Tickets to the Global Market: First US Patent Awards and Chinese Firm Exports*

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Abstract

We investigate how international patent activity enables firms from emerging economies to thrive in the global marketplace. We match Chinese customs data to US patent records, and leverage the quasi-random assignment of USPTO patent examiners to identify the causal effect of a US patent grant on the subsequent export performance of Chinese firms. Successful first-time patent applicants achieve significantly higher export growth, compared to otherwise similar first-time applicants that failed. This effect operates only in small part through market protection for technologically patent-related products in the US, and is largely driven by expansion in other markets. The response across destinations and products reveals that a US patent award signals the Chinese firm's capacity to produce high-quality products and credibility to honor contracts, mitigating information frictions in international trade. There is little evidence for the relaxation of financial constraints or the promotion of follow-on innovation.

Keywords: Patents, innovation, trade, exports, asymmetric information, signaling
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1 Introduction

Global patent activity has increased steadily in recent decades, with a remarkable rise in the number of patents taken out by foreign firms in a select few patent jurisdictions. For example, the United States Patent and Trademark Office (USPTO) - one of the largest, most active, and most reputed patent institutions in the world - receives over 500,000 applications each year, with the share of foreign applicants growing from 44% in 2000 to 51% in 2015 and the number of applicant countries expanding from 112 to 143. Given the role of innovation for economic growth and the need for intellectual property rights (IPR) protection to incentivize innovation, these trends raise policy questions of first-order importance: Why do firms patent their innovations abroad? What challenges do firms from emerging economies with weak IPR face in the global marketplace, and can established patent authorities in developed countries act as global hubs for alleviating these challenges?

Patent institutions in principle grant exclusive market rights only within their respective jurisdiction. Consistent with this, there is a strong positive correlation between the growth in the number of USPTO patent applications and the growth of exports to the US across countries over the 2000-2010 period (Figure 1A). At the same time, there is a similarly strong positive correlation across countries between USPTO patent applications and exports to the rest of the world (ROW) (Figure 1B). This raises the possibility that the US's global reputation for strict patent standards and strong IPR enforcement may confer additional advantages to successful USPTO applicants that extend beyond the US market. Indeed, two Chinese innovative leaders in the electronics industry, GRG Banking Equipment and Founder Microelectronics, prominently showcased their awards of a US patent respectively in 2011 and 2012 on leading state-owned media outlets and company websites (Figure A1).

[Figure 1]

To shed light on these questions, we investigate how the approval of a first US patent application affects the subsequent export performance of Chinese firms. We match Chinese customs data to US patent records, and leverage the quasi-random assignment of USPTO patent examiners to identify the causal effect of a US patent grant. Successful first-time patent applicants achieve significantly higher export growth. This effect operates only in small part through market protection for technologically patent-related products in the US, and is largely driven by expansion in other markets. The response across destinations and products reveals that a US patent award signals the Chinese firm's capacity to produce high quality and credibility to honor contracts, mitigating information frictions in international trade. There is, by contrast, little evidence for the relaxation of financial constraints or the promotion of follow-on innovation.

The US-China context is particularly well suited to studying these questions. While both countries have consistently ranked among the top-3 trading economies in the past decade, they emblematize an advanced economy with strong institutions and an emerging economy undergoing rapid structural transformation. Moreover, China's dramatic expansion in international trade since joining the WTO in 2001 has been accompanied by a steep rise in

Chinese patent applications both at home and abroad. Although China today hosts some global innovation leaders, there have been concerns about the quality of patents issued by China National Intellectual Property Administration (CNIPA).[1] In addition, Chinese products are often stigmatized to be of low average quality and high quality variance, in the face of significant contracting frictions and idiosyncratic Chinese institutions. Since the US is an important export market for China and US patents are highly regarded worldwide, the US patent activity of Chinese exporters thus provides an opportunity to assess the market protection and information signaling functions of foreign patents.

Our analysis requires comprehensive information on both patent and trade activity at the micro level. We therefore manually match for the first time three rich datasets for the 2001-2016 period: the universe of US patent applications from USPTO's Patent Examination Research Dataset (PatEx), the universe of Chinese firms' trade transactions from the Chinese Customs Trade Statistics (CCTS), and detailed accounting statements from the Chinese Annual Survey of Industrial Enterprises (ASIE). Our baseline sample comprises 2,831 Chinese exporters matched on firm name and location, which accounts for over half of all USPTO applicants from China.

Estimating the impact of a patent grant poses significant identification challenges due to concerns about omitted variable bias and reverse causality. Innovating firms are known to be bigger, more productive, more technologically advanced, and more successful in foreign markets (Aw *et al.* 2008, 2011). Chinese exporters filing for a US patent are indeed very different from exporters that do not. Separately, while firms' inherent innovation capability may drive their export performance, opportunities for export expansion may conversely incentivize innovation (Shu and Steinwender 2019).

We overcome this econometric challenge by capitalizing on institutional features of the USPTO review process: While each application is assigned to an art unit based on its technology class, the allocation of patents to examiners within an art unit has been described as close to a random lottery draw (Lemley and Sampat 2012; Sampat and Williams 2019). Moreover, there is systematic variation in examiners' proclivity to approve patents that is exogenous to the applicant and to the allocation process (Lemley and Sampat 2012).

We therefore identify the causal effect of a US patent by comparing the subsequent export performance of first-time Chinese applicants whose application has been approved vs. denied for arguably exogenous reasons. Following Sampat and Williams (2019) and Farre-Mensa *et al.* (2020), we instrument the outcome of a firm's USPTO application with the leniency of the assigned examiner. We proxy the latter with the share of patents the examiner has approved prior to that specific application, demeaned by art unit and year. This instrument delivers a powerful first stage, and is uncorrelated with a wide range of firm characteristics.

[1] In a survey of IPR professionals by Thomson Reuters and Intellectual Asset Management magazine, CNIPA patent quality ranked last among the world's five largest patent offices (Song and Li 2014), while an OECD study scored China's patent quality below the world average (Squicciarini *et al.* 2013). Boeing and Mueller (2019) compare patents filed under the Patent Cooperation Treaty (PCT), and find the average quality of Chinese applications to be only a third of that of non-Chinese applications and decreasing over time.

Rather than self-selected groups of innovative patent applicants and non-innovative non-patent filers, our treatment and control groups are thus both highly innovative firms that balance tests confirm are similar prior to their USPTO patent submission.

We find that USPTO patent approval significantly improves the export activity of Chinese firms. A successful first patent application increases annual export growth by 18 percentage points over the 3 years following the patent grant. This is driven in equal parts by greater survival and expansion in incumbent destination-product markets (87%), with limited contribution of entry into new markets (13%). Event studies reveal that the gains materialize quickly and persist, while placebo tests corroborate the lack of pre-trends. Although we focus on first-time applicants because of identification concerns with sparse serial applications, the evidence if anything suggests muted effects of subsequent patent approvals. These results obtain conditional on a stringent set of fixed effects and firm controls for initial exports, export experience, and size.

We consider several possible mechanisms for the effects of US patenting on Chinese firm exports that are not mutually exclusive. The premise of this analysis is that each mechanism would manifest in disproportionately higher growth in destination-product markets with certain characteristics. We evaluate this by assessing the contribution of different markets to firm-level export growth, as well as export survival and growth across markets within firms.

Since a patent gives exclusive rights to deploy an invention in the patent authority's jurisdiction, it may in the first instance strengthen market protection there. Such protection may allow firms to set monopoly prices and generate monopoly rents (Balasubramanian and Sivadasan 2011; Kogan *et al.* 2017; Kline *et al.* 2019), or offer legal security benefits that enable firms to expand their exports (De Rassenfosse *et al.* 2022). We identify products in a firm's export portfolio that are technologically related to a patent award and may therefore enjoy market protection in two ways: first, a novel semantic similarity analysis of the description of product categories and patent texts, including title, abstract, and technology class, using advanced Natural Language Processing (NLP) tools; and second, a crosswalk between HS6 product categories and patent technology classes developed by Lybbert and Zolas (2014); Goldschlag *et al.* (2020). We find that exports to the US of products that are technologically related to a firm's USPTO patent contribute under 15% of its overall export growth, while exports of unrelated products to the rest of the world account for 80%. Moreover, there is no differential growth in export sales or prices of related vs. unrelated products in the US vs. ROW within firms. This suggests that US patent grants bestow broader benefits to Chinese recipients that extend globally beyond market protection in the US.

We propose that US patent recognition acts as a signal that can alleviate information friction in international trade. Asymmetric information is arguably more prevalent and more costly in international than domestic transactions, because cross-border partners are less familiar with foreign economic and institutional conditions, risk bigger hold-up problems in finding alternative buyers and suppliers, and face greater contractual frictions due to transacting across jurisdictions. Asymmetric information would presumably be more problematic, and hence the value of a patent signal greater, for exporters that want to serve advanced economies from a country with less developed institutions and greater firm heterogeneity - such as China. Meeting the high standards of the USPTO examination process can give such firms a globally recognized stamp of approval, and thereby allow them to expand in destination-product markets that are not directly affected by the US patent.

We provide evidence consistent with a US patent sending a signal about two desirable attributes of a Chinese firm: its capacity to deliver high-quality products and its credibility to honor contractual obligations. US patents boost export growth relatively more for goods with greater scope for quality differentiation, especially in richer destinations that have greater willingness to pay for quality. We measure products' quality intensity with a product differentiation dummy and with the observed dispersion in inferred output quality across firms, as in Rauch (1999), Khandelwal (2010), and Manova and Zhang (2012). USPTO patent approval also stimulates exports relatively more for products with greater contract reliance, especially to destinations with a stronger rule of law and hence higher demand for such goods. We proxy contract reliance with the need for relationship-specific investments in production and with the complexity of managing more input suppliers, as in Nunn (2007) and Levchenko (2007). We also show that a US patent exerts bigger effects on less seasoned Chinese exporters and for markets with more competitive and more volatile Chinese sellers. This is consistent with a patent signal being more relevant when there is more asymmetric information about a specific supplier and greater supplier heterogeneity.

Finally, we find little support for two other mechanisms through which US patents could in principle enhance the export performance of Chinese firms. The estimated effects across firms with different degrees of financial vulnerability are not indicative of USPTO approval alleviating financial constraints, while patent activity within China does not suggest that patenting in the US enables follow-on innovation or patenting elsewhere.

Our work bridges two large and active strands of research on the drivers and consequences of innovation and patent activity, and on the two-way relationship between international trade and innovation. We bring novel insights that advance the understanding of questions at the heart of both literatures by focusing on the role of patenting for trade performance.

Focal to the innovation literature is how and why patent rights impact firm performance and ultimately aggregate growth. Domestic patent activity in the United States has been of particular interest, in part because USPTO data on both accepted and rejected applications permits causal identification, unlike accepted-only records for other patent authorities. Studies have explored the consequences for patent holders' survival, sales, subsequent innovation, and rent sharing (Galasso and Schankerman 2018; Kline *et al.* 2019; Argente *et al.* 2023), as well as for spillovers across the economy such as the diffusion of new products (Cockburn *et al.* 2016), start-up activity (Farre-Mensa *et al.* 2020), and follow-on innovation by other firms (Williams 2013; Galasso and Schankerman 2015; Williams 2017; Sampat and Williams 2019; Argente *et al.* 2023). Patents have been shown to operate by conferring IPR protection and associated market power within the patent-granting jurisdiction, with some evidence that they can also act as a signaling device to overcome information frictions in capital markets, input markets, and start-up financing (Long 2002; Hsu and Ziedonis 2013; Conti *et al.* 2013a,b). We advance this innovation literature by exploiting customs data to inform the rise in cross-border patent activity and the effects on firm sales both in and outside the patent jurisdiction. We thereby establish a novel quality and credibility signaling role for patents in transacting with buyers in global output markets.

In turn, the link between firm productivity, innovation and trade participation is central to the trade literature. However, selection bias and reverse causality have posed serious identification challenges. There is extensive evidence that firm productivity strongly predicts export activity, global input sourcing, and the response to trade reforms in the spirit of Melitz (2003).[2] There is also growing evidence that export demand shocks and export liberalization induce innovation and technology upgrading, by increasing the associated profit gains and thereby incentivizing firms to incur fixed innovation costs (Lileeva and Trefler 2010; Bustos 2011; Aw *et al.* 2011; Aghion *et al.* 2018; Liu and Ma 2020; Coelli *et al.* 2022).[3] Import competition can likewise boost innovation and upgrading as a means of retaining competitiveness and market share. We move this literature forward by shifting focus to the causal effects of patenting conditional on innovation.

Most directly, we contribute to growing research at the intersection of international trade, patent activity and intellectual property. Earlier macro analysis indicates that destinations with stronger IPR protection attract higher exports, especially for technologically sophisticated products, technologically advanced origin countries, and contexts with greater imitation risk (Maskus and Penubarti 1995; Smith 1999; Ivus 2010; Palangkaraya *et al.* 2017; Lin and Lincoln 2017). Recent work considers cross-border patent activity for the first time, and finds evidence consistent with patents bestowing market protection upon the patent holder in the patent jurisdiction. In the aggregate, Brunel and Zylkin (2022) show that cross-border patents increase the patent-filing country's exports to the patent-granting country. In concurrent work, De Rassenfosse *et al.* (2022) demonstrate that obtaining a patent in a given destination increases French firms' export quantities and sales to that market, using customs data as do we. We provide complementary micro-level evidence that patenting in a renowned patent office such as USPTO causally improves the export performance of firms from emerging markets, both in and outside that patent jurisdiction. We furthermore establish a novel underlying signaling mechanism that is distinct from the market protection mechanism suggested by the aforementioned literature.

Finally, we add to the literature on information asymmetry in international trade. Information frictions pose a substantial barrier to trade (Chaney 2014), as cross-border partners have incomplete information about the supply and demand shocks they incur and more

[2] Bøler *et al.* (2015) find that the introduction of an R&D tax credit in Norway stimulated R&D and imports of intermediates, but not exports. Others structurally evaluate the impact of R&D investment on export outcomes, such as Aw *et al.* (2011) and Maican *et al.* (2020).

[3] See Burstein and Melitz (2013) and Shu and Steinwender (2019) for recent reviews. Endogenous growth models (Costantini and Melitz 2008; Atkeson and Burstein 2010; Van Long *et al.* 2011) also show that lower trade costs can increase firms' incentive to invest in R&D or new technologies.

limited legal recourse in case of contract breaches.[4] This especially plagues exporters from developing countries that produce differentiated products and sell to developed destinations (Rauch 1999). The literature has uncovered various strategies for exporters to overcome this problem. These include reputation building (Banerjee and Duflo 2000), relational contracting and repeat buyer-seller relationships (Macchiavello and Morjaria 2015; Monarch and Schmidt-Eisenlohr 2017), business and social networks (Rauch 1999, 2001; Rauch and Trindade 2002; Guiso *et al.* 2009; Cristea 2011; Bailey *et al.* 2021), trade intermediation (Casella and Rauch 2002; Feenstra and Hanson 2004; Ahn *et al.* 2011), and information and communication technologies (Rauch and Trindade 2003; Steinwender 2018; Akerman *et al.* 2022). We complement this line of work by showing a novel strategy for firms to signal quality capacity and contract credibility, namely by obtaining patent recognition from a global patent hub such as the USPTO.

The remainder of the paper is organized as follows. Section 2 introduces the institutional context and the rich US and Chinese data. Section 3 outlines the empirical approach and IV strategy. Section 4 presents the baseline effects of a first US patent on Chinese exporters. Section 5 evaluates possible underlying mechanisms. The last section concludes.

2 Data and Institutional Context

2.1 Institutional Background

Intellectual property rights (IPR) protection has a long institutional history aimed at establishing new inventions and safeguarding their deployment. In particular, a *utility patent* is a patent that covers the creation of a new or improved product, process, or machine. Also known as a *patent for invention*, it prohibits other individuals or companies from making, using, or selling an invention without authorization.

One of the largest and most active institutions that grants patent recognition is the United States Patent and Trademark Office (USPTO). In the last decade, for example, the USPTO received over 500,000 patent applications each year, of which more than 50% submitted by foreign applicants.[5] USPTO patents legally guarantee IPRs only in the US market.

The USPTO review process ensures quality control and processing efficiency by adhering to a fixed series of steps. Figure A2 illustrates this so-called *patent prosecution process*. Each patent application is first assigned to an *art unit* consisting of a group of patent examiners who specialize in the technology fields related to the patent application. The relevant art unit then allocates the application to an *examiner* within the unit, who is responsible for determining whether the patent meets USPTO's requirements for novelty, non-obviousness,

[4]Most studies consider information frictions from the exporters' perspective. For example, exporters may have incomplete information about foreign demand and market prices (Albornoz *et al.* 2012; Defever *et al.* 2015; Allen 2014), or may need to incur search costs to match with foreign buyers (Eaton *et al.* 2021; Chaney 2014). We focus instead on the incomplete information of importers about the exporter.

[5]See US Patent Statistics Chart, Calendar Years 1963 - 2020.

and usefulness.[6] Finally, the assigned examiner reviews the application and evaluates the patentability of the claimed invention.

A patent examiner typically chooses between two possible *initial office decisions*: a *notice of allowance*, which opens the door to patent granting, or a *non-final rejection*, which requires further revisions by the applicant. The examiner issues a *letter of office action* to the applicant, outlining a detailed justification for the office decision. In the event of a non-final rejection, the applicant has six months to revise and re-submit the application. In an iterative process, the examiner can then issue a notice of allowance or another rejection. Patent applications ultimately end in either *approval* or *abandonment* if the applicant does not re-submit. In our 2001-2020 data, over 80% of initial decisions are non-final rejections, and 62% of all applications are ultimately approved. Foreign patent applications have comparable success rates at 68.9% overall and 70.3% for China.

While the allocation of patents to art units is rather deterministic based on the patent's technology class, the choice of examiner within an art unit exhibits a high degree of randomness. In particular, as Lemley and Sampat (2012) and Sampat and Williams (2019) point out, there is little evidence to suggest that a uniform procedure is implemented by all art units when assigning patent applications to examiners. Instead, each art unit normally adopts different rules, many of which would be functionally equivalent to random assignment. For example, some art units allocate applications to examiners based on the last digit of the application's serial number (Lemley and Sampat 2012). Coupled with significant variation in the conditional probability of granting a patent across examiners, this element of randomness will be key to our empirical identification strategy.

2.2 USPTO Patent Data

The USPTO Patent Examination Research Dataset (PatEx) provides detailed information on all publicly viewable patent applications from 2001 through 2020.[7] We obtain the universe of patent application and examination records for inventors located in mainland China for the period of 2001-2016. This choice of time horizon is governed by the coverage in other data sources we use as described in the next subsection.

We first extract PatEx information for all utility patent applications that are either granted or abandoned between 2001 and 2016.[8] Crucially, we observe the filing date, outcome (issuance or abandonment), and examiner identity for each patent application, as well as the examination history of the examiner.

[6]General Information Concerning Patents of the USPTO website provides a brief introduction of the conditions for obtaining a patent.

[7]For an introduction of the USPTO PatEx Dataset, see Patent Examination Research Dataset (PatEx).

[8]We exclude pending applications and Patent Cooperation Treaty (PCT) applications. PatEx provides no data on applications abandoned before public disclosure (18 months after initial filing), which accounts for around 15% of unsuccessful applications, see Farre-Mensa *et al.* (2020).

We then utilize the residence information in the inventor data to restrict the sample to incorporated assignees (i.e., firms rather than individuals) that are located in mainland China.[9] We later use the names of the patent assignees to match PatEx to Chinese customs data.

Finally, we identify both the ultimate outcome and the initial office decision for each patent from its prosecution process history, which includes the outcome at each examination step. We define the first notice of allowance or the first non-final rejection, whichever takes place first, as the first action taken by the patent's examiner. In the baseline analysis, we consider the impact of ultimate patent approval on export growth from this first-action date. We do not use the patent submission date or the final decision date, since the uncertainty concerning the patent application outcome is unresolved at the patent submission date, and the final decision date is likely endogenous (Farre-Mensa *et al.* 2020).

Key to the empirical analysis is identifying the first US patent application of each Chinese firm. To this end, we standardize assignee names in PatEx in order to track them over time, and exclude assignees with any patent records prior to 2001. We then define the first US patent application for each remaining applicant as the application with the earliest filing date.

