel B, we replace the indicator variables with the logged count of subsequent patent applications, specifically $ln(1+y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. Our main sample (Columns 1 through 4) contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. Due to potential right-censoring for the seen-year interval, we limit the sample for these regressions, shown Columns (5) and (6), to those applications with first-action year between 2006 and 2015. We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications and non-PCT application without a foreign priority are dropped from our sample.

Table A8: Ext. U.S. citations - Appl. with foreign priority or PCT parent (OLS & IV)

Variables	(1) 3 years	(2) 3 years	(3) 5 years	(4) 5 years	(5) 7 years	(6) 7 years
Panel A - Citation indicator						
Patent Grant	0.0492***	0.0379	0.0748***	0.0784***	0.0922***	0.0908***
	(0.00437)	(0.0240)	(0.00516)	(0.0278)	(0.00618)	(0.0332)
Constant	0.119***	0.127***	0.164***	0.161***	0.205***	0.206***
	(0.00309)	(0.0170)	(0.00365)	(0.0197)	(0.00419)	(0.0225)
Observations	34,445	34,445	34,445	34,445	26,384	26,384
R-squared	0.004		0.007		0.009	
Number of GAU-years	4,952	4,952	4,952	4,952	3,975	3,975
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.154	0.154	0.217	0.217	0.267	0.267
Panel B - Citation count						
Patent Grant	0.0442***	0.0336*	0.0719***	0.0692***	0.0932***	0.0825***
	(0.00376)	(0.0202)	(0.00469)	(0.0252)	(0.00586)	(0.0319)
Constant	0.0974***	0.105***	0.139***	0.141***	0.179***	0.187***
	(0.00266)	(0.0143)	(0.00332)	(0.0178)	(0.00397)	(0.0216)
Observations	34,445	34,445	34,445	34,445	26,384	26,384
R-squared	0.004		0.007		0.010	
Number of GAU-years	4,952	4,952	4,952	4,952	3,975	3,975
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.129	0.129	0.190	0.190	0.242	0.242

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year fixed effects and heteroskedastic-robust standard errors, as shown in Equation 1. The external U.S. citation indicator (Panel A) is equal to one if the focal application receives at least one non-continuation forward patent citation by a different U.S. assignee within three (Columns 1 and 2), five (Columns 3 and 4), and seven years (Columns 5 and 6) after the focal application's first-decision date. For Panel B, we replace the indicator variables with the logged count of non-continuation forward citations (by a U.S. assignee), specifically $ln(1 + y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. Our main sample (Columns 1 through 4) contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. Due to potential right-censoring for the seen-year interval, we limit the sample for these regressions, shown Columns (5) and (6), to those applications with first-action year between 2006 and 2015. We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications and non-PCT application without a foreign priority are dropped from our sample.

Table A9: Ext. U.S. citations - Citation-type robustness checks (OLS & IV)

Variables	(1) 3 years	(2) 3 years	(3) 5 years	(4) 5 years	(5) 7 years	(6) 7 years
Panel A - DOCDB family-to-family citations						
Patent Grant	0.126***	0.0643**	0.119***	0.0783***	0.112***	0.0726***
	(0.00584)	(0.0288)	(0.00544)	(0.0265)	(0.00556)	(0.0267)
Constant	0.561***	0.605***	0.662***	0.691***	0.734***	0.761***
	(0.00413)	(0.0204)	(0.00384)	(0.0188)	(0.00377)	(0.0181)
Observations	43,075	43,075	43,075	43,075	33,442	33,442
R-squared	0.014		0.015		0.017	
Number of GAU-years	5,305	5,305	5,305	5,305	4,281	4,281
Uncond. Mean DV	0.650	0.650	0.746	0.746	0.810	0.810
Panel B - Appl.-added cites & 20 or fewer backcites						
Patent Grant	0.0206***	0.0203	0.0405***	0.0413**	0.0562***	0.0449*
	(0.00277)	(0.0155)	(0.00333)	(0.0186)	(0.00409)	(0.0231)
Constant	0.0550***	0.0553***	0.0784***	0.0779***	0.101***	0.109***
	(0.00196)	(0.0110)	(0.00236)	(0.0132)	(0.00278)	(0.0157)
Observations	44,548	44,548	44,548	44,548	34,559	34,559
R-squared	0.001		0.003		0.005	
Number of GAU-years	5,334	5,334	5,334	5,334	4,307	4,307
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.070	0.070	0.107	0.107	0.140	0.140
Reg. Type	OLS	IV	OLS	IV	OLS	IV

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year fixed effects and heteroskedastic-robust standard errors, as shown in Equation 1. The DOCDB-family citation indicator (Panel A) is equal to one if any application in the focal application's DOCDB family receives at least one forward patent citation by a different U.S. assignee within three (Columns 1 and 2), five (Columns 3 and 4), and seven years (Columns 5 and 6) after the focal application's first-decision date. The external 'Appl.-added cites & 20 or fewer backcites' U.S. citation indicator (Panel A) is equal to one if the focal application receives at least one non-continuation forward patent citation by a different U.S. assignee within three (Columns 1 and 2), five (Columns 3 and 4), and seven years (Columns 5 and 6) after the focal application's first-decision date. Examiner-initiated citations are dropped from the calculation of this dependent variable, as are citations from U.S. patents with more than 20 backwards citations. Our main sample (Columns 1 through 4) contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. Due to potential right-censoring for the seen-year interval, we limit the sample for these regressions, shown Columns (5) and (6), to those applications with first-action year between 2006 and 2015. We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications are dropped from our sample.

Table A10: Follow-on applications - Random Assignment TCs and GAUs (OLS & IV)

Varaibles	(1) 3 years	(2) 3 years	(3) 5 years	(4) 5 years	(5) 7 years	(6) 7 years
Panel A - Patent indicator						
Patent Grant	0.105***	0.0711*	0.129***	0.0976**	0.137***	0.0979**
	(0.00610)	(0.0364)	(0.00665)	(0.0391)	(0.00719)	(0.0423)
Constant	0.102***	0.125***	0.122***	0.143***	0.136***	0.162***
	(0.00412)	(0.0246)	(0.00449)	(0.0264)	(0.00479)	(0.0282)
Observations	19,564	19,564	19,564	19,564	17,719	17,719
R-squared	0.015		0.020		0.022	
Number of GAU-years	2,918	2,918	2,918	2,918	2,492	2,492
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.173	0.173	0.209	0.209	0.227	0.227
Panel B - Patent count						
Patent Grant	0.116***	0.0581	0.155***	0.105**	0.177***	0.113*
	(0.00736)	(0.0445)	(0.00864)	(0.0520)	(0.00981)	(0.0604)
Constant	0.107***	0.147***	0.139***	0.172***	0.160***	0.202***
	(0.00497)	(0.0301)	(0.00583)	(0.0351)	(0.00654)	(0.0403)
Observations	19,564	19,564	19,564	19,564	17,719	17,719
R-squared	0.013		0.016		0.018	
Number of GAU-years	2,918	2,918	2,918	2,918	2,492	2,492
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.186	0.186	0.244	0.244	0.278	0.278

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year fixed effects and heteroskedastic-robust standard errors, as shown in Equation 1. For Panel A, the subsequent application indicator is equal to one if the focal assignee files at least one non-continuation application within a three (Columns 1 and 2), five (Columns 3 and 4), or seven years (Columns 5 and 6), respectively after the first-action date. For Panel B, we replace the indicator variables with the logged count of subsequent patent applications, specifically $ln(1+y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. Our main sample (Columns 1 through 4) contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. Due to potential right-censoring for the seen-year interval, we limit the sample for these regressions, shown Columns (5) and (6), to those applications with first-action year between 2006 and 2015. We further limit our sample to those applications docketed in TCs and GAUs where the random assignment assumption is more likely to hold (Righi and Simcoe 2019; Feng and Jaravel 2020), list available on request. We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications are dropped from our sample.