Of note, the USPTO began reporting the names of applicants on rejected applications in 2001, after the American Inventors Protection Act came into force in 2000 (Sampat and Lemley 2010). Our definition of a firm's first patent application might therefore be left-censored, as we are not able to verify if an applicant has filed unsuccessful applications prior to 2001. This would arguably occur infrequently, since only a few Chinese companies filed with USPTO before the early 2000s when China emerged on the global scene.

2.3 Chinese Customs and Production Data

The Chinese Customs Trade Statistics (CCTS) cover the universe of export and import transactions in China from 2000 to 2016. The raw data provides rich information at the firm-HS8 product-country transaction level, including the trade value, quantity, regime (ordinary, processing with imports, pure assembly), and transportation type (e.g., land, air).[10]

We are interested in the impact of US patent awards on the export performance of Chinese manufacturers. We, therefore, focus on export transactions under the ordinary and processing-with-imports trade regimes, as both imply full ownership and control over all inputs and production stages. We drop pure-assembly trade flows that entail assembly according to the designs of and with both inputs and distribution provided by a foreign party.[11]

[9] Some patent applications have multiple inventors, and we include them in our sample as long as at least one of the inventors is associated with a Chinese firm. We exclude applicants from Hong Kong, Macao, and Taiwan. We associate each application with the firm that originally submitted it, although the patent assignee (i.e., owner of the patent) can in principle change over time.

[10] Quantity information is missing for year 2016. The Harmonized System (HS) is an internationally standardized system that classifies traded products. There are approximately 8,000 HS-8 product codes, that belong to approximately 5,000 HS-6 product categories.

[11] Our main findings are robust to further restricting the sample to only ordinary exports or to enlarging the

We aggregate the data up to the level of the firm or firm-HS6-destination in different steps of the analysis.

We manually match CCTS export data to USPTO patent records in PatEx based on firms' names and locations. This process involves translating the PatEx names of applicant companies into Chinese. We first translate the keywords within the English names into Chinese, and search the publicly available Chinese company registration database, *TianYanCha*, for any possible matches.[12] To validate the matched outcomes, we then cross-check each candidate's location and main industry of activity against the address and technology class in the patent records. Lastly, we search the CCTS data for the exact Chinese name of the company in order to obtain its customs identifier. Appendix B illustrates this procedure.

We further merge the CCTS-PatEx matched sample with the Annual Survey of Industrial Enterprises (ASIE), which covers all above-scale manufacturing enterprises in China from 2000 to 2013.[13] ASIE provides standard balance-sheet characteristics, such as firm sales, employment, and operating profits, which we consider in robustness and extension exercises.

2.4 A First Glance at the Data

Figure 2 provides an overview of Chinese patent activity in the US and the success rate of the CCTS-PatEx match over the 2001-2016 period. The total number of first-time Chinese applicants in PatEx and the subset of these applicants that we can locate in CCTS have both grown fast during the last two decades, from below 20 in 2001 to around 1000 and 500 respectively in 2016. Furthermore, over half of all Chinese applicants to the USPTO can be matched to CCTS in any given year, suggesting that the majority of US patent applicants from China engage in export activities. Overall, the CCTS-PatEx matched data comprises 2,831 unique CCTS exporters that ever applied for a US patent during the sample period. Patenting is expectedly a rare event, in that these account for a negligible share of all Chinese traders: For example, only about 1% of all exporters in 2016 ever filed for a US patent.

[Figure 2]

Table 1 presents summary statistics for the CCTS-PatEx matched sample, and compares these firms to other exporters in the CCTS data. Exporters who submit for a US patent differ in almost every respect from other exporters: On average, they report two times larger total exports, and direct a bigger share of their exports to the United States (22% vs. 14%). CCTS-PatEx exporters also sell a broader range of products to more destinations, with substantially higher average exports per destination-product pair.

[Table 1]

sample to also include pure-assembly exports.

[12] To enhance our matching process, we utilize the additional information provided in the database, which includes each firm's used names and official English names (if available).

[13] The ASIE data includes all industrial enterprises (Mining, Manufacturing, and Utilities) with annual sales above 5 million RMB (20 million RMB after 2011).

Table A1 illustrates the significant diversification of Chinese patent activity across 450 USPC technology classes. It reports the share of patent applications filed in the top 10 technology classes across all first-time Chinese applicants to the USPTO, as well as in the subset of CCTS-PatEx matched applicants. In both samples, the top 10 technology areas account for under 25%, with pharmaceuticals, molecular- and micro-biology, and electrical systems, components and devices among the most common. These patterns suggest that the CCTS-PatEx matched sample is representative of all Chinese firms filing with the USPTO in terms of patent composition. Moreover, any patent effect we identify on export performance is unlikely to be specific to a few technology classes.

3 Estimation Strategy

How does a US patent grant affect the export performance of Chinese firms? To evaluate this question, we first exploit unique features of our empirical context to quantify the causal effect of a successful first US patent application on the subsequent export growth of Chinese manufacturers. We then examine several economic mechanisms that can rationalize this effect. This section introduces the estimation strategy that underpins our analysis.

3.1 Empirical Specifications

We estimate the impact of a successful first USPTO application on the export performance of Chinese firms with the following baseline specification:

$$\Delta_k EX_{it+k} = \beta \cdot \mathbb{1}(\text{SuccessFirstApp} = 1)_{iajt} + \Gamma Z_{it} + \lambda_{s\tau} + \epsilon_{it}, \tag{1}$$

where i indexes Chinese firms, s denotes i's main industry of activity, τ indicates the year when i filed a USPTO application for the first time, and t marks the year of the first action (i.e., initial outcome) on this application. Subscripts a and j correspond respectively to the USPTO art unit that was assigned to i's first patent application based on its technology class and to the specific examiner in that art unit who reviewed the application. The binary variable $\mathbb{1}(\text{SuccessFirstApp} = 1)_{iajt}$ takes the value of 1 if this patent application is ultimately approved and 0 otherwise. We cluster standard errors at the art-unit level, to allow for potentially correlated decision making across examiners within the same art unit.

In the baseline, we focus on the first US patent application a firm files for two reasons: the rare incidence of patent activity, and the potentially confounding effects of multiple applications over time. The sample in Specification 1 is thus all Chinese firms that have filed at least one US patent application, while the unit of observation is firm i with its first USPTO file. We later explore the role of subsequent patent applications.

The key outcome of interest is the growth in firm i's worldwide exports EX_{it} within k years of the first action on its first US patent application, from t to $t + k$. We set $k = 3$ in the baseline, and perform sensitivity analysis on this horizon. Formally, $\Delta_k EX_{it+k}$ is defined as:

$$\Delta_k EX_{it+k} = \frac{EX_{it+k} - EX_{it}}{0.5(EX_{it+k} + EX_{it})}. \tag{2}$$

The main coefficient of interest, β, in principle captures firm export growth that can be attributed to the granting of a US patent. To be precise, we examine export expansion from the first-action year t onward, consistent with Farre-Mensa *et al.* (2020). As Carley *et al.* (2015) note, a first-action letter provides detailed feedback from the examiner, and serves as a critical signal of the application's likelihood of ultimate success. Therefore, the effect of a patent grant would emerge following the resolution of uncertainty by a first-action letter. In contrast, the initial filing date, which usually occurs 1.5-2 years before the first action, clearly predates any patent-grant effects. The ultimate grant date for successful applications - which may or may not be the first-action date - is likewise problematic, as it is endogenously determined by the applicant's actions.[14]

Specification 1 implicitly and explicitly controls for various firm, sector, and macroeconomic conditions that may influence trade performance independently of patent activity. First, taking export growth as the outcome of interest is equivalent to first-differencing export levels in an event-study regression. We thus implicitly remove level effects of both intransient firm characteristics and time-variant firm attributes at the time of first action. This includes, for example, the firm's productivity level, management practices, quality standards, export experience, and innovation capacity.

Second, we allow for the possibility that certain firm characteristics such as size (which also proxies productivity) and export experience may exert growth effects, by conditioning on a set of firm controls, Z_{it}, as of the time of first action. In the CCTS-PatEx matched sample, these include firm i's log worldwide exports and export tenure, defined as years since the firm is first observed in the CCTS customs records. In the CCTS-ASIE-PatEx matched sample, we further control for log employment as another size metric.

Finally, we add a rich set of industry-application year pair fixed effects, $\lambda_{s\tau}$, that absorb supply and demand factors exogenous to the firm that may shape export growth. Note this is significantly more stringent than standard fixed effects in levels regressions, because these now take out systematic variation in growth rates rather than level shifts. We define these relative to application year τ to capture firms' information set and macroeconomic conditions that may have been relevant to their filing decision, and we later report robustness to alternative timing assumptions. In the broader CCTS-PatEx matched sample, we observe the universe of a firm's export transactions by HS-8 product, and define its primary industry of affiliation as the HS-2 sector with the highest share in its export basket. In the CCTS-ASIE-PatEx matched sample, we use instead the firms' reported main industry of activity at the CIC 2-digit level. In this sample, we are also able to account for time-varying systematic differences across firms of different ownership types (private domestic, state-owned

[14]On average, it takes 342 days from the first action to the final decision for first-time Chinese applicants. This duration is on average longer for approved applications (355 days) than for abandoned applications (307 days).

enterprise, foreign affiliate) with ownership-application year pair fixed effects.[15]

We inform the mechanisms through which patent success might shape export performance by estimating variants of Specification 1 that explore the evolution of different components of export growth at the firm level and the potentially varying expansion across products and destinations within firms.

We first decompose firms' export growth into constituent margins, and study the response of each component to a first US patent by using it as the outcome variable in Specification 1. We distinguish between adjustments along the intensive margin of surviving destination-HS6 product markets and along the extensive margin of new or dropped markets:

$$\begin{aligned}\Delta_k EX_i &\equiv \frac{EX_{ik} - EX_{i0}}{0.5(EX_{ik} + EX_{i0})} \\ &= \underbrace{\frac{\sum_{\omega \in \Omega_{i0}} (x_{i\omega k} - x_{i\omega 0})}{0.5(EX_{ik} + EX_{i0})}}_{\textit{Incumbent}} + \underbrace{\frac{\sum_{\omega \in \Omega_{ik} \setminus \Omega_{i0}} x_{i\omega k}}{0.5(EX_{ik} + EX_{i0})}}_{\textit{New}} \\ &= \underbrace{\frac{\sum_{\omega \in \Omega_{ik} \cap \Omega_{i0}} (x_{i\omega k} - x_{i\omega 0})}{0.5(EX_{ik} + EX_{i0})}}_{\textit{Continue}} - \underbrace{\frac{\sum_{\omega \in \Omega_{i0} \setminus \Omega_{ik}} x_{i\omega 0}}{0.5(EX_{ik} + EX_{i0})}}_{\textit{Drop}} + \underbrace{\frac{\sum_{\omega \in \Omega_{ik} \setminus \Omega_{i0}} x_{i\omega k}}{0.5(EX_{ik} + EX_{i0})}}_{\textit{New}}.\end{aligned} \tag{3}$$

Here Ω_{i0} and Ω_{ik} represent the set of a firm's destination-product relationships at times $t = 0$ and $t = k$, respectively, while $x_{i\omega t}$ denotes the value of a firm's exports to destination-product market ω in year t. We focus mainly on the two-part decomposition into "incumbent" and "new" components, with the former combining changes in activity in maintained markets (the "continue" component) and contraction through market exit (the "drop" component).

In a second exercise, we estimate the impact of a firm's successful first application on export activity directly at the granular destination-product level:

$$\Delta_k EX_{ipdt+k} = \beta' \cdot \mathbb{1}(\text{SuccessFirstApp} = 1)_{iajt} + \Gamma' Z_{ipdt} + \lambda_{p\tau} + \lambda_{d\tau} + \epsilon_{ipdt+k}, \tag{4}$$

where p indexes HS6 products and d denotes destination countries. While this analysis does not constitute an exact decomposition of export growth, it does reveal adjustments to an exporter's portfolio of markets. We focus on two export outcomes $\Delta_k EX_{ipdt+k}$: a binary indicator for the survival of an incumbent destination-product market, and the growth in the value of exports to surviving markets. At this more disaggregated level of analysis, we expand the set of control variables, Z_{ipdt}, to the firm-product-destination-year level. In particular, we now control not only for the firm's overall log exports and export tenure at

[15] Unlike Sampat and Williams (2019) and Farre-Mensa *et al.* (2020), we do not directly control for art-unit by year fixed effects due to a large occurrence of singletons. Instead, we accommodate similar forces by including art-unit by first-action year pair fixed effects when we construct the instrumental variables below.

time t, but also for its log exports and relative export tenure in the specific destination-product market at t[16]. We likewise include a richer set of fixed effects. In place of the HS2 industry-application year fixed effects in Specification 1, we now condition on a full set of HS6 product-application year and destination-application year fixed effects, $\lambda_{p\tau}$ and $\lambda_{d\tau}$. We continue to cluster standard errors at the art-unit level.

We also explore a number of mechanisms that predict a differential export effect of US patenting across products and destinations with specific characteristics. To this end, we adapt the two empirical exercises above to enable difference-in-differences analysis.

Our third exercise revisits the decomposition of export growth at the firm level to assess the contribution of different product and destination types. We now re-estimate Specification 1 for export growth components that capture trade in product category p (e.g., differentiated vs. non-differentiated) to destination category d (e.g., high-income vs. low-income):

$$\begin{aligned}\Delta_k EX_i &\equiv \frac{EX_{ik} - EX_{i0}}{0.5(EX_{ik} + EX_{i0})} \\ &= \frac{\Sigma_{p \in P} \Sigma_{d \in D} (EX_{ipdk} - EX_{ipd0})}{0.5(EX_{ik} + EX_{i0})},\end{aligned} \tag{5}$$

Finally, we operationalize a modified version of Specification 4 at the firm-product-destination-year level, where we consider the differential effect of a successful first US patent application within a firm across product and country categories. We now split the sample by product type, and interact the main indicator variable of interest, $\mathbb{1}(\text{SuccessFirstApp} = 1)_{iajt}$, with a relevant country characteristic, Z_d. In addition to product-application year and destination-application year pair fixed effects, we further add a full set of firm fixed effects, λ_i, which subsume the role of log exports and export tenure at the firm level. We continue to condition on firm-product-destination-year log exports and relative export tenure, as well as to cluster at the art-unit level:

$$\Delta_k EX_{ipdt+k} = \beta^{DD} \cdot \mathbb{1}(\text{SuccessFirstApp} = 1)_{iajt} \cdot Z_d + \Gamma^{DD} Z_{ipdt} + \lambda_i + \lambda_{p\tau} + \lambda_{d\tau} + \epsilon_{ipdt+k}. \tag{6}$$

3.2 Identification

Estimating the impact of a patent grant on trade performance poses identification challenges. Recall from Table 1 that Chinese firms filing for a US patent are very different from Chinese firms that do not, such that one cannot simply compare their export performance. One concern is omitted variable bias: the decision to apply for a US patent might be correlated with unobserved firm characteristics that also directly shape export performance, such as production efficiency or innovation capacity. Another concern is reverse causality: firms' opportunities for export expansion may boost their current R&D and patent intensity due

[16]Relative export tenure is defined as the firm's product-destination specific tenure divided by its overall export tenure.

to economies of scale in innovation.

We use a two-pronged strategy to overcome this identification challenge. The first prong is to restrict the sample to firms that file for patent recognition in the first place, and to assess the impact of a patent award conditional on a patent application. In other words, rather than comparing innovative firms to their non-innovative peers, our treatment and control groups are both highly innovative firms that we will see are observationally similar prior to their first US patent filing.

The coefficient of interest in Specification 1, β, should thus in principle reflect the average treatment effect (ATE) of a successful first US patent application on an applicant's subsequent overall export growth. Analogously, coefficient β' in Specification 4 should capture the ATE on a firm's export growth within individual destination-product markets, accounting for market-specific supply and demand conditions. The difference-in-differences coefficient β^{DD} in Specification 6 should in turn quantify the heterogeneous effect of a patent grant across destination and product markets within firms.

Even if successful and failed patent applicants are observationally similar ex-ante, OLS estimates of these coefficients could nevertheless still be biased. In particular, the unobserved quality of underlying R&D and the unobserved potential for export expansion may vary across patent applicants, such that some concerns with omitted variable bias and reverse causality may remain.

To isolate the causal effect of a successful first US patent application, the second prong of our identification strategy is to develop an instrument for patent approval that exploits idiosyncratic features of the USPTO institutional context. We use the random allocation of applications to examiners within an assigned art unit, combined with systematic variation in examiner leniency that is exogenous to the applicant and to the allocation process.

USPTO examiners have been shown to vary substantially in their propensity to grant patents (Lemley and Sampat 2012). In other words, given the quality of an invention, its patent application is more likely to be approved if it is assigned to a more lenient examiner. We thus follow Sampat and Williams (2019) and Farre-Mensa *et al.* (2020), and instrument the outcome of a firm's first US patent application, $\mathbb{1}(\text{SuccessFirstApp} = 1)_{it}$, with a proxy for the ex-ante expected approval rate of its quasi-randomly assigned USPTO examiner. We measure an examiner's (potentially time-varying) leniency relevant for a specific application based on their examination history prior to reviewing that application:

$$ApprovalRate_{iajt} = \frac{\#Granted_{iajt}}{\#Examined_{iajt}}.$$

Here $\#Examined_{iajt}$ and $\#Granted_{iajt}$ denote respectively the number of patents that examiner j in art unit a has examined and granted prior to making a decision on application i in year t.

As noted earlier, the USPTO assigns patent applications to the art unit specializing in the technology field of the underlying invention. In contrast, there are no explicit rules governing the assignment of applications to examiners within each art unit, such that it is quasi-random and can be viewed as a lottery (Farre-Mensa *et al.* 2020). Nevertheless, one may be concerned that approval rates vary systematically across art units and over time. Although it is arguably unlikely that firms have such real-time information and capacity to quickly act on it, they may in principle strategically time their patent application. To address this concern, we demean examiners' approval rates by art unit and first-action year. Figure A3 confirms that the distribution of the demeaned approval rates, $\widehat{ApprovalRate}_{iajt}$, is highly dispersed.

[Table 2]

Table 2 demonstrates that $\widehat{ApprovalRate}_{iajt}$ is indeed a strong predictor of a firm's first patent application outcome, $\mathbb{1}(\text{SuccessFirstApp} = 1)_{it}$, and thus meets the relevance criterion for instrumental validity. We report first-stage regressions for the subsequent second-stage IV estimation of Specification 1. We present results separately for the full sample of CCTS-PatEx matched firms and the subsample of CCTS-ASIE-PatEx matched firms, where we include the fixed effects and progressively richer firm-year controls as in Specification 1. A 1 percentage-point increase in the examiner's demeaned ex-ante approval rate induces $0.95 - 0.97$ percentage point higher likelihood of a patent grant. These effects are consistently highly statistically significant at 1%. Figure A4 verifies that the kernel density distribution of examiners' ex-ante approval rates for ex-post approved applications is a shift to the right compared to ex-post rejected applications.

We also perform balance tests to confirm that demeaned examiner approval rates are uncorrelated with observed ex-ante exporter characteristics. This lends credibility to the assumption of quasi-random allocation of patents to examiners that underpins the instrument's exclusion restriction. In Table 3, we regress a series of firm attributes as of the first-action year alternatively on $\mathbb{1}(\text{SuccessFirstApp} = 1)_{it}$ or $\widehat{ApprovalRate}_{iajt}$, controlling for the same set of fixed effects as in Specification 1. We find that neither variable is systematically correlated with firm profits, sales, employment, exports, number of export products, number of export destinations, or average exports per destination-product, with the exception of a weak negative correlation between product scope and application success (but importantly not with the instrument).[17]

[Table 3]

Righi and Simcoe (2019) point out that the matching of patent applications to examiners may not be completely random due to examiner specialization. They recommend conducting

[17] Table A2 conducts additional balance tests on the product and country composition of firm exports. While successful and unsuccessful applicants differ along a few dimensions (such as their share of exports to the US or OECD countries), the demeaned examiner approval rate is uncorrelated with all composition measures, except for the export share of products that are technologically related to the patent application. We have confirmed the robustness of the baseline results to further controlling for this variable.

validation tests on the first-stage estimation that control for additional examiner characteristics, to check whether the magnitudes of the estimated coefficients remain stable. In Table A3, we perform several such additional validation tests. We condition on examiner experience by adding the number of Chinese, foreign, and all patent applications she has reviewed as of the first-action year. We also construct an alternative approval rate that is demeaned by both art unit by first-action year and technology class by first-action year. The estimates for β range in the narrow band of 0.8 to 1 and within 10% of the baseline in Column 1. We conclude that the allocation of patent applications to examiners appears to be largely exogenous in our sample of Chinese applicants. This is plausible given China's small share of all USPTO filers.

Finally, while Barber IV and Diestre (2022) propose that some firms can influence examiner selection by strategically timing patent citations in their application, we believe this to be unlikely for first-time Chinese applicants. First, as Table 3 demonstrates, examiner leniency is not correlated with key firm characteristics, indicating that better-performing firms are not any more or less likely to be assigned more lenient USPTO examiners. Second, first-time foreign applicants are unlikely to have access to experienced patent prosecution lawyers who can identify lenient examiners. Lastly, Barber IV and Diestre (2022) suggest that examiner shopping is less prevalent in highly litigious technology fields such as pharmaceuticals and biotechnology, and we find little evidence that Chinese applicants avoid these fields (see Table A1).

4 Effect of US Patenting on Chinese Exporters

We analyze the effects of patenting in the US on the export performance of Chinese firms in two steps. In this section, we agnostically establish that a successful first US patent application significantly increases firms' subsequent export growth. We also examine the response of different trade margins. We then explore in Section 5 the mechanisms that give rise to these effects.

4.1 Event Study

We begin by documenting the evolution of Chinese firms' exports following a USPTO patent application with a flexible event study. We track the log exports of first-time patent applicants from five years before to five years after their first-action year. We estimate the export differential between successful and unsuccessful candidates for each year in this 11-year event window using an OLS regression with the same fixed effects as baseline Specification 1. We also estimate an OLS regression with the patent examiner leniency in place of the patent award indicator, which provides a reduced-form, event-study counterpart to the baseline 2SLS specification.

[Figure 3]

We visualize the event study in Figure 3. Reassuringly, we find no significantly different pre-trends between successful and unsuccessful applicants, nor among applicants assigned to examiners with varying rates of approval. After the patent event, by contrast, the exports of applicants with granted patents and with more lenient examiners expand significantly relative to those respectively with rejected applications and with stricter examiners. Moreover, the export gap widens quickly within 2 years of the patent decision, and remains stable thereafter.[18]

These findings suggest that the effects of a patent grant materialize quickly and are relatively persistent 5 years out. This motivates our focus on export growth in the 3 years after a favorable patent review in the empirical analysis below.

4.2 Baseline Results

We evaluate the baseline effects of a first US patent on the export growth of Chinese firms in Table 4. We present results from estimating Specification 1 in the full sample of CCTS-PatEx exporters (Columns 1-3) and in the subsample of CCTS-ASIE-PatEx matched exporters (Columns 4-6). We consider both the naive OLS regression and the 2SLS regression instrumenting the indicator for a successful first USPTO application with the demeaned examiner's approval leniency. We condition on a full set of HS2 industry by year pair fixed effects in the CCTS-PatEx data, and on a richer set of both CIC2 industry by year and ownership type by year pair fixed effects in the CCTS-ASIE-PatEx data.[19] We explore the stability of the results to controlling for initial log exports and export tenure, to account for potential convergence or divergence processes and to accommodate export life-cycle dynamics. In the CCTS-ASIE-PatEx panel, we further add log employment as a proxy for firm size. We cluster standard errors by art unit, to permit correlation in decision outcomes across applications reviewed by the same art unit.

[Table 4]

We find consistently large, positive effects of a successful first US patent application on the future export performance of Chinese applicants. Naive OLS estimates suggest that patent recipients experience 6-6.7 percentage points higher annualized 3-year export growth than rejected applicants. These estimates are highly significant at least at the 5% level. The 2SLS results indicate even larger causal effects significant at the 1%: A successful first patent application triggers 17.2-17.5 percentage points faster annual growth in the CCTS-PatEx sample, and grants as much as a 20.1-21.7 percentage point advantage in the CCTS-ASIE-PatEx subsample.[20] The findings are generally not sensitive to the choice of firm controls.

It is noteworthy that the 2SLS estimates in Table 4 are about three times bigger than the OLS estimates. One possibility is that OLS is subject to downward omitted variable bias due

[18] The rapid increase in the treatment effect during the first two years following the initial action aligns with the fact that 70.4% of applicants in our sample received final decisions (either granted or rejected) within a year of the first action.

[19] The sample spans 66 HS-2 industries and 28 CIC-2 industries.

[20] For reference, Farre-Mensa *et al.* (2020) estimate that a successful first US patent application leads to 80% higher cumulative 5-year sales growth in US start-up firms.

to unobserved firm or patent quality. Standard models of firm heterogeneity would predict that inherently better firms have both superior export performance and higher innovation quality. This would generate a positive correlation between export levels and the likelihood of a patent grant. Whether export growth and patent success would be positively or negatively correlated, however, depends on assumptions about export dynamics. Separately, firms may differ along two dimensions - production efficiency and innovation capacity - that can in principle be negatively correlated. Even if these were positively correlated in the long run or there were a single dimension of firm heterogeneity, there may be a trade-off between export and innovation success, at least short-term, because of limited managerial attention, financial constraints, or capacity constraints. These are examples of forces that can introduce negative bias in the baseline OLS regression.

A second possible explanation for the larger IV estimates is that they identify the causal local average treatment effect (LATE) of the patent grant on export growth, while OLS quantifies the average treatment effect (ATE). The LATE could be larger if exporters whose patent applications are marginally approved or rejected by USPTO examiners are more responsive to the patent grant event than the average exporter who applies for a US patent. In this case, the IV approach would still deliver more reliably causal and unbiased estimates, but they would need to be interpreted with caution when extrapolating to patent impacts across the full firm distribution.

4.3 Margins of Adjustment

How do Chinese firms expand exports following a successful US patent approval? We now examine how firms adjust along various margins, in order to guide the subsequent analysis of the mechanisms through which patent grants stimulate trade activity. We present results only for the CCTS-PatEx sample in the interest of space; similar patterns obtain in the matched CCTS-ASIE-PatEx subsample.

First, we assess the impact of a successful first US patent application on the growth rate of different trade margins. As shown in Table A4, a patent award triggers expansion along both the extensive and the intensive margins of exports. In particular, patent recipients do not significantly broaden their overall product portfolio or country reach, but they do serve more destination-product markets, evidently by offering more of their traded varieties to more of their trade destinations. Patent awardees also increase sales in incumbent destination-product markets. In terms of annualized 3-year growth rates, the number of markets and average exports per market grow respectively 7.8% and 11.4% faster for successful applicants than for rejected applicants.

[Table 5]

Second, we decompose firm-level export growth into constituent margins in an accounting exercise per Equation 3. Table 5 reports 2SLS results for the impact of a first US patent grant on the incumbent and new export components in terms of pre-existing and newly-added destination-product markets. Fully 87.4% (0.153/0.175) of the overall export effect is driven by growth in incumbent markets, with the point estimates highly significant at 1%. By contrast, new market entry explains only 12.6% (one eighth), and the point estimates are statistically insignificant.[21] Further explorations in Table A6 reveal that growth in the incumbent component reflects greater survival of existing destination-product links and expansion in continuing destination-product markets in equal measure. Since we don't observe the identity of foreign buyers in the Chinese trade data, the results are consistent with the granting of a US patent enabling exporters to increase sales to existing customers and/or to establish new trade relationships in incumbent destination-product markets.

Third, we further unpack these adjustment margins by analyzing the survival probability of incumbent export flows and the behavior of export value, price and quantity of continuing export flows at the firm-product-destination level. Table 6 reports the results from estimating Equation 4 with a full set of HS6 product by year and destination by year pair fixed effects.[22] This is a more stringent specification in that it accounts for supply and demand conditions not just across broad industries, but within narrower segments of the global economy. We purposefully do not add firm fixed effects, to make this margin analysis comparable to the baseline. However, we do control for initial log exports at both the firm and the firm-product-destination level, as well as for the overall export tenure of the applicant and the relative tenure of the specific product-destination in the applicant's export portfolio.

[Table 6]

Even at this granular level of analysis, we continue to observe that successful patent applicants have a much greater probability of maintaining existing destination-product markets and grow their export sales faster in continuing markets, compared to failed applicants. Although sizeable, the point estimates are statistically insignificant in the baseline IV regressions that give equal weight to all firm-product-destination triplets (Columns 2 and 5 in Panel A). However, they become larger and statistically significant at conventional levels when we account for the skewed distribution of firms' export portfolios and weight observations by their firm-specific initial export share (Columns 3 and 6 in Panel A): A successful first application improves the survival rate of incumbent export flows by 14.3% and the value growth of surviving relationships by 23.3%. The stronger weighted-IV results suggest that patent grants are especially beneficial for the core destination-product markets in a firm's export basket, rather than for its peripheral links. Panel B in turn examines the sources of export value growth in maintained destination-product markets. Export expansion occurs entirely through higher quantities traded, while export prices barely move.

Finally, we consider patent activity beyond the first patent application. Our baseline examines the effect of a successful first US patent application for two reasons. Conceptually, we conjecture that the first patent grant is the most critical event, compared to potential subsequent applications. Moreover, patent activity is rare in the full population of Chinese

[21] Table A5 repeats the decomposition exercise in the CCTS-ASIE-PatEx subsample. The point estimate on the new component becomes statistically significant at 5%, but still explains only 24% of the overall export growth effect.

[22] There are approximately $2,900$ HS-6 product categories in our sample.

exporters, while 39.6% of patent applicants in the CCTS-PatEx panel file multiple times with USPTO. Pooling the effects of all of a firm's patents - or comparing the effects of its first, second or third patents - may thus be prone to sample selection bias, confounding effects across applications, and weak identification power.

For completeness, we explore the role of a successful second patent application in Table A7. The sample is now reduced to the second patent filing of 274 Chinese exporters that have submitted at least two USPTO applications and had their first application approved. Consistent with our conjecture, a second patent award exerts a much smaller effect on annualized 3-year export growth (2.6%-5.0%) than the first, and the 2SLS estimates are statistically insignificant. This echoes evidence in Farre-Mensa *et al.* (2020) that unlike a first US patent, a second US patent has no further effect on US start-ups. Nevertheless, given the limited sample size, we view this as only suggestive evidence.

In sum, a first US patent grant significantly stimulates firms' export growth by raising firms' survival probability in incumbent destination-product markets and by increasing export quantities and thereby export sales in surviving markets. These effects are economically large and become muted for subsequent patent approvals.

4.4 Sensitivity Analysis

We next confirm the robustness of the baseline results to several sensitivity checks. We begin with a placebo test of whether export growth over the three years prior to a patent grant "responds" to the award of a first successful US patent. Recall from the balance tests (Table 3) and event study (Figure 3) that successful and unsuccessful patent applicants have similar ex-ante export trends. Consistent with this, both the OLS and the IV placebo estimates in Table A8 are small in magnitude and statistically insignificant. This provides further assurance that the baseline findings are unlikely to be driven by the correlation of unobserved ex-ante determinants of export performance and USPTO decisions.

We next demonstrate in Table A9 that our results are robust to a number of alternative specifications. Column 1 replicates the baseline regression from Column 3 of Table 4 for reference. Column 2 uses an alternative instrumental variable, whose construction removes not only art unit by year but also technology class by year pair fixed effects. Column 3 presents bootstrap-cluster standard errors to address concerns that demeaning the examiner leniency measure may bias standard errors in the 2SLS regression (Dobbie *et al.* 2018).[23] Column 4 controls for additional examiner characteristics following Righi and Simcoe (2019), namely their years of experience and log numbers of foreign and Chinese patents reviewed. Columns 5-7 experiment with different sets of fixed effects at the level of HS2 by first-action year, application year, or first-action year, in place of the baseline HS2 by application year fixed effects. All estimates remain highly statistically significant and quantitatively similar across

[23]Specifically, we re-sample the full sample of patent examination records at the examiner level with replacement, compute the demeaned examiner leniency, and then run the 2SLS regressions within the sample data. Column 3 reports results from the bootstrap procedure with 200 simulations.

perturbations.

Finally, we consider the role of a successful US patent application in relation to firms' patent activity in other jurisdictions. Firms can in principle secure IPR protection for the same patent in multiple countries by submitting it to each of their respective patent authorities; such multiple applications constitute a patent family. While each authority makes an independent decision that grants market rights only in its jurisdiction, there is a multinational Patent Cooperation Treaty (PCT) that allows patents approved by multiple authorities to be legally valid as of the first of these approval dates. Since a Chinese exporter getting a US patent may in principle also obtain patent rights in other jurisdictions, it is possible that the estimated effects of a US patent capture instead of the role of patent awards elsewhere or depend on the precedence of the US patent in case of multiple patent awards.

Using data on Chinese firms' global patent activity, we find that a first successful US patent significantly boosts export growth independently of whether the same patent is filed with three other leading patent agencies. In particular, we obtain data on Chinese firms' applications under the same patent family as their first USPTO application filed with the European Patent Office (EPO), the Japanese Patent Office (JPO), or the China National Intellectual Property Administration (CNIPA) from De Rassenfosse *et al.* (2019). For each USPTO application, we construct indicator variables for whether an application from the same patent family is ever submitted to EPO, JPO, and CNIPA, respectively. We also construct an indicator for whether the US application was filed first, making it the priority claim of the patent family. In Table A10, we repeat the baseline analysis controlling for these four dummies. Columns 1 and 2 show that both the OLS and the IV estimates remain qualitatively and quantitatively unchanged. Column 3 further establishes that the impact of a first US patent grant does not depend on its priority-claim status. While these results further corroborate the significant causal effect of a first US patent grant, they should not be taken as implying that patenting in other jurisdictions has no impact on firms' export activities, as any such impact is beyond the scope of our empirical design. We have confirmed the robustness of all other results in the paper to controlling for global patent activity.

5 Impact Mechanisms

Why should a US patent grant benefit Chinese firms' export growth? We next consider several possible mechanisms that are not mutually exclusive, and confront their distinctive predictions with data. We conclude that the effects of a US patent award cannot be easily attributed to the protection of a firm's market power in the patent's jurisdiction. Instead, we find evidence consistent with a US patent providing both a *quality capacity signal* and a *contract credibility signal* that reduce asymmetric information about a firm's output quality and contractual trustworthiness. Additional analysis reveals little support for US patent awards alleviating *financial constraints* or enabling *follow-on innovation*.

5.1 Market Protection

By definition, a patent grants the patent owner exclusive rights to the use of a new technological solution (invention) for a specified period of time. Thus, a natural conjecture is that patents bestow market protection that allows the inventing firm to charge monopoly prices and gain monopoly profits (Balasubramanian and Sivadasan 2011; Kogan *et al.* 2017; Kline *et al.* 2019), or secure legal rights to expand their sales in the patent jurisdiction (Brunel and Zylkin 2022; De Rassenfosse *et al.* 2022). Since a patent granted by the USPTO to a Chinese firm has legal recognition only in the US market, this market protection mechanism would imply that the Chinese firm would be able to charge a higher export price and/or expand its export scale in the US, but not in other markets. Moreover, these effects would be confined to the products that are directly covered by the patent and not carry over to other products:[24]

Hypothesis 1 (Market Protection) US patent rights strengthen exporters' market protection and sales of protected products in the US, but not in other products or markets.

To test this hypothesis, we examine whether the overall patent effect on export growth is driven by exports to the US of products in a firm's portfolio that are most likely to be covered by its patent award. We also assess whether both the value and the price of such export flows increase.

These exercises require a mapping between patents in PatEx and HS 6-digit products in customs data. We identify products that are technologically related to a given patent and thus arguably have the greatest probability of patent protection based on two alternative semantic similarity analyses. The first method applies Natural Language Processing (NLP) and machine learning techniques to the textual descriptions of individual patents and HS-6 product categories (similar to Argente *et al.* (2023)). For each patent, we define technologically related products to be those above a threshold of 80% semantic similarity (see Appendix C for details). The second method applies Algorithmic Links with Probabilities (ALP) weights to similarity indices for keywords in the descriptions of USPC technology classes and HS-6 products, constructed by Lybbert and Zolas (2014) and Goldschlag *et al.* (2020). We pair HS-6 products and USPC classes based on a conservative cut-off of ALP weights $> 5\%$, but our results are robust to using ALP weights $> 0\%$.[25] While the first method offers greater accuracy in matching products to specific patents rather than patent classes, we view the two methods as providing lower and upper bounds for the market protection channel manifesting in the data.

[24] Complementarity or substitution in consumption could in principle increase or decrease sales of other products in the firm's portfolio to the US, but still not to other destination countries.

[25] We use the ALP weights from Lybbert and Zolas (2014), who develop them as follows: (1) Compare keywords in HS-6 product descriptions with keywords in patent abstracts; (2) Tabulate the number of patents in each USPC class X HS-6 product pair in the resultant m-to-m matches; (3) Re-weight the results using a modified Bayesian weighting scheme, the hybrid weighting approach, which increases the weights of specific matches and reduces the weights of generalized matches. Branstetter *et al.* (2021) also use these weights.

We perform two tests of Hypothesis 1. We first implement a growth accounting exercise following Equation 5. We decompose firms' total export growth four-way into exports to the US vs. Rest Of the World (ROW) and products that are technologically related vs. unrelated to the firm's patent. We quantify the impact of a successful first US patent application on each of these constituent components, such that the coefficient estimates across them add up to the total growth effect. We use the CCTS-PatEx sample and the same fixed effects and controls as in the baseline. We report the full regression results in Table A11, and visualize the response of each destination-product type market with bar plots in Figure 4.

We find that the export growth of Chinese firms following the approval of their first US patent application is driven mainly by an expansion of exports of patent-unrelated products to the ROW, whose growth share amounts to 79.5% – 82%. Instead, exports of patent-related products to the US contribute a trivial 0.3% using the stringent NLP patent-product match and a statistically significant but nevertheless modest 15% using the more liberal ALP patent class-product match.[26]

[Figure 4]

As a second test of Hypothesis 1, we turn to the granular firm-destination-product level. In Table 7, we evaluate the differential impact of a US patent award on the growth in export values and prices across destinations and products within firms, for the sample of continuing firm-destination-product triplets. We estimate Specification 6, where we regress the growth of the relevant export margin on the indicator for a successful first US patent application interacted with a dummy for the US as the destination country. We run this regression first pooling all products and then separately for products that are technologically related vs. unrelated to the firm's patent application. We add all controls, product-application year and destination-application year pair fixed effects as in the baseline, but now further include firm-application year fixed effects. We consistently observe that Chinese exporters do not revise the pricing or sales of their surviving relationships differentially in the US market. This holds regardless of how we measure product relatedness.

[Table 7]

In sum, we find little evidence for the market protection mechanism, whereby a first US patent grant improves the export performance of Chinese awardees by giving them exclusive market rights for patent-protected products in the US. Instead, results point to alternative mechanisms that enable broader-based expansion of a firm's export activity across products and markets.

[26] In a separate exercise, we repeat the baseline regression for the export growth rate of each component of firms' total exports, instead of its contribution to the growth in total exports; the difference is in the denominator of each component. Table A12 demonstrates that the impact of the first US patent grant on export growth in the US market, particularly for technologically unrelated products, is statistically significant and of a similar magnitude to the effect on the export growth in non-US markets of technologically unrelated products. In line with Figure 4, this suggests that although firms' exports to the US market rise following their first US patent grant, this constitutes a minor portion of their total export growth.

Our findings differ from and complement recent evidence in Brunel and Zylkin (2022) and De Rassenfosse *et al.* (2022) of pro-exports effect of patenting driven by market protection, i.e. firms securing legal rights and competitive advantages in the patent jurisdiction. We attribute this to differences in both the institutional context and the scope of analysis. First, while these studies explore the level (and differential) effects of cross-border patenting on exports to the patent jurisdiction (relative to elsewhere), we explicitly assess the main and differential effects on export growth to both the patent jurisdiction and the rest of the world. Second, while Brunel and Zylkin (2022) and De Rassenfosse *et al.* (2022) evaluate patenting across many jurisdictions, we focus on patenting in the US, the most established and renowned patent jurisdiction that may therefore confer reputational benefits beyond local market protection. Finally, while the previous analyses consider firms from either advanced economies or a wide spectrum of origins, we examine firms in China, an emerging economy with relatively weak IPR and notorious reputation for product quality and contract enforcement. We conclude that a US patent boosting Chinese firms' export growth to the US (Table A12) is consistent with the market protection mechanism established in earlier work, but this mechanism alone explains little of the overall export growth of Chinese patenting firms (Figure 4).