Table A11: Ext. U.S. citations - Random Assignment TCs and GAUs (OLS & IV)

Variables	(1) 3 years	(2) 3 years	(3) 5 years	(4) 5 years	(5) 7 years	(6) 7 years
Panel A - Citation indicator						
Patent Grant	0.0719***	0.0414	0.111***	0.0861**	0.126***	0.109**
	(0.00631)	(0.0361)	(0.00722)	(0.0406)	(0.00781)	(0.0443)
Constant	0.165***	0.186***	0.215***	0.232***	0.250***	0.261***
	(0.00426)	(0.0244)	(0.00487)	(0.0274)	(0.00521)	(0.0296)
Observations	19,564	19,564	19,564	19,564	17,719	17,719
R-squared	0.007		0.013		0.015	
Number of GAU-years	2,918	2,918	2,918	2,918	2,492	2,492
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.214	0.214	0.290	0.290	0.334	0.334
Panel B - Citation count						
Patent Grant	0.0717***	0.0285	0.117***	0.0698*	0.140***	0.101**
	(0.00601)	(0.0341)	(0.00731)	(0.0417)	(0.00825)	(0.0481)
Constant	0.144***	0.174***	0.197***	0.229***	0.234***	0.260***
	(0.00406)	(0.0230)	(0.00494)	(0.0282)	(0.00550)	(0.0320)
Observations	19,564	19,564	19,564	19,564	17,719	17,719
R-squared	0.007		0.013		0.016	
Number of GAU-years	2,918	2,918	2,918	2,918	2,492	2,492
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.193	0.193	0.276	0.276	0.327	0.327

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year fixed effects and heteroskedastic-robust standard errors, as shown in Equation 1. The external U.S. citation indicator (Panel A) is equal to one if the focal application receives at least one non-continuation forward patent citation by a different U.S. assignee within three (Columns 1 and 2), five (Columns 3 and 4), and seven years (Columns 5 and 6) after the focal application's first-decision date. For Panel B, we replace the indicator variables with the logged count of non-continuation forward citations (by a U.S. assignee), specifically $ln(1 + y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. Our main sample (Columns 1 through 4) contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. Due to potential right-censoring for the seen-year interval, we limit the sample for these regressions, shown Columns (5) and (6), to those applications with first-action year between 2006 and 2015. We further limit our sample to those applications docketed in TCs and GAUs where the random assignment assumption is more likely to hold (Righi and Simcoe 2019; Feng and Jaravel 2020), list available on request. We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications are dropped from our sample.

Table A12: Subsequent applications - with first-action pend. (OLS & IV)

Variables	(1) 3 years	(2) 3 years	(3) 5 years	(4) 5 years	(5) 7 years	(6) 7 years
Panel A - Patent indicator						
Patent Grant	0.0942***	0.0561**	0.117***	0.0761***	0.125***	0.0682**
	(0.00408)	(0.0263)	(0.00443)	(0.0283)	(0.00511)	(0.0319)
First-action pend.	-2.37e-05***	3.87e-05	-2.89e-05***	5.50e-05	-2.50e-05**	2.12e-05
	(8.32e-06)	(5.79e-05)	(9.09e-06)	(6.32e-05)	(1.04e-05)	(6.62e-05)
Constant	0.129***	0.115**	0.155***	0.130**	0.170***	0.177***
	(0.00631)	(0.0486)	(0.00695)	(0.0525)	(0.00816)	(0.0558)
Observations	44,548	44,548	44,548	44,548	34,559	34,559
R-squared	0.012		0.016		0.018	
Number of GAU-years	5,334	5,334	5,334	5,334	4,307	4,307
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.180	0.180	0.220	0.220	0.238	0.238
Panel B - Patent count						
Patent Grant	0.103***	0.0686**	0.138***	0.102***	0.159***	0.103**
	(0.00474)	(0.0309)	(0.00563)	(0.0363)	(0.00694)	(0.0438)
First-action pend.	-1.36e-05	3.58e-05	-1.90e-05	7.23e-05	-1.34e-05	8.53e-05
	(9.90e-06)	(6.71e-05)	(1.17e-05)	(8.02e-05)	(1.44e-05)	(9.06e-05)
Constant	0.124***	0.116**	0.162***	0.129*	0.187***	0.158**
	(0.00746)	(0.0566)	(0.00886)	(0.0669)	(0.0111)	(0.0769)
Observations	44,548	44,548	44,548	44,548	34,559	34,559
R-squared	0.010		0.013		0.015	
Number of GAU-years	5,334	5,334	5,334	5,334	4,307	4,307
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.188	0.188	0.248	0.248	0.286	0.286