5.2 Asymmetric Information

Chinese firms may apply for a US patent not only to ensure market protection for a specific product in the US, but also to enhance their export activity in other destination-product markets. One possibility is that receiving a US patent constitutes a signal that can alleviate information frictions in international trade. In the presence of such frictions, meeting the high standards of the USPTO examination process can give firms a globally recognized stamp of approval, and thereby allow them to expand into products and destinations that are not directly affected by the market protection granted by the US patent. Moreover, this signaling mechanism can rationalize not only the large export boost following a successful first US patent application, but also the insignificant impact of subsequent patent awards that presumably contain less novel information on the margin.

Information asymmetry between buyers and sellers can arise for various reasons and therefore manifest in different ways. It is arguably more costly in international than domestic transactions, because international partners are less familiar with foreign economic conditions, risk bigger hold-up problems in finding alternative buyers and suppliers, and face greater contractual frictions due to transacting across jurisdictions. Asymmetric information would presumably be more problematic, and hence the value of a patent signal greater, for exporters from a country with less developed institutions and greater heterogeneity in firm quality and credibility, such as China.

We now provide evidence consistent with a US patent sending a signal about two desirable attributes of a Chinese firm: the capacity to deliver high-quality products and the credibility to honor contractual obligations. The common premise of both signaling mechanisms is that they would be more important for some products and destinations than others, such that we can exploit cross-group heterogeneity to uncover evidence of each mechanism that cannot easily be accounted for by alternative explanations.

5.2.1 Quality Capacity Signal

More successful exporters have been shown to use higher-quality inputs to produce higher-quality products, sell to customers in more destinations, and generate higher export revenues (Manova and Zhang 2012; Manova and Yu 2017).[27] These forces are especially relevant for products with greater scope for quality differentiation and for richer markets with greater willingness to pay for quality under non-homothetic preferences.

We conjecture that when downstream producers and final consumers have imperfect information about the quality of a firm's products, the approval of a US patent invented by that firm can convey a strong signal about the firm's capacity to deliver high quality in principle and to enforce quality control in practice. Such a signal can plausibly improve a seller's image across its product portfolio. We expect the quality signal to stimulate trade relatively more for products with greater scope for quality differentiation, when buyers are especially concerned about transacting with a reliable supplier. Moreover, imperfect information about product quality would be more problematic, and hence quality assurance more consequential, for buyers located in markets with richer consumers that value quality more:

Hypothesis 2 (Quality Capacity) US patent rights signal firms' quality capacity under asymmetric information, and increase firm exports disproportionately more for products with greater scope for quality differentiation, especially to destinations with higher income.

We confront Hypothesis 2 with data using the two complementary exercises: export growth accounting at the firm level, and assessing the differential export growth across destination-product markets within firms. We obtain cross-country data on log GDP per capita from the World Bank Data, and classify countries above the sample median as high-income. We exploit two standard proxies in the literature for the scope for quality differentiation at the level of HS 6-digit products. The first is an indicator for differentiated goods that are neither traded on an organized exchange nor listed in reference-price volumes, as in Rauch (1999). The second is the coefficient of variation of estimated quality across firms within an HS-6 product. We compute the latter in the full CCTS panel of Chinese exporters, after inferring each firm's export quality from its export quantity and price data as in Khandelwal (2010).[28]

[Figure 5]

Figure 5 visualizes the four-way decomposition of the effect of a US patent grant on the export growth of Chinese applicants, based on the regression analysis in Table A13. Consistent with the quality signal mechanism, a US patent award acts almost entirely by expanding sales of products with high scope for quality differentiation, with a small and statistically insignificant effect on other products. While exports increase to destinations with income above and below the median, this expansion is always concentrated in products with more

[27] See also the pricing-to-market literature (e.g., Jung *et al.* 2019) and the quality-and-trade literature (e.g., Fan *et al.* 2020) featuring variable markups under the assumption of non-homothetic preferences.

[28] Specifically, we assume $\ln q = \sigma \ln p + \ln x$, where q is quality, p is price, x is quantity, and $\sigma = 5$.

quality heterogeneity. Overall, about 61-73% of the overall export growth of patent recipients is driven by exports of quality-sensitive goods to richer markets (0.106/0.175 - 0.128/0.175). These patterns hold when we distinguish between differentiated and non-differentiated goods, as well as when we compare products with estimated quality dispersion above vs. below the median.

[Table 8]

We complement this growth decomposition with corroborative evidence for the differential effect of a US patent award across products and destinations within firms. In Table 8, we examine the probability of export survival and export growth conditional on survival at the firm-product-destination level. We regress each outcome on the interaction of a successful US patent application with destination log GDP per capita, and consider both the full sample and subsamples of products with high vs. low scope for quality differentiation. We find strong evidence that an approved US patent improves the probability of export survival disproportionately more for richer markets. This effect is moreover fully driven by goods with a high degree of quality heterogeneity. In contrast, continuing export flows to incumbent markets grow at the same pace across products and destinations within firms.

5.2.2 Contract Credibility Signal

Buyers and suppliers often have to make relationship-specific investments, such as customizing production equipment, sourcing appropriate inputs, and manufacturing according to precise product specifications. This gives rise to hold-up problems ex-post and under-investment ex-ante when contracts are incomplete and cannot be fully enforced (Grossman and Hart 1986; Hart and Moore 1990). Because country borders raise information asymmetry and hinder contract enforcement, contractual frictions are especially acute in international trade and significantly deter trade activity. Indeed, countries with stronger rule of law and contract enforcement have been found to export significantly more in contract-intensive sectors that require more relationship-specific investments and to display greater import demand (Anderson and Marcouiller 2002; Nunn 2007).[29]

We conjecture that the approval of a US patent can send a strong signal about the contract credibility of the Chinese patent recipient. This signal can reassure buyers in any market that the Chinese supplier has the technological know-how to make relationship-specific investments and the trustworthiness to honor contracts. We expect this signal to give more impetus to trade in products with higher contract reliance. Moreover, we reason that buyers in countries with stronger contract enforcement will respond more to a credibility signal because they are more capable of transacting in contract-reliant goods and thus have higher demand for such goods:

Hypothesis 3 (Contract Credibility) US patent rights signal firms' contract credibility under asymmetric information, and increase firm exports disproportionately more for products with higher contract reliance, especially to destinations with stronger rule of law.

[29] A large literature also examines the impact of contractual frictions on the organization of multinational activity, see for example Antràs (2003).

We empirically evaluate Hypothesis 3 by examining to what extent the rise in export growth following the award of a US patent is driven by exports of contract-sensitive goods and markets with sound contract institutions. We measure the strength of countries' contract enforcement with the overall rule of law index from Kaufmann *et al.* (2003), as in Nunn (2007). We exploit two standard industry indicators of contract reliance, which we map to HS 6-digit products in our data: contract intensity from Nunn (2007) at the ISIC 3-digit level, and complexity (or institutional intensity) from Levchenko (2007) at the SIC 4-digit level. The former reflects the value share of an industry's inputs that are differentiated and presumably require relationship-specific investments in production. The latter is the inverse of the Herfindahl index of intermediate input use across input categories, meant to capture the number of essential suppliers that firms need to contract with.

[Figure 6]

Figure 6 decomposes the effect of receiving a US patent on Chinese firms' export growth four-way according to product contract reliance and destination contract enforcement, based on regression estimates in Table A15. Consistent with the credibility signal mechanism, the baseline patent effect is almost entirely driven by the expansion of exports to countries with a strong contract environment. Moreover, within those markets export expansion is concentrated in products that are highly reliant on relationship-specific investments and complex products that depend on many production inputs. Approximately $66\% - 74\%$ of the overall boost to export growth stemming from a first US patent thus occurs in contract-sensitive goods markets to countries with strict rule of law (0.115/0.175 - 0.130/0.175).

[Table 9]

Table 9 provides further support for the credibility signaling mechanism based on the differential response of export activity across products and destinations within firms. We now regress the survival indicator and export growth in continuing markets on the interaction of a first successful US patent and the importer's rule of law at the firm-product-destination level. We do so first pooling across all products and then distinguishing between products with contract reliance above vs. below the median. We find that patent recipients enjoy disproportionately higher export survival rates in destinations with stronger contract enforcement. Furthermore, this operates predominantly through contract-sensitive products in exporters' portfolio. Similar to the evidence for the quality signal, we observe no statistically significant effects on expansion into maintained destination-product markets.

5.2.3 Signal Relevance

The evidence above is consistent with a US patent signaling the quality capacity and contract credibility of Chinese exporters. Such a signal would arguably be more valuable when there is more information asymmetry specifically about Chinese sellers to a given market. A signal would presumably also be more informative and consequential for firms that have had less time to establish their reputation. As additional evidence for the signaling function of patent grants, we now demonstrate that Chinese exporters indeed benefit more from a

US patent grant in destination-product markets where it is especially important for them to stand out among their Chinese competitors. We also show that firms with less export experience enjoy a bigger boost to their export growth upon receiving a US patent award.

We first consider two dimensions of information asymmetry at the origin(China)-destination-product(-year) level: market competitiveness and market volatility. This complements the earlier analysis of the variation in Chinese firms' export expansion across destination-product markets based on destination and product characteristics that are independent of the exporter's origin country (China).

We surmise that buyers face more uncertainty about a seller's type when there is less market concentration and fewer established market leaders, as well as when there is less fluctuation in seller activity over time. Our first indicator of information asymmetry is thus market competitiveness, measured by the Herfindhal Index (HHI) across Chinese exporters at the destination-HS6 product-year level. A lower HHI signifies a more competitive market for Chinese exporters, which we interpret in terms of a denser and more dispersed distribution of firm exports and underlying desirable firm attributes. Our second indicator of information asymmetry is Chinese export volatility at the destination-HS6 product level. We construct this by first computing the coefficient of variation in exports within a firm-destination-product over time, and then averaging across firms to the destination-product level. The rationale is that more volatile firm exports reflect supplier-specific shocks, conditional on demand-side fluctuations.

We find patterns consistent with a US patent providing a more pertinent signal about Chinese exporters' capability and reliability in markets with greater information asymmetry, both when we decompose overall export growth and when we examine differential performance across markets within firms. Figure A5 displays the estimated effect of a US patent grant on two constituent components of Chinese firms' total export growth, namely in destination-product markets with information asymmetry above vs. below the median. Practically all of patent recipients' export expansion occurs in markets with tight Chinese competition and highly volatile Chinese firm-level exports. Turning to the firm-destination-product level, Table A17 reports the heterogeneous effect of a successful US patent application on export outcomes across destinations and products within firms. Patent awardees have a significantly higher export survival probability in more competitive and more volatile destination-product markets. In line with earlier evidence, they do not record systematically different export growth in continuing markets conditional on survival.

Lastly, we consider the signal relevance of a US patent from the perspective of the individual firm. We take export tenure as a proxy for the time the firm has had to build up its reputation for being a desirable and reliable trade partner. We re-estimate the baseline specification separately for less vs. more experienced Chinese applicants to the USPTO in Table A18. We find a large and highly significant effect of a US patent grant on less seasoned Chinese exporters with up to five years of export experience, amounting to a rise of 23.6 percentage points in the annualized 3-year export growth rate. By contrast, we find a marginally insignificant boost of 10.0 percentage points for more mature exporters.

For comparison, the baseline estimate in the full sample stands at a strong and significant expansion of 17.5 percentage points. We view these differential effects across the export tenure ladder as further evidence consistent with the signaling mechanism.

5.3 Alternative Mechanisms

Our analysis has revealed evidence consistent with a successful US patent stimulating firms' export growth by alleviating information asymmetry in international trade. It has in contrast uncovered limited benefits to export activity through market protection. We conclude by considering two other mechanisms through which patenting has been found to improve domestic firm performance in the prior literature, and show that they do not exert similar effects on export expansion.

One potential mechanism is that patents help attract external investors and thus ease firms' financial frictions (Budish *et al.* 2016; Farre-Mensa *et al.* 2020). A large literature has documented that credit constraints are an important hindrance to international trade (Manova 2013). Moreover, exporting is significantly more reliant on external finance than production for the domestic market, because cross-border sales incur additional upfront costs, longer processing times, and higher transaction risk. A US patent award can thus make it easier for an exporter to raise external finance if it increases expected revenues and profits, for instance through the market protection, quality signal or credibility signal channels.

We confront this financial frictions channel with data in Table A19. We split the sample into Chinese firms with measured financial vulnerability above vs. below the sample median, and estimate the effect of a US patent grant on applicants' three-year annualized export growth in each subsample. The prior literature has argued that for technological reasons external to the firm, sectors differ in their external finance dependence for long-term capital expenditures, liquidity needs for short-term operations, and availability of tangible assets that can be collateralized to raise capital. We construct three corresponding measures of financial vulnerability at the firm level by taking the weighted average of these industry variables using the share of each industry in the firm's exports as weights.[30]

We find no consistent evidence for the financial frictions mechanism: While US patent approval does stimulate export growth relatively more for firms with low asset tangibility, it also counter-intuitively expands exports disproportionately more for firms with external finance dependence and liquidity needs below the median. The differences between these point estimates are, however, not statistically significant.[31]

A final transmission channel we explore is the effect of a first US patent award on follow-on innovation. Prior evidence indicates that US start-ups increase their innovation activity

[30]External finance dependence is constructed as the share of capital expenditures not financed with internal cash flows from operations; liquidity needs are measured with the inventories-to-sales ratio; and asset tangibility is calculated as the share of plant, property, and equipment in total book-value assets. We use the measures from Manova (2013) and Manova and Yu (2016) at the ISIC 3-digit level.

[31]In unreported analysis, we have estimated the impact of US patent approval on firms' financial outcomes, such as debt growth and leverage. Estimates were statistically insignificant and of small magnitude.

upon receiving their first US patent (Farre-Mensa *et al.* 2020). In our context, a US patent grant could improve Chinese entrepreneurs' expectations about the success of their subsequent innovation or patenting, and thereby of their profitability. This could in turn induce them to conduct more R&D, increase productivity, upgrade product quality, and/or climb up the value chain (Chor *et al.* 2021), all of which could act to expand exports. To evaluate this potentiality, we once again exploit data on patent filings with CNIPA, in the absence of other systematic information on Chinese firms' innovation intensity. In Table A20, we estimate the effect of a successful first US patent application on the growth in Chinese firms' CNIPA patent applications within three years of the US patent award. We find no evidence that the first US patent stimulates future patenting in China.

6 Conclusion

Global patent activity has gained momentum in the 21st century, with firms in developing countries increasingly innovating at the technological frontier and successfully attaining patents in leading patent jurisdictions such as the US, EU, Japan and South Korea. We examine the patent activity of Chinese firms in the United States to inform the mechanisms behind these phenomena.

We identify the impact of a successful first US patent application on the subsequent export performance of Chinese firms. We match for the first time uniquely rich data on the universe of USPTO patent applications and the universe of Chinese customs transactions, and exploit the pseudo-random assignment of USPTO examiners to establish causality. We show that a successful first-time US patent file substantially improves the applicant's future export growth. Unpacking potential mechanisms, we find evidence consistent with US patent approval signaling the quality capacity and contractual credibility of the Chinese exporter, and thereby alleviating information frictions in international trade. We observe only a limited role for the US patent ensuring market protection in the US, and no consistent support for it relaxing financial frictions or facilitating follow-on innovation.

Our findings raise open questions at the heart of academic research and policy debates. Of great interest is the optimal design of national and global patent policy with view to advancing both global growth and global equality. While the legal deployment of developed-country inventions and cross-country differences in intellectual property rights protection have typically been in focus, our work suggests that frontier-shifting innovation occurs in countries both with and without strong IPR institutions. Global patenting may thus provide valuable incentives for such innovation to take place, especially if global patent hubs enable poor-country inventors to access worldwide markets. Separately, and also important to understand, is the significance of global production networks and multinational activity for innovation and firm performance across countries. The co-existence of these economic forces points to interdependences in the design of international patent, trade and investment policies, which would inform the merits and principles of multilateral and deep-integration initiatives.

References

Aghion, P., Bergeaud, A., Lequien, M. and Melitz, M. (2018). *The Heterogeneous Impact of Market Size on Innovation: Evidence from French Firm-Level Exports*. Tech. Rep. w24600, National Bureau of Economic Research, Cambridge, MA.

Ahn, J., Khandelwal, A. K. and Wei, S.-J. (2011). The role of intermediaries in facilitating trade. *Journal of International Economics*, **84** (1), 73–85.

Akerman, A., Leuven, E. and Mogstad, M. (2022). Information Frictions, Internet, and the Relationship between Distance and Trade. *American Economic Journal: Applied Economics*, **14** (1), 133–163.

Albornoz, F., Calvo Pardo, H. F., Corcos, G. and Ornelas, E. (2012). Sequential exporting. *Journal of International Economics*, **88** (1), 17–31.

Allen, T. (2014). Information Frictions in Trade: Information Frictions in Trade. *Econometrica*, **82** (6), 2041–2083.

Anderson, J. E. and Marcouiller, D. (2002). Insecurity and the pattern of trade: An empirical investigation. *Review of Economics and Statistics*, **84** (2), 342–352.

Antràs, P. (2003). Firms, contracts, and trade structure. *The Quarterly Journal of Economics*, **118** (4), 1375–1418.

Argente, D., Baslandze, S., Hanley, D. and Moreira, S. (2023). Patents to products: Product innovation and firm dynamics.

Atkeson, A. and Burstein, A. T. (2010). Innovation, firm dynamics, and international trade. *Journal of Political Economy*, **118** (3), 433–484.

Aw, B. Y., Roberts, M. J. and Xu, D. Y. (2008). R&D investments, exporting, and the evolution of firm productivity. *American Economic Review*, **98** (2), 451–56.

—, — and — (2011). R&D Investment, Exporting, and Productivity Dynamics. *American Economic Review*, **101** (4), 1312–1344.

Bailey, M., Gupta, A., Hillenbrand, S., Kuchler, T., Richmond, R. and Stroebel, J. (2021). International trade and social connectedness. *Journal of International Economics*, **129**, 103418.

Balasubramanian, N. and Sivadasan, J. (2011). What happens when firms patent? new evidence from us economic census data. *The Review of Economics and Statistics*, **93** (1), 126–146.

Banerjee, A. V. and Duflo, E. (2000). Reputation effects and the limits of contracting: A study of the indian software industry. *The Quarterly Journal of Economics*, **115** (3), 989–1017.

Barber IV, B. and Diestre, L. (2022). Can firms avoid tough patent examiners through examiner-shopping? strategic timing of citations in uspto patent applications. *Strategic Management Journal*, **43** (9), 1854–1871.

Boeing, P. and Mueller, E. (2019). Measuring china's patent quality: Development and validation of isr indices. *China Economic Review*, **57**, 101331.

Bøler, E. A., Moxnes, A. and Ulltveit-Moe, K. H. (2015). R&D, International Sourcing, and the Joint Impact on Firm Performance. *American Economic Review*, **105** (12), 3704–3739.

Branstetter, L. G., Chen, J.-R., Glennon, B. and Zolas, N. (2021). Does offshoring production reduce innovation: Firm-level evidence from taiwan. *NBER Working Paper*.

Brunel, C. and Zylkin, T. (2022). Do cross-border patents promote trade? *Canadian Journal of Economics/Revue canadienne d'économique*, **55** (1), 379–418.

Budish, E., Roin, B. and Williams, H. (2016). Patents and research investments: Assessing the empirical evidence. *American Economic Review P&P*, **106** (5), 183–187.

Burstein, A. T. and Melitz, M. (2013). Trade liberalization and firm dynamics. advances in economics and econometrics tenth world congress. *Applied Economics. Econometric Society Monographs*, **2**.

Bustos, P. (2011). Trade liberalization, exports, and technology upgrading: Evidence on the impact of mercosur on argentinian firms. *American Economic Review*, **101** (1), 304–340.

Carley, M., Hegde, D. and Marco, A. (2015). What is the probability of receiving a u.s. patent? *Yale Journal of Law and Technology*, **17**, 204–223.