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year fixed effects and heteroskedastic-robust standard errors, as shown in Equation 1. For Panel A, the subsequent application indicator is equal to one if the focal assignee files at least one non-continuation application within a three (Columns 1 and 2), five (Columns 3 and 4), or seven years (Columns 5 and 6), respectively after the first-action date. For Panel B, we replace the indicator variables with the logged count of subsequent patent applications, specifically $ln(1 + y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. First-action pendency is defined as the length of time between application filing date and the first-action date. Our main sample (Columns 1 through 4) contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. Due to potential right-censoring for the seen-year interval, we limit the sample for these regressions, shown Columns (5) and (6), to those applications with first-action year between 2006 and 2015. We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications are dropped from our sample.

Table A13: Ext. U.S. citations - with first-action pend. (OLS & IV)

Variables	(1) 3 years	(2) 3 years	(3) 5 years	(4) 5 years	(5) 7 years	(6) 7 years
Panel A - Citation indicator						
Patent Grant	0.0597***	0.0590**	0.0874***	0.0906***	0.104***	0.0949***
	(0.00394)	(0.0250)	(0.00461)	(0.0280)	(0.00544)	(0.0318)
fa_pend	3.13e-05***	0.000137**	2.21e-05**	0.000102	2.05e-05*	0.000116*
	(8.14e-06)	(5.70e-05)	(9.28e-06)	(6.42e-05)	(1.10e-05)	(6.93e-05)
Constant	0.110***	0.0416	0.163***	0.110**	0.207***	0.148**
	(0.00610)	(0.0478)	(0.00687)	(0.0532)	(0.00829)	(0.0579)
Observations	44,548	44,548	44,548	44,548	34,559	34,559
R-squared	0.005		0.008		0.011	
Number of GAU-years	5,334	5,334	5,334	5,334	4,307	4,307
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.172	0.172	0.240	0.240	0.293	0.293
Panel B - Citation count						
Patent Grant	0.0562***	0.0681***	0.0880***	0.0999***	0.111***	0.107***
	(0.00353)	(0.0232)	(0.00436)	(0.0277)	(0.00539)	(0.0329)
fa_pend	2.58e-05***	0.000184***	2.19e-05**	0.000168***	2.38e-05**	0.000190***
	(7.59e-06)	(5.32e-05)	(9.13e-06)	(6.34e-05)	(1.14e-05)	(7.24e-05)
Constant	0.0922***	-0.0192	0.140***	0.0369	0.183***	0.0725
	(0.00561)	(0.0450)	(0.00670)	(0.0531)	(0.00860)	(0.0609)
Observations	44,548	44,548	44,548	44,548	34,559	34,559
R-squared	0.005		0.009		0.012	
Number of GAU-years	5,334	5,334	5,334	5,334	4,307	4,307
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.149	0.149	0.217	0.217	0.275	0.275

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year fixed effects and heteroskedastic-robust standard errors, as shown in Equation 1. The external U.S. citation indicator (Panel A) is equal to one if the focal application receives at least one non-continuation forward patent citation by a different U.S. assignee within three (Columns 1 and 2), five (Columns 3 and 4), and seven years (Columns 5 and 6) after the focal application's first-decision date. For Panel B, we replace the indicator variables with the logged count of non-continuation forward citations (by a U.S. assignee), specifically $ln(1 + y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. First-action pendency is defined as the length of time between application filing date and the first-action date. Our main sample (Columns 1 through 4) contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. Due to potential right-censoring for the seen-year interval, we limit the sample for these regressions, shown Columns (5) and (6), to those applications with first-action year between 2006 and 2015. We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications are dropped from our sample.