Casella, A. and Rauch, J. E. (2002). Anonymous market and group ties in international trade. *Journal of International Economics*, p. 29.

Chaney, T. (2014). The Network Structure of International Trade. *American Economic Review*, **104** (11), 3600–3634.

Chor, D., Manova, K. and Yu, Z. (2021). Growing like china: Firm performance and global production line position. *Journal of International Economics*, **130**, 103445.

Cockburn, I. M., Lanjouw, J. O. and Schankerman, M. (2016). Patents and the global diffusion of new drugs. *American Economic Review*, **106** (1), 136–64.

Coelli, F., Moxnes, A. and Ulltveit-Moe, K. H. (2022). Better, Faster, Stronger: Global Innovation and Trade Liberalization. *The Review of Economics and Statistics*, pp. 1–12.

Conti, A., Thursby, J. and Thursby, M. (2013a). Patents as signals for startup financing. *The Journal of Industrial Economics*, **61** (3), 592–622.

—, Thursby, M. and Rothaermel, F. T. (2013b). Show me the right stuff: Signals for high-tech startups. *Journal of Economics & Management Strategy*, **22** (2), 341–364.

Costantini, J. A. and Melitz, M. J. (2008). To trade liberalization. *The Organization of Firms in a Global Economy*, **107**.

Cristea, A. D. (2011). Buyer-seller relationships in international trade: Evidence from us states' exports and business-class travel. *Journal of international economics*, **84** (2), 207–220.

De Rassenfosse, G., Grazzi, M., Moschella, D. and Pellegrino, G. (2022). International patent protection and trade: Transaction-level evidence. *European Economic Review*, p. 104160.

—, Kozak, J. and Seliger, F. (2019). Geocoding of worldwide patent data. *Scientific data*, **6** (1), 1–15.

Defever, F., Heid, B. and Larch, M. (2015). Spatial exporters. *Journal of International Economics*, **95** (1), 145–156.

Dobbie, W., Goldin, J. and Yang, C. S. (2018). The effects of pre-trial detention on conviction, future crime, and employment: Evidence from randomly assigned judges. *American Economic Review*, **108** (2), 201–240.

Eaton, J., Eslava, M., Jinkins, D. C., Krizan, C. J. and Tybout, J. (2021). A Search and Learning Model of Export Dynamics. *SSRN Electronic Journal*.

Fan, H., Li, Y. A., Xu, S. and Yeaple, S. R. (2020). Quality, variable markups, and welfare: A quantitative general equilibrium analysis of export prices. *Journal of International Economics*, **125**, 103327.

Farre-Mensa, J., Hegde, D. and Ljungqvist, A. (2020). What is a patent worth? evidence from the u.s. patent "lottery". *The Journal of Finance*, **75** (2), 639–682.

Feenstra, R. C. and Hanson, G. H. (2004). Intermediaries in Entrepot Trade: Hong Kong Re-Exports of Chinese Goods. *Journal of Economics and Management Strategy*, **13** (1), 3–35.

Galasso, A. and Schankerman, M. (2015). Patents and cumulative innovation: Causal evidence from the courts. *The Quarterly Journal of Economics*, **130** (1), 317–369.

— and — (2018). Patent rights, innovation, and firm exit. *The RAND Journal of Economics*, **49** (1), 64–86.

Goldschlag, N., Lybbert, T. J. and Zolas, N. J. (2020). Tracking the technological composition of industries with algorithmic patent concordances. *Economics of Innovation and New Technology*, **29** (6), 582–602.

Grossman, S. J. and Hart, O. D. (1986). The costs and benefits of ownership: A theory of vertical and lateral integration. *Journal of Political Economy*, **94** (4), 691–719.

Guiso, L., Sapienza, P. and Zingales, L. (2009). Cultural biases in economic exchange? *The quarterly journal of economics*, **124** (3), 1095–1131.

Hart, O. and Moore, J. (1990). Property rights and the nature of the firm. *Journal of Political Economy*, **98** (6), 1119–1158.

Hoberg, G. and Phillips, G. (2016). Text-based network industries and endogenous product differentiation. *Journal of Political Economy*, **124** (5), 1423–1465.

Hsu, D. H. and Ziedonis, R. H. (2013). Resources as dual sources of advantage: Implications for valuing entrepreneurial-firm patents. *Strategic Management Journal*, **34** (7), 761–781.

Ivus, O. (2010). Do stronger patent rights raise high-tech exports to the developing world? *Journal of International Economics*, **81** (1), 38–47.

Jung, J. W., Simonovska, I. and Weinberger, A. (2019). Exporter heterogeneity and price discrimination: A quantitative view. *The Review of Economic Studies*, **116** (1), 103–124.

Kaufmann, D., Kraay, A. and Mastruzzi, M. (2003). Governance matters: Governance indicators for 1996-2002. iii. *World Bank*, **3106** (2).

Khandelwal, A. (2010). The long and short (of) quality ladders. *The Review of Economic Studies*, **77** (4), 1450–1476.

Kline, P., Petkova, N., Williams, H. and Zidar, O. (2019). Who profits from patents? rent-sharing at innovative firms. *The Quarterly Journal of Economics*, **134** (3), 1343–1404.

Kogan, L., Papanikolaou, D., Seru, A. and Stoffman, N. (2017). Technological innovation, resource allocation, and growth. *The Quarterly Journal of Economics*, **132** (2), 665–712.

Lemley, M. and Sampat, B. (2012). Examiner characteristics and patent office outcomes. *The Review of Economics and Statistics*, **94** (3), 817–827.

Levchenko, A. A. (2007). Institutional quality and international trade. *The Review of Economic Studies*, **74** (3), 791–819.

Lileeva, A. and Trefler, D. (2010). Improved access to foreign markets raises plant-level productivity⋯for some plants. *The Quarterly Journal of Economics*, **125** (3), 1051–1099.

Lin, J. X. and Lincoln, W. F. (2017). Pirate's treasure. *Journal of International Economics*, **109**, 235–245.

Liu, Q. and Ma, H. (2020). Trade policy uncertainty and innovation: Firm level evidence from China's WTO accession. *Journal of International Economics*, **127**, 103387.

Long, C. (2002). Patent signals. *The University of Chicago Law Review*, pp. 625–679.

Lybbert, T. J. and Zolas, N. J. (2014). Getting patents and economic data to speak to each other: An 'algorithmic links with probabilities' approach for joint analyses of patenting and economic activity. *Economics of Innovation and New Technology*, **43** (3), 530–542.

Macchiavello, R. and Morjaria, A. (2015). The Value of Relationships: Evidence from a Supply Shock to Kenyan Rose Exports. *American Economic Review*, **105** (9), 2911–2945.

Maican, F. G., Orth, M., Roberts, M. J. *et al.* (2020). *The dynamic impact of exporting on firm R&D investment*. Tech. rep., National Bureau of Economic Research.

Manova, K. (2013). Credit constraints, heterogeneous firms, and international trade. *Review of Economic Studies*, **80** (2), 711–744.

— and Yu, Z. (2016). How firms export: Processing vs. ordinary trade with financial frictions. *Journal of International Economics*, **100**, 120–137.

— and — (2017). Multi-product firms and product quality. *Journal of International Economics*, **109**, 116–137.

— and Zhang, Z. (2012). Export prices across firms and destinations. *The Quarterly Journal of Economics*, **127** (1), 379–436.

Maskus, K. E. and Penubarti, M. (1995). How trade-related are intellectual property rights? *Journal of International economics*, **39** (3-4), 227–248.

Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, **71** (6), 1695–1725.

Monarch, R. and Schmidt-Eisenlohr, T. (2017). Learning and the Value of Trade Relationships. *International Finance Discussion Paper*, **2017** (1218), 1–61.

Nunn, N. (2007). Relationship-specificity, incomplete contracts, and the pattern of trade. *The Quarterly Journal of Economics*, **122** (2), 569–600.

Palangkaraya, A., Jensen, P. H. and Webster, E. (2017). The effect of patents on trade. *Journal of International Economics*, **105**, 1–9.

Rauch, J. E. (1999). Networks versus markets in international trade. *Journal of International Economics*, p. 29.

— (2001). Business and Social Networks in International Trade. *Journal of Economic Literature*, **39** (4), 1177–1203.

— and Trindade, V. (2002). Ethnic chinese networks in international trade. *Review of Economics and Statistics*, **84** (1), 116–130.

— and — (2003). Information, International Substitutability, and Globalization. *American Economic Review*, **93** (3), 775–791.

Righi, C. and Simcoe, T. (2019). Patent examiner specialization. *Research Policy*, **48** (1), 137–148.

Sampat, B. and Lemley, M. (2010). Examining patent examination. *Stanford Technology Law Review*, **2**.

— and Williams, H. (2019). How do patents affect follow-on innovation? evidence from the human genome. *American Economic Review*, **109** (1), 203–236.

Shu, P. and Steinwender, C. (2019). The Impact of Trade Liberalization on Firm Productivity and Innovation. *Innovation Policy and the Economy*, **19**, 39–68.

Smith, P. J. (1999). Are weak patent rights a barrier to us exports? *Journal of International Economics*, **48** (1), 151–177.

Song, H. and Li, Z. (2014). Patent quality and the measuring indicator system: Comparison among china provinces and key countries. In *Berkeley center for law & technology IP scholars conference*.

Squicciarini, M., Dernis, H. and Criscuolo, C. (2013). Measuring patent quality: Indicators of technological and economic value.

Steinwender, C. (2018). Real Effects of Information Frictions: When the States and the Kingdom Became United. **108** (3), 657–696.

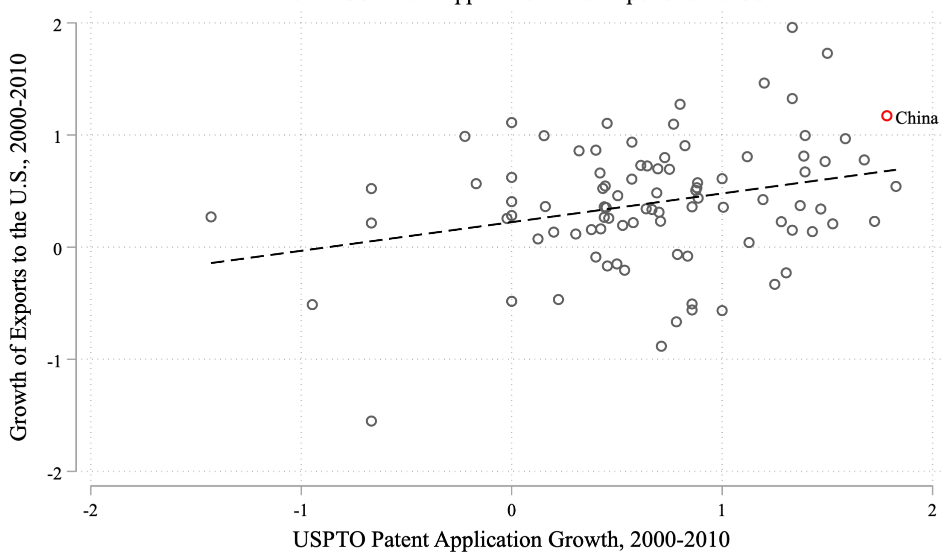
Van Long, N., Raff, H. and Stähler, F. (2011). Innovation and trade with heterogeneous firms. *Journal of International Economics*, **84** (2), 149–159.

Williams, H. L. (2013). Intellectual property rights and innovation: Evidence from the human genome. *Journal of Political Economy*, **121** (1), 1–27.

— (2017). How do patents affect research investments? *Annual Review of Economics*, **9**, 441–469.

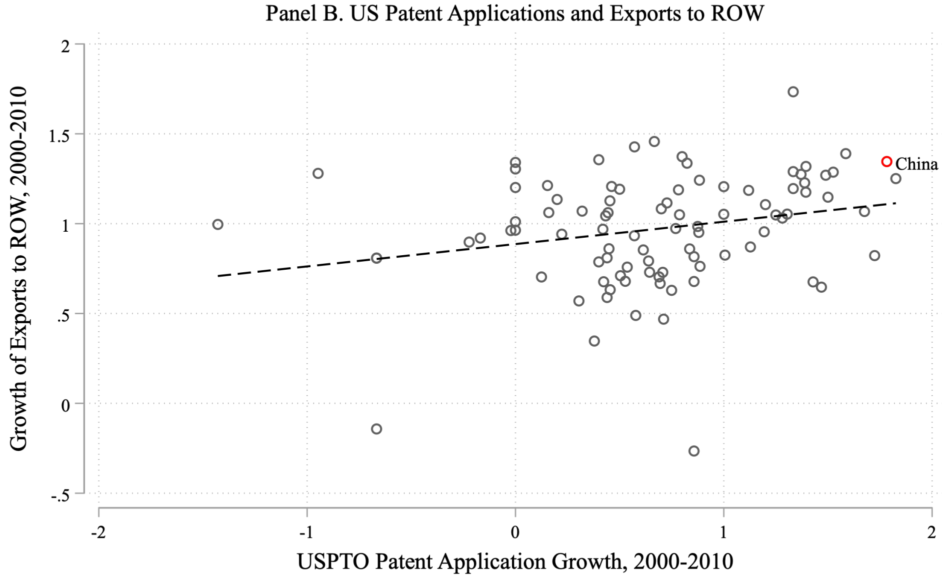
Figure 1: USPTO Patent Applications and Exports Across Countries

Panel A. US Patent Applications and Exports to the US



Fitted line slope (standard error): 0.256 (0.105)

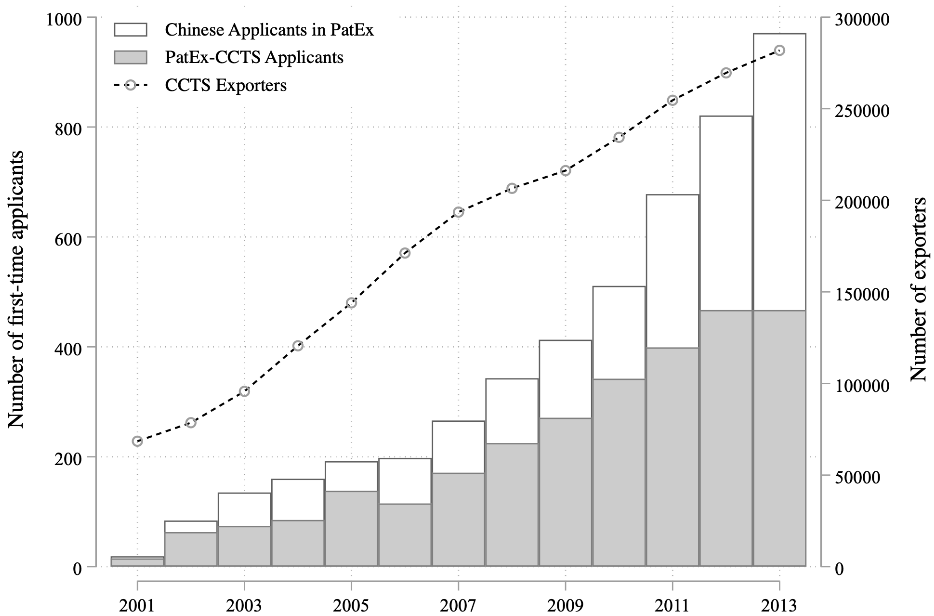
Panel B. US Patent Applications and Exports to ROW



Fitted line slope (standard error): 0.124 (0.059)

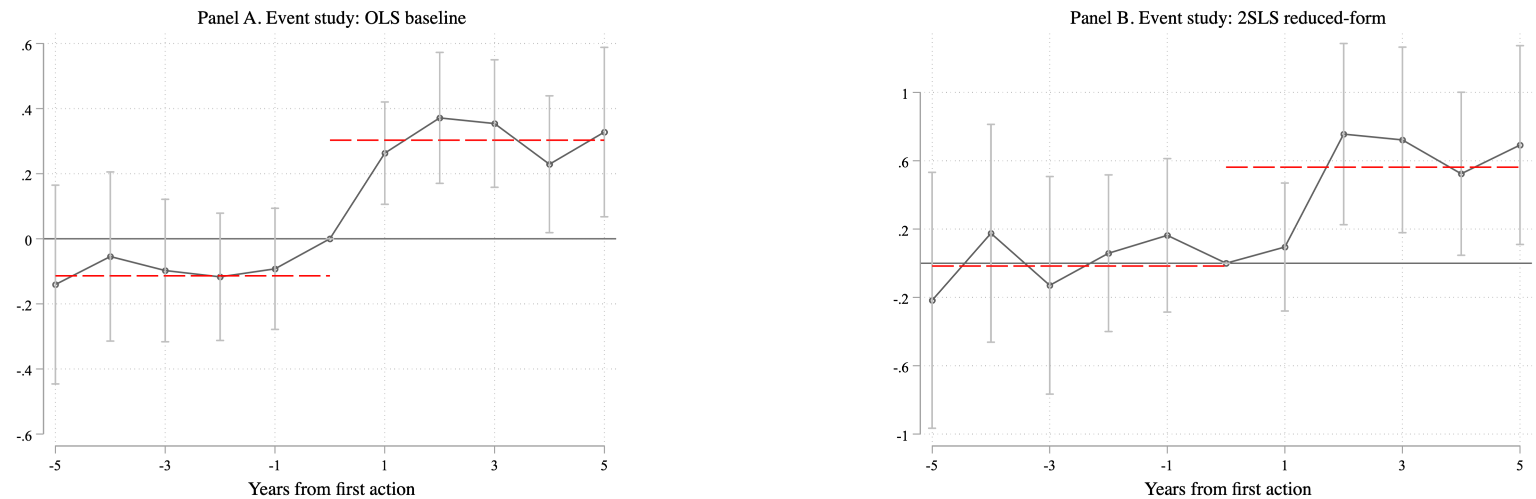
Note: These figures plot the growth in exports respectively to the U.S. and to the rest of the world across countries against the growth in USPTO patent applications over the 2000-2010 period. The slope of the corresponding fitted line and its robust standard error are reported below each figure.

Figure 2: Chinese Trade and USPTO Patent Activity Over Time



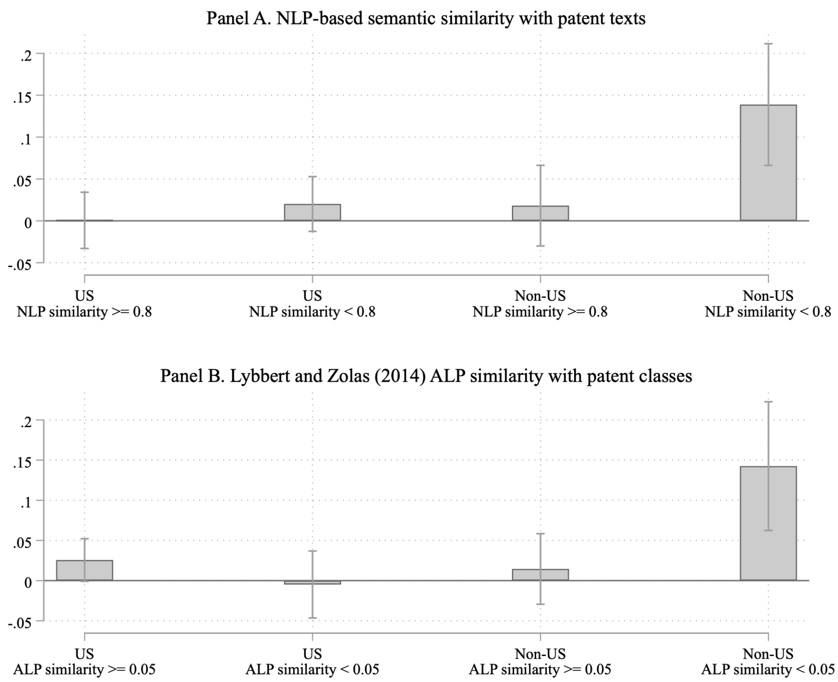
Note: This figure traces the evolution of Chinese trade and USPTO patent activity over time. The white bars display the number of Chinese firms that file a USPTO patent application for the first time in a given first-action year. The grey bars display the subset of these firms that can be matched to exporters in the CCTS-PatEx data. The dashed line displays the total number of CCTS exporters.

Figure 3: Event Study



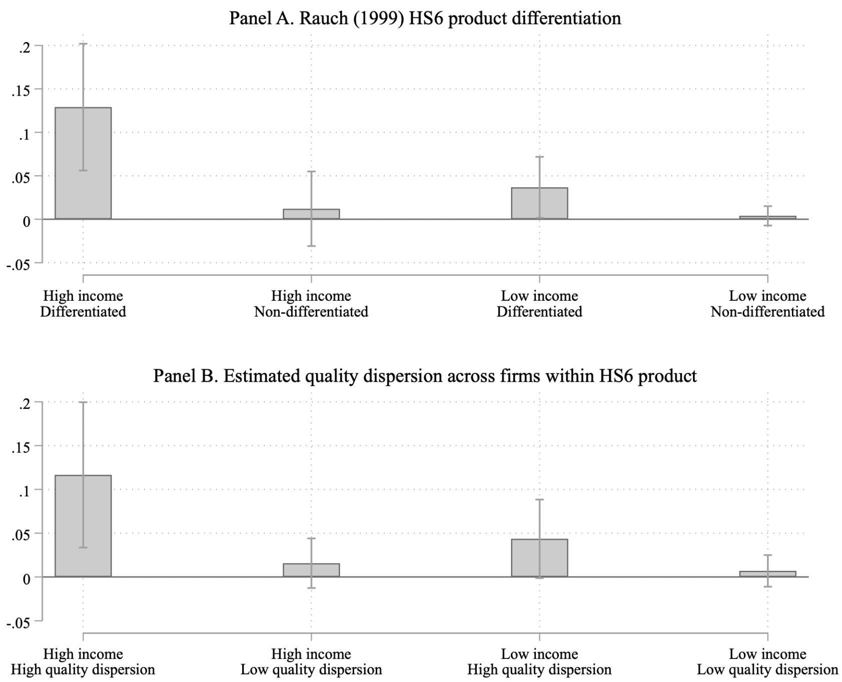
Note: This figure plots event-study estimates for the effects of a successful first US patent application and a more lenient USPTO patent examiner on the exports of first-time Chinese applicants. The sample covers all CCTS-PatEx matched exporters. The dependent variable is log exports. The regressors comprise interactions of time dummies with an indicator for a successful patent application in Panel A and with the patent examiner's demeaned approval rate in Panel B. Both regressions include firm fixed effects and HS2 sector by year pair fixed effects. Heteroskedasticity-consistent standard errors are clustered by examiner art unit.

Figure 4: Market Protection: Export Growth Decomposition



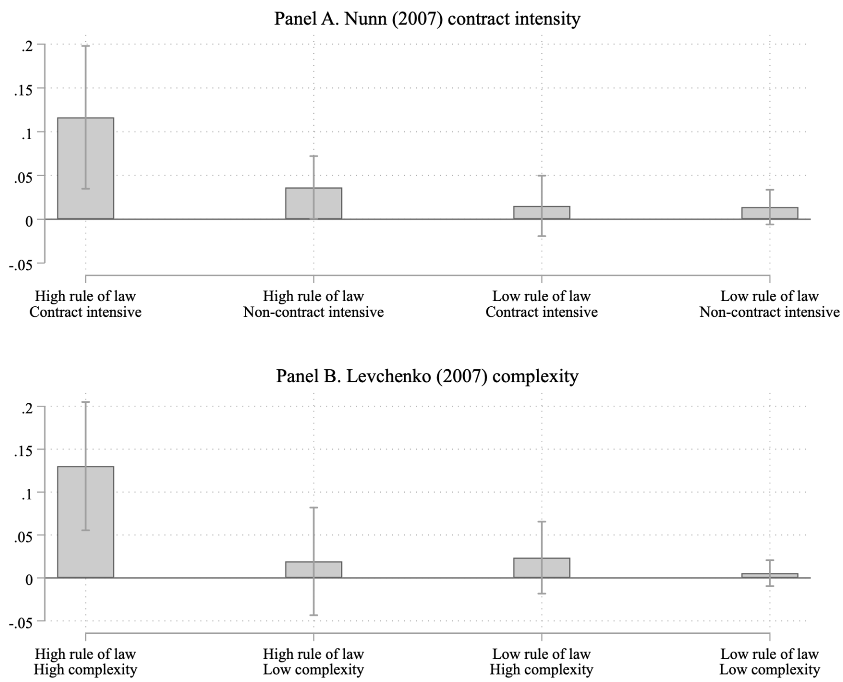
Note: This figure visualizes the estimated effect of a successful first U.S. patent application on constituent components of the export growth of Chinese applicants, based on the regression analysis in Table A11. Total firm growth is decomposed four-way into exports to the U.S. vs. Rest of the World (ROW) and products that are technologically related vs. unrelated to the firm's patent. Products are technologically related to a patent or patent technology class if their descriptions have semantic similarity above 80% based on the NLP method in Panel A (see Appendix C for details) or ALP weights above 5% based on Lybbert and Zolas (2014) approach in Panel B. The sample covers all CCTS-PatEx matched exporters. All coefficients are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. All regressions include HS2 sector by year pair fixed effects, and control for initial log exports and firm export tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Figure 5: Quality Signal: Export Growth Decomposition



Note: This figure visualizes the estimated effect of a successful first U.S. patent application on constituent components of the export growth of Chinese applicants, based on the regression analysis in Table A13. Total firm growth is decomposed four-way into exports to high- vs. low-income countries and products with high vs. low scope for quality differentiation. Products have high scope for quality differentiation if they are differentiated according to the Rauch (1999) classification or if the coefficient of variation of estimated quality across firms within a product is above the median. All coefficients are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. All regressions include HS2 sector by year pair fixed effects, and control for initial log exports and firm export tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Figure 6: Credibility Signal: Export Growth Decomposition



Note: This figure visualizes the estimated effect of a successful first U.S. patent application on constituent components of the export growth of Chinese applicants, based on the regression analysis in Table A15. Total firm growth is decomposed four-way into exports to countries with high vs. low rule of law and products that belong to industries with high vs. low contract reliance. Industries' contract reliance is proxied with the Nunn (2007) measure of contract intensity or with the Levchenko (2007) measure of complexity. All coefficients are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. All regressions include HS2 sector by year pair fixed effects, and control for initial log exports and firm export tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 1: Chinese Patent Applicants vs. Other Chinese Exporters

	Matched patent applicants		*Other exporters*		*Difference*	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Log exports	15.28	2.71	13.16	2.34	2.12***	0.021
Log exports to the U.S.	10.01	6.61	5.00	6.14	5.01***	0.054
Log exports to OECD	13.14	5.11	9.94	5.65	3.21***	0.050
Share of exports to the U.S.	0.22	0.30	0.14	0.28	0.090***	0.0025
Share of exports to OECD	0.54	0.36	0.52	0.41	0.024***	0.0037
Number of products	16.18	40.87	14.58	48.41	1.59***	0.43
Number of destinations	19.68	21.14	8.39	12.76	11.29***	0.11
Avg exports per dest-prod (1,000 RMB)	1423.76	8081.73	405.49	5826.35	1018.28***	51.67
# Observations	12,850		2,318,957			

Note: This table compares CCTS-PatEx matched exporters to other CCTS exporters. Columns 1-2 and 3-4 show the mean and standard deviation of key export statistics in the panel, respectively for CCTS-PatEx matched Chinese patent applicants and for all other CCTS exporters. Columns 5 and 6 show the mean and standard deviation of the difference in export statistics between the two groups. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 2: First Stage: Examiner Approval Rate and Patent Approval

Dependent variable	*Successful USPTO application*			
	(1)	(2)	(3)	(4)
Examiner approval rate	0.970***	0.968***	0.950***	0.955***
	(0.0689)	(0.0693)	(0.0783)	(0.0787)
Log exports		0.00227		0.0146*
		(0.00567)		(0.00750)
Export tenure		-0.00789*		-0.00181
		(0.00436)		(0.00508)
Log employment				-0.0105
				(0.0107)
HS2-year fixed effects	Yes	Yes		
Industry-year fixed effects			Yes	Yes
Ownership-year fixed effects			Yes	Yes
Sample	CCTS		CCTS-ASIE	
F-test: IV = 0	198.07***	195.26***	147.05***	147.44***
# Observations	1,156	1,156	940	940

Note: This table reports first-stage regression results for the predictive power of an examiner's *ex-ante* demeaned approval rate for the success of an exporter's first USPTO patent application. The sample covers all CCTS-PatEx matched exporters in Columns 1-2 and all CCTS-ASIE-PatEx matched exporters in Columns 3-4. Column 2 controls for initial log exports and export tenure. Column 4 further controls for log employment. Columns 1-2 include HS2 sector by year pair fixed effects, while Columns 3-4 include CIC2 industry by year and ownership type by year pair fixed effects. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 3: Balance Tests

Sample	*Firm Characteristic*	*Successful USPTO application*	*Examiner approval rate*
CCTS (Sample size = 1,156)	Log exports (CCTS)	-0.0209	0.0893
		(0.162)	(0.463)
	Log # products	-0.149*	-0.0974
		(0.0756)	(0.227)
	Log # destinations	-0.0252	0.141
		(0.0746)	(0.197)
	Log avg exports per dest-prod	0.0942	0.0223
		(0.125)	(0.373)
CCTS-ASIE (Sample size = 940)	Log sales	0.0363	-0.366
		(0.143)	(0.341)
	Log employment	-0.0109	-0.0127
		(0.0977)	(0.244)
	Log exports (ASIE)	0.241	-0.343
		(0.189)	(0.532)
	Operating profit margin	0.00974	-0.0323
		(0.00930)	(0.0223)

Note: This table reports results from regressing CCTS or CCTS-ASIE matched exporters' *ex-ante* characteristics on an indicator for a successful patent application and on examiner approval rate. The CCTS sample covers continuing exporters matched to USPTO patent applicants. The CCTS-ASIE sample covers all continuing CCTS exporters matched to both USPTO and ASIE. Regressions on the CCTS sample control for HS2 sector by year pair fixed effects. Regressions on the CCTS-ASIE sample control for CIC2 industry by year and ownership type by year pair fixed effects. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4: Effect of First U.S. Patent on Chinese Firms' Export Growth

Dependent variable	*Annualized 3-year export growth*					
	(1)	(2)	(3)	(4)	(5)	(6)
Successful USPTO application	0.0667***	0.172***	0.175***	0.0599**	0.217***	0.201***
	(0.0214)	(0.0564)	(0.0522)	(0.0253)	(0.0691)	(0.0621)
Log exports			-0.0367***			-0.0457***
			(0.00492)			(0.00593)
Export tenure			-0.00299			-0.0141***
			(0.00366)			(0.00371)
Log employment						0.0294***
						(0.00856)
HS2-year fixed effects	Yes	Yes	Yes			
Industry-year fixed effects				Yes	Yes	Yes
Ownership-year fixed effects				Yes	Yes	Yes
Model	OLS	2SLS	2SLS	OLS	2SLS	2SLS
Sample		CCTS			CCTS-ASIE	
F-stat		198.07	195.26		147.05	147.44
# Observations	1,156	1,156	1,156	940	940	940

Note: This table reports the estimated effect of a successful first U.S. patent application on the subsequent export growth of Chinese applicants. The dependent variable is the annualized 3-year export growth rate. The sample covers all CCTS-PatEx matched exporters in Columns 1-3 and all CCTS-ASIE-PatEx matched exporters in Columns 4-6. Columns 1 and 4 are estimated with OLS, while Columns 2, 3, 5, and 6 are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. Column 3 controls for initial log exports and export tenure. Column 6 further controls for log employment. Columns 1-3 include HS2 sector by year pair fixed effects, while Columns 4-6 include CIC2 industry by year and ownership type by year pair fixed effects. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5: Export Growth Decomposition: Incumbent and New Markets

Dependent variable	*Component of annualized 3-year export growth*			
	Incumbent dest-prod markets		New dest-prod markets	
	(1)	(2)	(3)	(4)
Successful USPTO application	0.153***	0.153***	0.0195	0.0217
	(0.0486)	(0.0487)	(0.0309)	(0.0260)
Log exports		-0.00562		-0.0311***
		(0.00407)		(0.00232)
Export tenure		-0.0000904		-0.00290*
		(0.00314)		(0.00149)
HS2-year fixed effects	Yes	Yes	Yes	Yes
F-stat	198.07	195.26	198.07	195.26
# Observations	1,156	1,156	1,156	1,156

Note: This table reports the estimated effect of a successful first U.S. patent application on constituent components of the subsequent export growth of Chinese applicants. The dependent variable in Columns 1-2 and 3-4 is the contribution of expansion in a firm's incumbent and new destination-product markets respectively to its total export growth. The sample covers all CCTS-PatEx matched exporters. All columns are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. Columns 2 and 4 control for initial log exports and export tenure. All columns include HS2 sector by year pair fixed effects. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 6: Export Survival and Growth by Destination-Product Market

Panel A. Market survival and export growth conditional on survival

Dependent variable	*Survival indicator*			*Export value growth*		
	(1)	(2)	(3)	(4)	(5)	(6)
Successful USPTO application	0.0768***	0.127	0.143**	0.0218	0.0836	0.233***
	(0.0177)	(0.0809)	(0.0693)	(0.0143)	(0.0614)	(0.0821)
F-stat		27.97	105.87		21.20	57.23
# Observations	86,681	86,681	86,681	38,940	38,940	38,940

Panel B. Export price and quantity growth conditional on survival

Dependent variable	*Export price growth*			*Export quantity growth*		
	(1)	(2)	(3)	(4)	(5)	(6)
Successful USPTO application	0.0195	-0.0764	-0.00433	0.00875	0.135**	0.211**
	(0.0144)	(0.0728)	(0.0786)	(0.0176)	(0.0682)	(0.0917)
F-stat		15.10	45.66		15.10	45.66
# Observations	31,320	31,320	31,320	31,320	31,320	31,320

Controls	Firm level log exports and export tenure					
	Firm-dest-prod level log exports and relative export tenure					
Fixed effects	HS6-year and destination-year fixed effects					
Model	OLS	IV	Weighted IV	OLS	IV	Weighted IV

Note: This table reports the estimated effect of a successful first U.S. patent application on the survival probability of incumbent firm-destination-product triplets and the growth in export value, price, and quantity of continuing firm-destination-product triplets. The sample in Columns 1-3 of Panel A (Panel B and Columns 4-6 of Panel A) covers all incumbent (all continuing) firm-destination-product triplets for CCTS-PatEx matched exporters. Columns 1 and 4 are estimated with OLS, while Columns 2, 3, 5, and 6 are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. Columns 3 and 6 weight observations by their initial value share in a firm's export portfolio. All columns include HS6 by year and destination by year pair fixed effects, and control for firm-level initial log exports and tenure and firm-destination-product level initial log exports and relative tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7: Market Protection: Exports Across Markets Within Firms

Panel A. NLP-based semantic similarity with patent texts						
Dependent variable	*Export value growth*			*Export price growth*		
Technologically related products	All	Yes	No	All	Yes	No
	(1)	(2)	(3)	(4)	(5)	(6)
Successful USPTO application × U.S.	0.112	-0.120	0.295	0.0497	0.0186	0.0322
	(0.115)	(0.119)	(0.194)	(0.0647)	(0.0995)	(0.103)
F-stat	6.96	20.06	3.89	6.33	25.19	3.43
# Observations	38,824	14,601	23,517	31,226	12,129	18,524
Panel B. Lybbert and Zolas (2014) ALP similarity with patent classes						
Dependent variable	*Export value growth*			*Export price growth*		
Technologically related products	All	Yes	No	All	Yes	No
	(1)	(2)	(3)	(4)	(5)	(6)
Successful USPTO application × U.S.	0.112	-0.133	0.139	0.0497	0.0432	0.0149
	(0.115)	(0.243)	(0.121)	(0.0647)	(0.165)	(0.0738)
F-stat	6.96	7.83	5.93	6.33	8.82	5.23
# Observations	38,824	7,774	30,411	31,226	6,634	24,061
Controls	Firm-dest-prod level log exports and relative export tenure					
Fixed effects	Firm-year, HS6-year, and destination-year fixed effects					

Note: This table reports the heterogeneous effect of a successful first U.S. patent application on the growth in export values and prices across destinations and products within firms, for the sample of continuing firm-destination-product triplets of CCTS-PatEx matched exporters. The variable U.S. is an indicator equal to 1 if the export destination is the U.S. The standalone term of Successful USPTO application is absorbed by the firm by year pair fixed effects. Columns 1 and 4 cover all products, while Columns 2 and 5 (Columns 3 and 6) restrict the sample to products that are technologically related (unrelated) to a firm's patent. Products are technologically related to a patent or patent technology class if their descriptions have semantic similarity above 80% based on the NLP method in Panel A (see Appendix C for details) and ALP weights above 5% based on Lybbert and Zolas (2014) approach in Panel B. All columns are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. All columns include HS6 by year, destination by year, and firm by year pair fixed effects, and control for firm-destination-product level initial log exports and relative tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 8: Quality Signal: Exports Across Markets Within Firms

Panel A. Rauch (1999) HS6 product differentiation

Dependent variable	*Survival Indicator*			*Export value growth*		
Differentiated products	All	Yes	No	All	Yes	No
	(1)	(2)	(3)	(4)	(5)	(6)
Successful USPTO application × ln(GDP per capita)	0.0207*	0.0302**	0.00159	0.00255	-0.00423	0.0330
	(0.0119)	(0.0130)	(0.0248)	(0.0194)	(0.0220)	(0.0407)
F-stat	32.59	26.78	49.92	21.14	18.35	16.92
# Observations	85,955	70,123	10,555	38,665	32,251	4,112

Panel B. Estimated quality dispersion across firms within HS6 product

Dependent variable	*Survival Indicator*			*Export value growth*		
High quality-dispersion products	All	Yes	No	All	Yes	No
	(1)	(2)	(3)	(4)	(5)	(6)
Successful USPTO application × ln(GDP per capita)	0.0207*	0.0285**	-0.0107	0.00255	0.000385	0.0142
	(0.0119)	(0.0134)	(0.0228)	(0.0194)	(0.0236)	(0.0217)
F-stat	32.59	25.99	56.73	21.13	15.27	37.11
# Observations	85,955	71,677	13,557	38,665	31,753	6,430
Controls	Firm-dest-prod level log exports and relative export tenure					
Fixed effects	Firm-year, HS6-year, and destination-year fixed effects					

Note: This table reports the heterogeneous effect of a successful first U.S. patent application on the survival probability and export growth across destinations and products within firms. The variable ln(GDP per capita) is the log GDP per capita of the destination country. The standalone term of Successful USPTO application is absorbed by the firm by year pair fixed effects. The sample in Columns 1-3 (Columns 4-6) covers all incumbent (all continuing) firm-destination-product triplets for CCTS-PatEx matched exporters. Columns 1 and 4 cover all products, while Columns 2 and 5 (Columns 3 and 6) restrict the sample to products with high (low) scope for quality differentiation. Products have high scope for quality differentiation if they are differentiated according to the Rauch (1999) classification in Panel A and if the coefficient of variation of estimated quality across firms within a product is above the median in Panel B. All columns are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. All columns include HS6 by year, destination by year, and firm by year pair fixed effects, and control for firm-destination-product level initial log exports and relative tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 9: Credibility Signal: Exports Across Markets Within Firms

Panel A. Nunn (2007) contract intensity						
Dependent variable	*Survival Indicator*			*Export value growth*		
High-contract-intensity industries	All	Yes	No	All	Yes	No
	(1)	(2)	(3)	(4)	(5)	(6)
Successful USPTO application × rule of law	0.0308**	0.0358**	0.0253	0.00472	0.00269	0.0261
	(0.0149)	(0.0147)	(0.0304)	(0.0242)	(0.0233)	(0.0534)
F-stat	25.96	23.85	21.73	17.49	14.31	13.43
# Observations	86,319	56,481	29,237	38,752	26,283	12,009
Panel B. Levchenko (2007) complexity						
Dependent variable	*Survival Indicator*			*Export value growth*		
High-complexity industries	All	Yes	No	All	Yes	No
	(1)	(2)	(3)	(4)	(5)	(6)
Successful USPTO application × rule of law	0.0308**	0.0374**	0.0152	0.00472	-0.00686	0.0523
	(0.0149)	(0.0148)	(0.0252)	(0.0242)	(0.0253)	(0.0437)
F-stat	25.96	20.37	26.27	17.49	15.65	10.41
# Observations	86,319	54,390	31,388	38,752	25,162	13,106
Controls	Firm-dest-prod level log exports and relative export tenure					
Fixed effects	Firm-year, HS6-year, and destination-year fixed effects					