Table A14: Follow-on Patenting Results - with USPC fixed effects (OLS & IV)

Variables	(1) Subseq. Inv. 3 years	(2) Subseq. Inv. 3 years	(3) Subseq. Inv. 5 years	(4) Subseq. Inv. 5 years	(5) Subseq. Inv. 7 years	(6) Subseq. Inv. 7 years
Panel A - Patent indicator						
Patent Grant	0.0959***	0.0467*	0.119***	0.0602**	0.126***	0.0580*
	(0.00414)	(0.0261)	(0.00447)	(0.0281)	(0.00517)	(0.0334)
Constant	0.152***	0.197***	0.150**	0.204***	0.168**	0.233***
	(0.0577)	(0.0630)	(0.0600)	(0.0651)	(0.0718)	(0.0787)
Observations	44,548	44,548	44,548	44,548	34,559	34,559
R-squared	0.024		0.028		0.034	
Uncond. Mean DV	0.180	0.180	0.220	0.220	0.238	0.238
Panel B - Patent count						
Patent Grant	0.104***	0.0556*	0.139***	0.0735**	0.160***	0.0673
	(0.00476)	(0.0307)	(0.00566)	(0.0361)	(0.00698)	(0.0462)
Constant	0.137**	0.181**	0.157**	0.216**	0.208**	0.297***
	(0.0679)	(0.0741)	(0.0783)	(0.0850)	(0.104)	(0.113)
Observations	44,548	44,548	44,548	44,548	34,559	34,559
R-squared	0.024		0.028		0.033	
Number of GAU-years	5,334	5,334	5,334	5,334	4,307	4,307
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.188	0.188	0.248	0.248	0.286	0.286

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year and USPC fixed effects and heteroskedastic-robust standard errors, as shown in Equation 1. For Panel A, the subsequent application indicator is equal to one if the focal assignee files at least one non-continuation application within a three (Columns 1 and 2), five (Columns 3 and 4), or seven years (Columns 5 and 6), respectively after the first-action date. For Panel B, we replace the indicator variables with the logged count of subsequent patent applications, specifically $ln(1+y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. Our main sample (Columns 1 through 4) contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. Due to potential right-censoring for the seen-year interval, we limit the sample for these regressions, shown Columns (5) and (6), to those applications with first-action year between 2006 and 2015. We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications are dropped from our sample.

Table A15: External U.S. Forward Citations - with USPC fixed effects (OLS & IV)

Variables	(1) 3 years	(2) 3 years	(3) 5 years	(4) 5 years	(5) 7 years	(6) 7 years
Panel A - Citation indicator						
Patent Grant	0.0602***	0.0289	0.0882***	0.0621**	0.106***	0.0617*
	(0.00400)	(0.0240)	(0.00470)	(0.0274)	(0.00556)	(0.0329)
Constant	0.0891*	0.118**	0.105*	0.128**	0.152**	0.194***
	(0.0511)	(0.0544)	(0.0591)	(0.0637)	(0.0639)	(0.0701)
Observations	44,548	44,548	44,548	44,548	34,559	34,559
R-squared	0.019		0.023		0.030	
Uncond. Mean DV	0.172	0.172	0.240	0.240	0.293	0.293
Panel B - Citation count						
Patent Grant	0.0571***	0.0334	0.0894***	0.0676**	0.113***	0.0727**
	(0.00359)	(0.0217)	(0.00444)	(0.0266)	(0.00551)	(0.0338)
Constant	0.0657	0.0872*	0.0592	0.0789	0.109	0.148*
	(0.0450)	(0.0482)	(0.0610)	(0.0648)	(0.0715)	(0.0774)
Observations	44,548	44,548	44,548	44,548	34,559	34,559
R-squared	0.021		0.025		0.031	
Number of GAU-years	5,334	5,334	5,334	5,334	4,307	4,307
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.149	0.149	0.217	0.217	0.275	0.275

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year and USPC fixed effects and heteroskedastic-robust standard errors, as shown in Equation 1. The external U.S. citation indicator (Panel A) is equal to one if the focal application receives at least one non-continuation forward patent citation by a different U.S. assignee within three (Columns 1 and 2), five (Columns 3 and 4), and seven years (Columns 5 and 6) after the focal application's first-decision date. For Panel B, we replace the indicator variables with the logged count of non-continuation forward citations (by a U.S. assignee), specifically $ln(1+y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. Our main sample (Columns 1 through 4) contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. Due to potential right-censoring for the seen-year interval, we limit the sample for these regressions, shown Columns (5) and (6), to those applications with first-action year between 2006 and 2015. We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications are dropped from our sample.

Table A16: Follow-on Patenting Results - Orbis start-up sample (OLS & IV)

Variables	(1) Subseq. Inv. 3 years	(2) Subseq. Inv. 3 years	(3) Subseq. Inv. 5 years	(4) Subseq. Inv. 5 years	(5) Subseq. Inv. 7 years	(6) Subseq. Inv. 7 years
Panel A - Patent indicator						
Patent Grant	0.0964***	0.0525*	0.119***	0.0691**	0.126***	0.0805**
	(0.00471)	(0.0273)	(0.00508)	(0.0295)	(0.00587)	(0.0347)
Constant	0.131***	0.162***	0.158***	0.194***	0.177***	0.208***
	(0.00337)	(0.0196)	(0.00364)	(0.0212)	(0.00405)	(0.0239)
Observations	36,221	36,221	36,221	36,221	28,148	28,148
R-squared	0.011		0.014		0.017	
Uncond. Mean DV	0.200	0.200	0.243	0.243	0.264	0.264
Panel B - Patent count						
Patent Grant	0.107***	0.0705**	0.143***	0.0992**	0.165***	0.115**
	(0.00552)	(0.0326)	(0.00657)	(0.0388)	(0.00811)	(0.0489)
Constant	0.134***	0.160***	0.175***	0.207***	0.207***	0.242***
	(0.00396)	(0.0234)	(0.00471)	(0.0278)	(0.00559)	(0.0337)
Observations	36,221	36,221	36,221	36,221	28,148	28,148
R-squared	0.009		0.012		0.014	
Number of GAU-years	5,149	5,149	5,149	5,149	4,153	4,153
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.211	0.211	0.278	0.278	0.321	0.321

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year fixed effects and heteroskedastic-robust standard errors, as shown in Equation 1. For Panel A, the subsequent application indicator is equal to one if the focal assignee files at least one non-continuation application within a three (Columns 1 and 2), five (Columns 3 and 4), or seven years (Columns 5 and 6), respectively after the first-action date. For Panel B, we replace the indicator variables with the logged count of subsequent patent applications, specifically $ln(1+y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. Our main sample (Columns 1 through 4) contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. Due to potential right-censoring for the seen-year interval, we limit the sample for these regressions, shown Columns (5) and (6), to those applications with first-action year between 2006 and 2015. We drop all continuations from our sample, except bypass continuations of a PCT. For these regressions, we also drop non-start-ups from our sample — defined as firms founded before 1990 in Orbis. Firms that matched to Orbis but are missing founding year information are included in the sample. Finally, all pending applications are dropped from our sample.