Note: This table reports the heterogeneous effect of a successful first U.S. patent application on the survival probability and export growth across destinations and products within firms. The variable rule of law is the index value of rule of law of the destination country. The standalone term of Successful USPTO application is absorbed by the firm by year pair fixed effects. The sample in Columns 1-3 (Columns 4-6) covers all incumbent (all continuing) firm-destination-product triplets for CCTS-PatEx matched exporters. Columns 1 and 4 cover all products, while Columns 2 and 5 (Columns 3 and 6) restrict the sample to products that belong to industries with high (low) contract reliance above (below) the median. Industries' contract reliance is proxied with the Nunn (2007) measure of contract intensity in Panel A and with the Levchenko (2007) measure of complexity in Panel B. All columns are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. All columns include HS6 by year, destination by year, and firm by year pair fixed effects, and control for firm-destination-product level initial log exports and relative tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix A Additional Figures and Tables

Figure A1: Publicizing US Patent Grants: Chinese Media Examples

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随着我国企业“走出去”的步伐加快，知识产权日益成为参与国际竞争的核心要素，越来越多的企业开始通过提升知识产权能力在激烈的全球市场竞争中掌握主动权。日前，从中国ATM厂商广电运通获悉，其发明专利“读卡器异物检测装置及读卡器插口”，于2013年1月8日正式获得美国国家专利局授权，授权公告号US8, 348, 162B2。

2013年03月13日08:57 来源：中国经营报 手机看新闻

随着我国企业“走出去”的步伐加快，知识产权日益成为参与国际竞争的核心要素，越来越多的企业开始通过提升知识产权能力在激烈的全球市场竞争中掌握主动权。日前，从中国ATM厂商广电运通获悉，其发明专利“读卡器异物检测装置及读卡器插口”，于2013年1月8日正式获得美国国家专利局授权，授权公告号US8, 348, 162B2。同时，该专利也在欧盟、澳大利亚、越南、伊朗等国家进入公示阶段。此前广电运通已在海外市场获得多项专利授权，此次首获美国专利授权，将是中国ATM企业在海外尤其是欧美国 专利授权取得的又一突破。

Panel A. GRG Banking Equipment

方正微电子第一个海外专利授权

发布时间2014-06-15

6月上旬获悉，由方正集团和深圳方正微电子有限公司共同申报的发明专利《METHOD FOR MANUFACTURING DOUBLE-LAYER POLYSILICON GATE》于5月13日在美国授权；这项专利的应用，可解决某研发项目长期以来遗留的一个重大技术难题，提高产品的附加值。方正微电子从2007年开始自主知识产权的布局工作，于2008年4月向国家专利局递交第一篇专利稿，2009年4月第一个实用新型专利在国内授权，2010年3月第一个发明专利在国内授权，2012年12月第一次向美国专利局递交专利申报稿。此次的美国专利授权，是方正微电子在海外授权的第一个专利，是方正微电子知识产权工作的又一个重要里程碑。半导体行业是全球范围内竞争的技术密集型产业，企业的竞争某种程度上是技术创新和知识产权的竞争，近年来，国内企业逐步重视海外专利的申请和保护。

Panel B. Founder Microelectronics

Note: This figure presents examples of Chinese companies prominently publicizing their award of a US patent in Chinese state media and company websites. Panel A: screenshot from people.cn, one of the largest state-owned online news agencies, reporting on the first US patent obtained by GRG Banking Equipment: “This first US patent license will be another breakthrough for Chinese ATM companies operating in foreign markets, especially in Europe and America.” Panel B: screenshot from the company website of Founder Microelectronics, presenting its first US patent: “This US patent grant is the first patent obtained by Founder Microelectronics overseas and is another important milestone in Founder Microelectronics’ intellectual property work.”

Figure A2: The USPTO Patent Prosecution Process

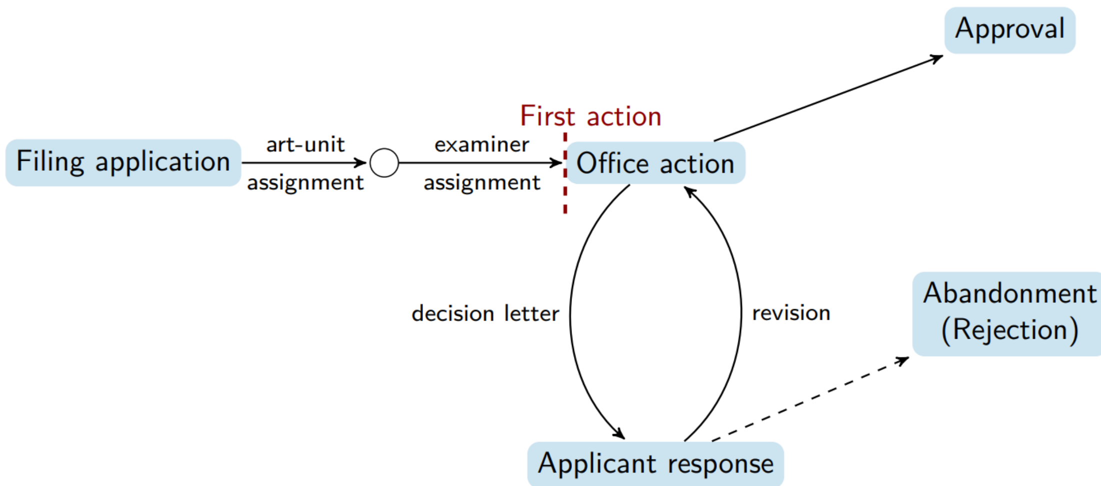
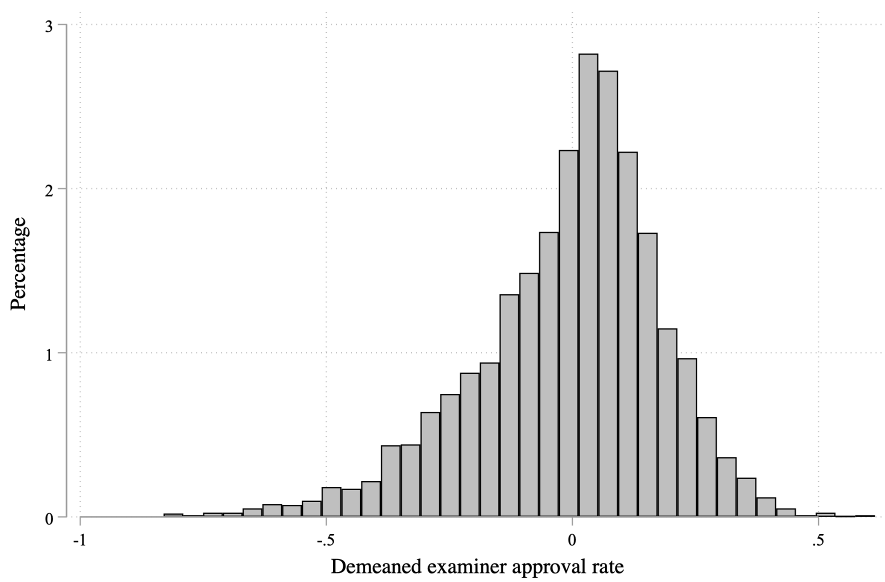
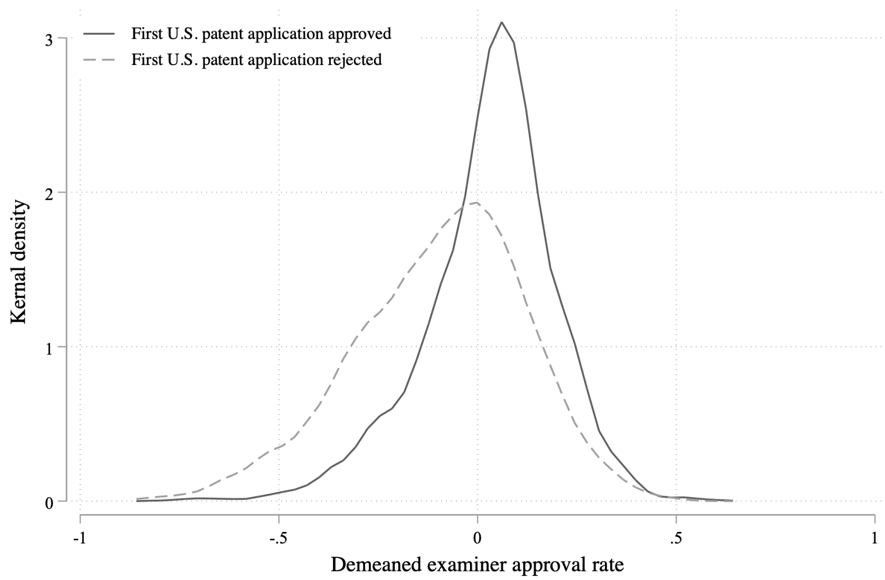


Figure A3: Distribution of Examiner Approval Rates



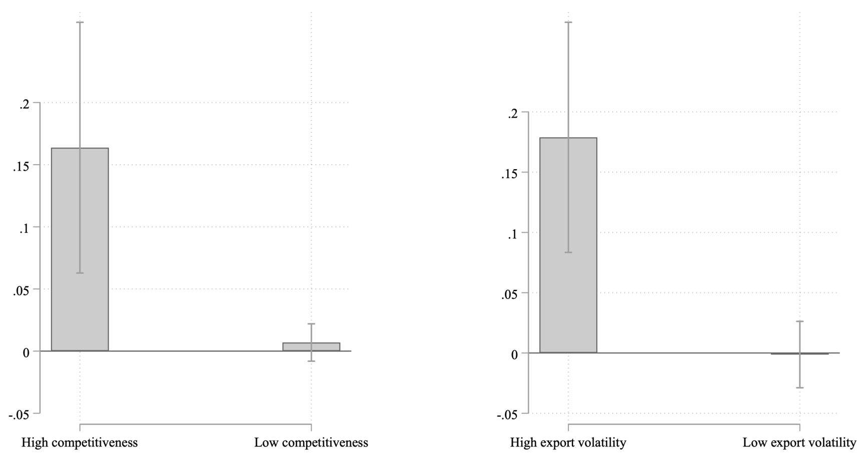
Note: This figure shows the distribution of the demeaned approval rate of USPTO patent examiners assigned to first-time patent applications by CCTS-PatEx Chinese exporters. Examiner approval rates are demeaned by art unit and first-action year.

Figure A4: Examiner Approval Rates for Approved and Rejected Applications



Note: This figure shows the kernel density of demeaned examiner approval rates separately for successful and unsuccessful patent applications. The sample covers all first-time USPTO applications by CCTS-PatEx Chinese exporters. Examiner approval rates are demeaned by art unit and first-action year.

Figure A5: Signal Relevance: Export Growth Decomposition



Note: This figure visualizes the estimated effect of a successful first U.S. patent application on constituent components of the export growth of Chinese applicants. Total firm growth is decomposed two-way into exports to destination-product markets with high vs. low information asymmetry. Markets have high information asymmetry if their competitiveness or volatility is above the median. Market competitiveness is the Herfindhal Index (HHI) across Chinese exporters in a given destination-product-year market. Market volatility is the coefficient of variation of exports within a firm-destination-product over time, averaged across firms to the destination-product level. All coefficients are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. All regressions include HS2 sector by year pair fixed effects, and control for initial log exports and firm export tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit.

Table A1: Technology Classes of USPTO Patent Applications by Chinese Applicants

Rank	USPC class	USPC title	Number	Percentage (%)
Sample: all first-time USPTO patent applicants from China				
1	514	Drug, bio-affecting and body treating compositions	266	5.55
2	424	Drug, bio-affecting and body treating compositions	196	4.09
3	435	Chemistry: molecular biology and microbiology	144	3.01
4	362	Illumination	112	2.34
5	439	Electrical connectors	84	1.75
6	257	Active solid-state devices	77	1.61
7	455	Telecommunications	71	1.48
8	361	Electricity: electrical systems and devices	69	1.44
9	428	Stock material or miscellaneous articles	68	1.42
10	345	Computer graphics processing and selective visual display systems	67	1.40
		Other	3637	75.91
Sample: first-time USPTO patent applicants matched to CCTS				
Rank	USPC class	USPC title	Number	Percentage (%)
1	424	Drug, bio-affecting and body treating compositions	117	4.13
2	514	Drug, bio-affecting and body treating compositions	96	3.39
3	362	Illumination	86	3.04
4	435	Chemistry: molecular biology and microbiology	80	2.83
5	439	Electrical connectors	66	2.33
6	428	Stock material or miscellaneous articles	50	1.77
7	257	Active solid-state devices	45	1.59
8	345	Computer graphics processing and selective visual display systems	41	1.45
9	361	Electricity: electrical systems and devices	40	1.41
10	536	Organic compounds	34	1.20
		Other	2116	76.86

Note: This table shows the top 10 technology classes of the first USPTO patent applications filed by Chinese applicants. The top panel considers all first-time Chinese applicants to the USPTO. The bottom considers the subset of first-time Chinese applicants to the USPTO in the matched CCTS-PatEx sample.

Table A2: Additional Balance Tests

Sample	*Firm Characteristic*	*Successful USPTO application*	*Examiner approval rate*
CCTS (Sample size = 1,156)	Share of tech. related exports (conservative with NLP)	0.0219	0.145**
		(0.0286)	(0.0666)
	Share of tech. related exports (liberal with ALP)	0.00972	0.113
		(0.0306)	(0.0708)
	Share of differentiated exports	-0.0376*	0.0427
		(0.0201)	(0.0608)
	Share of high-quality-dispersion exports	0.0182	0.0302
		(0.0263)	(0.0607)
	Share of contract intensive exports	-0.00328	0.0206
		(0.0138)	(0.0371)
	Share of high-complexity exports	-0.00101	0.0268
		(0.0232)	(0.0571)
	Share of exports to the U.S.	-0.0405*	0.0127
		(0.0220)	(0.0466)
	Share of exports to high-income countries	-0.0452**	-0.0349
		(0.0175)	(0.0431)
	Share of exports to high-rule-of-law index countries	-0.0329**	-0.0616
		(0.0146)	(0.0390)

Note: This table reports results from regressing exporters' *ex-ante* characteristics on an indicator for a successful patent application and on examiner approval rate. The sample covers all continuing CCTS-PatEx matched exporters. All regressions control for HS2 by application year pair fixed effects. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A3: Examiner Specialization Tests

Dependent variable	*Successful USPTO application*			
	(1)	(2)	(3)	(4)
Examiner approval rate (residual 1)	0.968***	0.870***		
	(0.0693)	(0.0894)		
Examiner approval rate (residual 2)			0.993***	0.872***
			(0.0678)	(0.0882)
Log exports	0.00227	0.00165	0.00323	0.00233
	(0.00567)	(0.00572)	(0.00579)	(0.00584)
Export tenure	-0.00789*	-0.00766*	-0.00770*	-0.00741*
	(0.00436)	(0.00435)	(0.00453)	(0.00448)
Log examiner's Chinese applications		-0.0142		-0.0170
		(0.0230)		(0.0235)
Log examiner's foreign applications		0.0610**		0.0767***
		(0.0267)		(0.0269)
Log examiner's years of experience		-0.0488		-0.0601
		(0.0425)		(0.0428)
HS2-year fixed effects	Yes	Yes	Yes	Yes
F-test: IV = 0	195.26***	94.70***	214.36***	97.61***
# Observations	1,156	1,156	1,156	1,156

Note: This table reports validation test results for the exogeneity of patent assignment to examiners. The sample covers all CCTS-PatEx matched exporters. Examiner approval rate (residual 1) is an examiner's approval rate demeaned by art unit and first-action year. Examiner approval rate (residual 2) is an examiner's approval rate demeaned by both art unit by first-action year and technology class by first-action year. All columns control for HS2 sector by year pair fixed effects. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A4: Growth of Extensive and Intensive Export Margins

Dependent variable	*Annualized 3-year growth*			
	# Prod	# Dest	# Dest-prod	Avg exports per dest-prod
	(1)	(2)	(3)	(4)
Successful USPTO application	0.0660	0.0531	0.0782*	0.114**
	(0.0412)	(0.0344)	(0.0406)	(0.0478)
Log exports	-0.00183	-0.0128***	-0.0104***	-0.0372***
	(0.00329)	(0.00297)	(0.00361)	(0.00407)
Export tenure	-0.00442**	-0.00541**	-0.00626***	0.00286
	(0.00224)	(0.00212)	(0.00232)	(0.00310)
HS2-year fixed effects	Yes	Yes	Yes	Yes
F-stat	195.26	195.26	195.26	195.26
# Observations	1,156	1,156	1,156	1,156

Note: This table reports the estimated effect of a successful first U.S. patent application on the annualized 3-year growth rate of different export margins of Chinese applicants. The sample covers all CCTS-PatEx matched exporters. All columns are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. All columns include HS2 sector by year pair fixed effects, and control for initial log exports and export tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A5: Export Growth Decomposition in CCTS-ASIE-PatEx Sample

Dependent variable	*Components of annualized 3-year export growth*			
	Incumbent dest-prod markets		New dest-prod markets	
	(1)	(2)	(3)	(4)
Successful USPTO application	0.157**	0.153**	0.0598**	0.0480**
	(0.0628)	(0.0610)	(0.0286)	(0.0230)
Log exports		-0.0120**		-0.0337***
		(0.00550)		(0.00323)
Export tenure		-0.00724**		-0.00685***
		(0.00332)		(0.00156)
Log employment		0.0110		0.0184***
		(0.00719)		(0.00421)
Industry-year fixed effects	Yes	Yes	Yes	Yes
Ownership-year fixed effects	Yes	Yes	Yes	Yes
F-stat	147.05	147.44	147.05	147.44
# Observations	940	940	940	940

Note: This table reports the estimated effect of a successful first U.S. patent application on constituent components of export growth of Chinese applicants in the subsample of CCTS-ASIE-PatEx matched exporters. All columns are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. Columns 2, 4, and 6 control for initial log exports, export tenure, and log employment. All columns include CIC2 industry by year and ownership type by year pair fixed effects. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A6: Three-Part Export Growth Decomposition

Dependent variable	*Components of annualized 3-year export growth*					
	Continuing dest-prod markets		Dropped dest-prod markets		New dest-prod markets	
	(1)	(2)	(3)	(4)	(5)	(6)
Successful USPTO application	0.0678*	0.0681*	-0.0850***	-0.0851***	0.0195	0.0217
	(0.0358)	(0.0349)	(0.0311)	(0.0309)	(0.0309)	(0.0260)
Log exports		-0.00977***		-0.00415*		-0.0311***
		(0.00292)		(0.00241)		(0.00232)
Export tenure		-0.00244		-0.00235		-0.00290*
		(0.00209)		(0.00204)		(0.00149)
HS2-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
F-stat	198.07	195.26	198.07	195.26	198.07	195.26
# Observations	1,156	1,156	1,156	1,156	1,156	1,156

Note: This table reports the estimated effect of a successful first U.S. patent application on constituent components of the export growth of Chinese applicants. The sample covers all CCTS-PatEx matched exporters. All columns are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. Columns 2, 4, and 6 control for initial log exports and export tenure. All columns include HS2 sector by year pair fixed effects. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A7: Second U.S. Patent Application

Dependent variable	*Annualized 3-year export growth*		
	(1)	(2)	(3)
Successful second USPTO application	0.0262	0.0309	0.0502
	(0.0177)	(0.0853)	(0.0824)
Log exports			-0.0104***
			(0.00278)
Export tenure			-0.00167
			(0.00243)
HS2-year fixed effects	Yes	Yes	Yes
Model	OLS	2SLS	2SLS
F-stat		10.87	11.19
# Observations	274	274	274

Note: This table reports the estimated effect of a successful second U.S. patent application on the subsequent export growth of Chinese applicants, conditional on a first patent application being successful. The dependent variable is the annualized 3-year export growth rate. The sample covers CCTS-PatEx matched exporters with a successful first U.S. patent application. Column 1 is estimated with OLS, while Columns 2 and 3 are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. Column 3 controls for initial log exports and export tenure. All columns include HS2 sector by year pair fixed effects. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A8: Placebo Test