Table A17: External U.S. Forward Citations - Orbis start-up sample (OLS & IV)

Variables	(1) 3 years	(2) 3 years	(3) 5 years	(4) 5 years	(5) 7 years	(6) 7 years
Panel A - Citation indicator						
Patent Grant	0.0612***	0.0388	0.0867***	0.0719**	0.103***	0.0749**
	(0.00448)	(0.0244)	(0.00531)	(0.0281)	(0.00624)	(0.0334)
Constant	0.129***	0.145***	0.179***	0.189***	0.222***	0.242***
	(0.00321)	(0.0175)	(0.00381)	(0.0202)	(0.00430)	(0.0230)
Observations	36,221	36,221	36,221	36,221	28,148	28,148
R-squared	0.005		0.008		0.011	
Uncond. Mean DV	0.173	0.173	0.241	0.241	0.293	0.293
Panel B - Citation count						
Patent Grant	0.0565***	0.0376*	0.0866***	0.0714***	0.109***	0.0799**
	(0.00397)	(0.0215)	(0.00498)	(0.0264)	(0.00612)	(0.0332)
Constant	0.109***	0.123***	0.156***	0.166***	0.200***	0.220***
	(0.00284)	(0.0154)	(0.00357)	(0.0189)	(0.00422)	(0.0229)
Observations	36,221	36,221	36,221	36,221	28,148	28,148
R-squared	0.005		0.009		0.012	
Number of GAU-years	5,149	5,149	5,149	5,149	4,153	4,153
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.149	0.149	0.218	0.218	0.275	0.275

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year and USPC fixed effects and heteroskedastic-robust standard errors, as shown in Equation 1. The external U.S. citation indicator (Panel A) is equal to one if the focal application receives at least one non-continuation forward patent citation by a different U.S. assignee within three (Columns 1 and 2), five (Columns 3 and 4), and seven years (Columns 5 and 6) after the focal application's first-decision date. For Panel B, we replace the indicator variables with the logged count of non-continuation forward citations (by a U.S. assignee), specifically $ln(1 + y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. Our main sample (Columns 1 through 4) contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. Due to potential right-censoring for the seen-year interval, we limit the sample for these regressions, shown Columns (5) and (6), to those applications with first-action year between 2006 and 2015. We drop all continuations from our sample, except bypass continuations of a PCT. For these regressions, we also drop non-start-ups from our sample — defined as firms founded before 1990 in Orbis. Firms that matched to Orbis but are missing founding year information are included in the sample. Finally, all pending applications are dropped from our sample.

Table A18: Follow-on Patenting Results - Anderson-Rubin (1949) Robustness Check (OLS & IV)

Variables	(1) Subseq. Inv. 3 years	(2) Subseq. Inv. 3 years	(3) Subseq. Inv. 5 years	(4) Subseq. Inv. 5 years	(5) Subseq. Inv. 7 years	(6) Subseq. Inv. 7 years
Panel A - Patent indicator						
Patent Grant	0.0950***	0.0485**	0.118***	0.0653**	0.127***	0.0555**
	(0.00407)	(0.0238)	(0.00441)	(0.0259)	(0.00460)	(0.0268)
Constant	0.113***	0.146***	0.136***	0.173***	0.146***	0.197***
	(0.00289)	(0.0169)	(0.00313)	(0.0184)	(0.00326)	(0.0190)
Observations	44,548	44,548	44,548	44,548	44,548	44,548
R-squared	0.011	0.000	0.015	0.000	0.017	0.000
Uncond. Mean DV	0.180	0.180	0.220	0.220	0.236	0.236
Panel B - Patent count						
Patent Grant	0.103***	0.0615**	0.139***	0.0875***	0.159***	0.0866**
	(0.00472)	(0.0279)	(0.00562)	(0.0332)	(0.00614)	(0.0364)
Constant	0.115***	0.145***	0.149***	0.186***	0.167***	0.219***
	(0.00335)	(0.0198)	(0.00398)	(0.0235)	(0.00436)	(0.0258)
Observations	44,548	44,548	44,548	44,548	44,548	44,548
R-squared	0.010	0.000	0.013	0.000	0.014	0.000
Number of GAU-years	5,334	5,334	5,334	5,334	5,334	5,334
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.188	0.188	0.248	0.248	0.280	0.280

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year fixed effects and heteroskedastic-robust standard errors, as shown in Equation 1. Standard errors are calculated according to Anderson and Rubin (1949), which are less susceptible to power asymmetry than normal 2SLS standard errors (Keane and Neal 2024). For Panel A, the subsequent application indicator is equal to one if the focal assignee files at least one non-continuation application within a three (Columns 1 and 2), five (Columns 3 and 4), or seven years (Columns 5 and 6), respectively after the first-action date. For Panel B, we replace the indicator variables with the logged count of subsequent patent applications, specifically $ln(1 + y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. Our main sample (Columns 1 through 4) contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. Due to potential right-censoring for the seen-year interval, we limit the sample for these regressions, shown Columns (5) and (6), to those applications with first-action year between 2006 and 2015. We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications are dropped from our sample.

Table A19: External U.S. Forward Citations - Anderson-Rubin (1949) Robustness Check (OLS & IV)

Variables	(1) 3 years	(2) 3 years	(3) 5 years	(4) 5 years	(5) 7 years	(6) 7 years
Panel A - Citation indicator						
Patent Grant	0.0586***	0.0320	0.0866***	0.0706***	0.0978***	0.0856***
	(0.00394)	(0.0220)	(0.00462)	(0.0255)	(0.00486)	(0.0268)
Constant	0.131***	0.150***	0.178***	0.190***	0.207***	0.216***
	(0.00279)	(0.0156)	(0.00328)	(0.0181)	(0.00345)	(0.0190)
Observations	44,548	44,548	44,548	44,548	44,548	44,548
R-squared	0.005	0.000	0.008	0.000	0.009	0.000
Uncond. Mean DV	0.172	0.172	0.240	0.240	0.276	0.276
Panel B - Citation count						
Patent Grant	0.0552***	0.0317	0.0873***	0.0667***	0.104***	0.0873***
	(0.00353)	(0.0197)	(0.00437)	(0.0245)	(0.00478)	(0.0270)
Constant	0.110***	0.126***	0.155***	0.169***	0.184***	0.195***
	(0.00251)	(0.0140)	(0.00310)	(0.0174)	(0.00339)	(0.0191)
Observations	44,548	44,548	44,548	44,548	44,548	44,548
R-squared	0.005	0.000	0.009	0.000	0.010	0.000
Number of GAU-years	5,334	5,334	5,334	5,334	5,334	5,334
Reg. Type	OLS	IV	OLS	IV	OLS	IV
Uncond. Mean DV	0.149	0.149	0.217	0.217	0.257	0.257

Significant at *** p<0.01, ** p<0.05, * p<0.10. Each regression contains GAU-by-year fixed effects and heteroskedastic-robust standard errors, as shown in Equation 1. Standard errors are calculated according to Anderson and Rubin (1949), which are less susceptible to power asymmetry than normal 2SLS standard errors (Keane and Neal 2024). The external U.S. citation indicator (Panel A) is equal to one if the focal application receives at least one non-continuation forward patent citation by a different U.S. assignee within three (Columns 1 and 2), five (Columns 3 and 4), and seven years (Columns 5 and 6) after the focal application's first-decision date. For Panel B, we replace the indicator variables with the logged count of non-continuation forward citations (by a U.S. assignee), specifically $ln(1+y_{i,t+k})$, where $y_{i,t+k}$ is the outcome of interest and k is the number of years of observation post-FAOM date. Our main sample (Columns 1 through 4) contains initial applications filed by small-entity, foreign technological entrants, with a first-action year between 2006 and 2017. Due to potential right-censoring for the seen-year interval, we limit the sample for these regressions, shown Columns (5) and (6), to those applications with first-action year between 2006 and 2015. We drop all continuations from our sample, except bypass continuations of a PCT. Finally, all pending applications are dropped from our sample.