Dependent variable	*Annualized 3-year export growth, 3-year lagged*		
	(1)	(2)	(3)
Successful USPTO application	0.00381	0.00926	0.0115
	(0.00845)	(0.0223)	(0.0215)
Log exports, 3-year lagged			-0.00952***
			(0.00146)
Export tenure, 3-year lagged			-0.00917***
			(0.00136)
HS2-year fixed effects	Yes	Yes	Yes
Model	OLS	2SLS	2SLS
F-stat		154.13	152.46
# Observations	947	947	947

Note: This table reports the estimated effect of a successful first U.S. patent application on the 3-year lagged annualized export growth of Chinese applicants as a placebo test. The sample covers all CCTS-PatEx matched exporters. Column 1 is estimated with OLS, while Columns 2 and 3 are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. Column 3 controls for 3-year lagged log exports and export tenure. All columns include HS2 sector by year pair fixed effects. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A9: Alternative Specifications

Dependent variable	*Annualized 3-year export growth*						
	Baseline	Alternative IV	Bootstrap	Examiner control	Alternative FEs		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Successful USPTO application	0.175***	0.160***	0.180***	0.247***	0.179***	0.193***	0.172***
	(0.0522)	(0.0540)	(0.0530)	(0.0734)	(0.0487)	(0.0513)	(0.0492)
Log exports	-0.0367***	-0.0367***	-0.0382***	-0.0367***	-0.0398***	-0.0376***	-0.0379***
	(0.00492)	(0.00491)	(0.00468)	(0.00499)	(0.00473)	(0.00400)	(0.00405)
Export tenure	-0.00299	-0.00313	-0.00207	-0.00248	-0.000505	-0.00242	-0.00163
	(0.00366)	(0.00364)	(0.00363)	(0.00381)	(0.00381)	(0.00294)	(0.00305)
Log examiner's Chinese applications				0.000780			
				(0.0149)			
Log examiner's foreign applications				-0.0204			
				(0.0210)			
Log examiner's years of experience				0.00210			
				(0.0278)			
HS2-application year fixed effects	Yes	Yes	Yes	Yes			
HS2-first-action year fixed effects					Yes		
Application year fixed effects						Yes	
First-action year fixed effects							Yes
F-stats	195.26	214.36		94.70	156.55	187.19	182.60
Observations	1,156	1,156	1,156	1,156	1,171	1,282	1,282

Note: This table explores the robustness of the estimated effect of a successful first U.S. patent application on the 3-year lagged annualized export growth of Chinese applicants across alternative specifications. The sample covers all CCTS-PatEx matched exporters. Column 1 replicates the baseline. Column 2 uses an alternative instrument that excludes both art unit by year and technology class by year pair fixed effects. Column 3 adds controls for examiner experience. Columns 4,5 and 6 replace the baseline HS2 sector by application year pair fixed effects respectively with HS2 by first-action year, application year, or first-action year fixed effects. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A10: Controlling for Global Patent Activity

Dependent variable	*Annualized 3-year export growth*		
	(1)	(2)	(3)
Successful USPTO application	0.0674***	0.187***	0.171**
	(0.0200)	(0.0529)	(0.0678)
Successful USPTO application× USPTO priority			0.0434
			(0.106)
Log exports	-0.0378***	-0.0380***	-0.0381***
	(0.00493)	(0.00501)	(0.00503)
Export tenure	-0.00344	-0.00239	-0.00227
	(0.00349)	(0.00367)	(0.00370)
USPTO priority	-0.00218	-0.00693	-0.0351
	(0.0247)	(0.0250)	(0.0775)
EPO application	0.00134	0.00357	0.00475
	(0.0234)	(0.0242)	(0.0243)
JPO application	-0.0334	-0.0380	-0.0376
	(0.0232)	(0.0238)	(0.0239)
CNIPA application	0.0197	0.0190	0.0187
	(0.0240)	(0.0245)	(0.0243)
HS2-year fixed effects	Yes	Yes	Yes
Model	OLS	IV	IV
F-stat		191.28	57.73
# Observations	1,101	1,101	1,101

Note: This table reports the estimated effect of a successful first U.S. patent application on the subsequent export growth of Chinese applicants, controlling for patent family submissions to EPO, JPO, and CNIPA. The dependent variable is the annualized 3-year export growth rate. All columns include an indicator for whether the U.S. application is the priority claim of the patent family, and indicators for whether an application from the same patent family is ever filed respectively with EPO, JPO, and CNIPA. Column 1 is estimated with OLS, while Columns 2 and 3 are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A11: Market Protection: Export Growth Decomposition

Panel A. NLP-based semantic similarity with patent texts				
	U.S. Related (1)	U.S. Unrelated (2)	Non-U.S. Related (3)	Non-U.S. Unrelated (4)
Successful USPTO Application	0.000594	0.0202	0.0182	0.139***
	(0.0171)	(0.0167)	(0.0246)	(0.0371)
Panel B. Lybbert and Zolas (2014) ALP similarity with patent classes				
	U.S. Related (1)	U.S. Unrelated (2)	Non-U.S. Related (3)	Non-U.S. Unrelated (4)
Successful USPTO Application	0.0256*	-0.00485	0.0145	0.143***
	(0.0135)	(0.0213)	(0.0224)	(0.0409)
Controls	Log exports and export tenure			
HS2-year fixed effects	Yes	Yes	Yes	Yes
F-stat	195.257	195.257	195.257	195.257
# Observations	1,156	1,156	1,156	1,156

Note: This table reports the estimated effect of a successful first U.S. patent application on constituent components of the export growth of Chinese applicants. Total firm growth is decomposed four-way into exports to the U.S. vs. Rest of the World (ROW) and products that are technologically related vs. unrelated to the firm's patent. Products are technologically related to a patent or patent technology class if their descriptions have semantic similarity above 80% based on the NLP method in Panel A (see Appendix C for details) and ALP weights above 5% based on Lybbert and Zolas (2014) approach in Panel B. The sample covers all CCTS-PatEx matched exporters. All columns are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. All columns include HS2 sector by year pair fixed effects, and control for initial log exports and firm export tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A12: Market Protection: Growth by Market Type

Panel A. NLP-based semantic similarity with patent texts				
	U.S. Related	U.S. Unrelated	Non-U.S. Related	Non-U.S. Unrelated
	(1)	(2)	(3)	(4)
Successful USPTO Application	0.0419	0.178*	0.0624	0.191***
	(0.138)	(0.106)	(0.0833)	(0.0730)
F-stat	74.43	133.06	125.96	182.68
# Observations	604	791	834	1,051
Panel B. Lybbert and Zolas (2014) ALP similarity with patent classes				
	U.S. Related	U.S. Unrelated	Non-U.S. Related	Non-U.S. Unrelated
	(1)	(2)	(3)	(4)
Successful USPTO Application	0.211	0.213**	0.0746	0.181***
	(0.191)	(0.0977)	(0.119)	(0.0639)
F-stat	36.05	129.75	103.40	189.08
# Observations	447	878	677	1,108
Controls	Log exports and export tenure			
HS2-year fixed effects	Yes	Yes	Yes	Yes

Note: This table reports the estimated effect of a successful first U.S. patent application on the subsequent export growth of Chinese applicants in each of four market types. These market types are defined based on the destination country (U.S. vs. Rest of the World, ROW) and product type (technologically related vs. unrelated to the firm's patent). Products are technologically related to a patent or patent technology class if their descriptions have semantic similarity above 80% based on the NLP method in Panel A (see Appendix C for details) and ALP weights above 5% based on Lybbert and Zolas (2014) approach in Panel B. The sample covers all CCTS-PatEx matched exporters. All columns are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. All columns include HS2 sector by year pair fixed effects, and control for initial log exports and firm export tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A13: Quality Signal: Export Growth Decomposition

Panel A. Rauch (1999) HS6 product differentiation				
	High income Differentiated (1)	High income Non-differentiated (2)	Low income Differentiated (3)	Low income Non-differentiated (4)
Successful USPTO Application	0.128***	0.0123	0.0341*	0.00395
	(0.0374)	(0.0219)	(0.0176)	(0.00571)
Panel B. Estimated quality dispersion across firms within HS6 product				
	High income High quality dispersion (1)	High income Low quality dispersion (2)	Low income High quality dispersion (3)	Low income Low quality dispersion (4)
Successful USPTO Application	0.106***	0.0256	0.0307*	0.0173
	(0.0394)	(0.0325)	(0.0177)	(0.0140)
Controls	Log exports and export tenure			
HS2-year fixed effects	Yes	Yes	Yes	Yes
F-stat	195.26	195.26	195.26	195.26
# Observations	1,156	1,156	1,156	1,156

Note: This table reports the estimated effect of a successful first U.S. patent application on constituent components of the export growth of Chinese applicants. Total firm growth is decomposed four-way into exports to high- vs. low-income countries and products with high vs. low scope for quality differentiation. The sample covers all CCTS-PatEx matched exporters. All columns are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. All columns include HS2 sector by year pair fixed effects, and control for initial log exports and firm export tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A14: Quality Signal: Growth by Market Type

Panel A. Rauch (1999) HS6 product differentiation				
	High income Differentiated (1)	High income Non-differentiated (2)	Low income Differentiated (3)	Low income Non-differentiated (4)
Successful USPTO Application	0.133**	0.115	0.0420	0.133
	(0.0649)	(0.101)	(0.0845)	(0.162)
F-stat	179.53	135.60	147.76	75.38
# Observations	1,063	760	875	431
Panel B. Estimated quality dispersion across firms within HS6 product				
	High income High quality dispersion (1)	High income Low quality dispersion (2)	Low income High quality dispersion (3)	Low income Low quality dispersion (4)
Successful USPTO Application	0.158**	0.0603	0.0733	0.331**
	(0.0642)	(0.0934)	(0.0897)	(0.138)
F-stat	173.753	146.97	146.076	89.311
# Observations	1,099	689	911	447
Controls	Log exports and export tenure			
HS2-year fixed effects	Yes	Yes	Yes	Yes

Note: This table reports the estimated effect of a successful first U.S. patent application on the subsequent export growth of Chinese applicants in each of four market types. These market types are defined based on the destination country (high-income vs. low-income) and product type (high vs. low scope for quality differentiation). The sample covers all CCTS-PatEx matched exporters. All columns are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. All columns include HS2 sector by year pair fixed effects, and control for initial log exports and firm export tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A15: Credibility Signal: Export Growth Decomposition

Panel A. Nunn (2007) contract intensity

	High rule of law Contract intensive (1)	High rule of law Non-contract intensive (2)	Low rule of law Contract intensive (3)	Low rule of law Non-contract intensive (4)
Successful USPTO Application	0.115***	0.0369**	0.0150	0.0125
	(0.0418)	(0.0184)	(0.0176)	(0.00981)

Panel B. Levchenko (2007) complexity

	High rule of law High complexity (1)	High rule of law Low complexity (2)	Low rule of law High complexity (3)	Low rule of law Low complexity (4)
Successful USPTO Application	0.130***	0.0191	0.0217	0.00581
	(0.0382)	(0.0320)	(0.0212)	(0.00770)
Controls	Log exports and export tenure			
HS2-year fixed effects	Yes	Yes	Yes	Yes
F-stat	195.26	195.26	195.26	195.26
# Observations	1,156	1,156	1,156	1,156

Note: This table reports the estimated effect of a successful first U.S. patent application on constituent components of the export growth of Chinese applicants. Total firm growth is decomposed four-way into exports to countries with high vs. low rule of law and products with high vs. low contract reliance. The sample covers all CCTS-PatEx matched exporters. All columns are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. All columns include HS2 sector by year pair fixed effects, and control for initial log exports and firm export tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A16: Credibility Signal: Growth by Market Type

Panel A. Nunn (2007) contract intensity

	High rule of law Contract intensive (1)	High rule of law Non-contract intensive (2)	Low rule of law Contract intensive (3)	Low rule of law Non-contract intensive (4)
Successful USPTO Application	0.112*	0.199**	0.0880	0.234
	(0.0578)	(0.0977)	(0.0991)	(0.145)
F-stat	177.79	133.13	131.87	78.63
# Observations	1,047	887	799	542

Panel B. Levchenko (2007) complexity

	High rule of law High complexity (1)	High rule of law Low complexity (2)	Low rule of law High complexity (3)	Low rule of law Low complexity (4)
Successful USPTO Application	0.115*	0.0576	0.153	0.0397
	(0.0669)	(0.0738)	(0.0992)	(0.113)
F-stat	170.25	174.76	122.36	135.54
# Observations	985	972	723	630
Controls	Log exports and export tenure			
HS2-year fixed effects	Yes	Yes	Yes	Yes

Note: This table reports the estimated effect of a successful first U.S. patent application on the subsequent export growth of Chinese applicants in each of four market types. These market types are defined based on the destination country (high vs. low rule of law) and product type (high vs. low contract reliance). The sample covers all CCTS-PatEx matched exporters. All columns are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. All columns include HS2 sector by year pair fixed effects, and control for initial log exports and firm export tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A17: Signal Relevance: Exports Across Markets Within Firms

Panel A. Destination-product market HHI		
Dependent variable	*Survival Indicator*	*Export value growth*
	(1)	(2)
Successful USPTO application × HHI	-0.401***	0.0407
	(0.110)	(0.107)
F-stat	33.83	21.87
# Observations	86,627	38,822
Panel B. Export volatility in the destination-product market		
Dependent variable	*Survival Indicator*	*Export value growth*
	(1)	(2)
Successful USPTO application × Export volatility	0.271**	-0.176
	(0.107)	(0.126)
F-stat	32.99	20.74
# Observations	86,091	38,797
Controls	Firm-dest-prod level log exports, relative export tenure, and HHI/export volatility	
Fixed effects	Firm-year, HS6-year, and destination-year fixed effects	

Note: This table reports the heterogeneous effect of a successful first U.S. patent application on the survival probability and export growth across destination-product markets within firms. The sample in Columns 1 (Columns 2) covers all incumbent (all continuing) firm-destination-product triplets for CCTS-PatEx matched exporters. Destination-product markets have high information asymmetry if their competitiveness is above the median in Panel A and if their sales volatility is above the median in Panel B. Market competitiveness is the Herfindhal Index (HHI) across Chinese exporters in a given destination-product-year market. Market volatility is the coefficient of variation of exports within a firm-destination-product over time, averaged across firms to the destination-product level. All columns are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. All columns include HS6 by year, destination by year, and firm by year pair fixed effects, and control for firm-destination-product level initial log exports and relative tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A18: Signal Relevance: Export Tenure

Dependent variable	*Annualized 3-year export growth*		
	(1)	(2)	(3)
Successful USPTO application	0.175***	0.236***	0.0996
	(0.0522)	(0.0788)	(0.0790)
Log exports	-0.0367***	-0.0412***	-0.0274***
	(0.00492)	(0.00606)	(0.00915)
Export tenure	-0.00299	-0.0103	-0.00371
	(0.00366)	(0.00981)	(0.00764)
HS2-year fixed effects	Yes	Yes	Yes
Sample	All applicants	Tenure <= 5	Tenure > 5
F-stat	187.19	81.17	65.46
# Observations	1,156	646	427

Note: This table reports the heterogeneous effect of a successful first U.S. patent application on the subsequent annualized 3-year export growth of Chinese applicants with different export tenure. The sample in Columns 1 covers all CCTS-PatEx matched exporters. The sample in Column 2 (3) covers CCTS-PatEx matched exporters with export tenure below (above) the median (5 years). All columns are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. All columns include HS2 sector by year pair fixed effects, and control for initial log exports and export tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A19: Financial Constraints

Dependent variable	*Annualized 3-year export growth*					
	External Finnancial Dependence		*Liquidity Needs*		*Asset Tangibility*	
Firm Fin Vulnerability	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)
Successful USPTO application	0.149**	0.183***	0.154**	0.226***	0.138**	0.263***
	(0.0682)	(0.0615)	(0.0619)	(0.0766)	(0.0659)	(0.0813)
Difference (High - Low)	-0.0368		-0.799		-0.130	
	(0.0894)		(0.0971)		(0.0999)	
Controls	Log exports, export tenure					
HS2-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
K-P rk Wald F-stats	147.46	135.58	180.43	101.28	138.46	102.99
Observations	473	644	646	470	591	511

Note: This table reports the heterogeneous effect of a successful first U.S. patent application on the subsequent annualized 3-year export growth of Chinese applicants with different levels of financial vulnerability. The sample in Columns 1, 3, and 5 (2, 4, and 6) covers CCTS-PatEx matched exporters with financial vulnerability above (below) the median. A firm's financial vulnerability is measured with the weighted average of industry-level financial vulnerability, using industries' share of firm exports as weights. Industry's financial vulnerability is measured by their external finance dependence, liquidity needs (inventories-to-sales ratio), or asset tangibility. All columns are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. All columns include HS2 sector by year pair fixed effects, and control for initial log exports and export tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A20: Follow-on Innovation

Dependent variable	*Annualized 3-year growth of CNIPA patents*		
	(1)	(2)	(3)
Successful UPSTO application	0.0659	-0.0583	-0.0494
	(0.0461)	(0.120)	(0.0993)
Log exports	0.0119*	0.0123*	0.00184
	(0.00624)	(0.00644)	(0.00640)
Export tenure	-0.00871	-0.00874	-0.00460
	(0.00654)	(0.00664)	(0.00637)
HS2-year fixed effects	Yes	Yes	Yes
Model	OLS	2SLS	2SLS
Sample	All applicants	All applicants	Continuing applicants
F-stat		146.65	147.78
Observations	797	797	724

Notes: This table reports the estimated effect of a successful first U.S. patent application on a Chinese applicant's subsequent patent applications in China. The sample covers CCTS-ORBIS-PatEx matched exporters. Column 1 is estimated with OLS, while Columns 2 and 3 are estimated with 2SLS, using the demeaned examiner approval rate as an instrument. All columns include HS2 by application year pair fixed effects, and control for initial log exports and export tenure. Heteroskedasticity-consistent standard errors are clustered by examiner art unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix B An Example of CCTS-PatEx Matching Procedure

This section provides an example of the matching procedure between the English names of patent application assignees in the USTPO PatEx and patent assignment database and the Chinese names of exporters in the CCTS database.

(12) **United States Patent**
Wang et al.

(10) **Patent No.: US 7,339,289 B2**
(45) **Date of Patent: Mar. 4, 2008**

(54) **SYNCHRONOUS PERMANENT MAGNET PLANAR MOTOR**

(75) Inventors: **Jinsong Wang**, Beijing (CN); **Yu Zhu**, Beijing (CN); **Jiayong Cao**, Beijing (CN); **Wensheng Yin**, Beijing (CN); **Guanghong Duan**, Beijing (CN)

(73) Assignees: **Tsinghua University**, Beijing (HK); **Shanghai MicroElectronics Equipment Co., Ltd.**, Shanghai (HK)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/207,425**

(22) Filed: **Aug. 19, 2005**

(65) **Prior Publication Data**

US 2006/0049699 A1 Mar. 9, 2006

(30) **Foreign Application Priority Data**

Aug. 20, 2004 (CN) 2004 1 0009472

(51) **Int. Cl.**
H20K 41/00 (2006.01)
(52) **U.S. Cl.** **310/12**; 310/13; 310/15
(58) **Field of Classification Search** 310/12, 310/13, 15
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,563,602 A *	1/1986	Nagasaka	....	310/12
4,945,268 A *	7/1990	Nihei et al.	....	310/12
5,138,206 A *	8/1992	Schmidt	....	310/12
5,352,946 A *	10/1994	Hoffman et al.	....	310/12
6,144,118 A *	11/2000	Cahill et al.	....	310/12
6,236,124 B1 *	5/2001	Sekiyama et al.	....	310/12
6,339,266 B1 *	1/2002	Tanaka	....	310/12
6,703,726 B2 *	3/2004	Itoh et al.	....	310/12
6,835,941 B1 *	12/2004	Tanaka	....	250/491.1
6,864,602 B2 *	3/2005	Korenaga	....	310/12
6,927,505 B2 *	8/2005	Binnard et al.	....	310/12

OTHER PUBLICATIONS

Han-Sam Cho and Hyun-Kyo Jung, Analysis and Design of Synchronous Permanent-Magnet Planar Motors, IEEE Transactions of Energy Conversion, vol. 17, No. 4, Dec. 2002.

Ir. J.C. Compter, Electro-dynamic planar motor, Department of Mechanical Engineering, Section Precision Engineering, Technical University Eindhoven, Eindhoven, The Netherlands, Aug. 13, 2003, Science Direct, Precision Engineering 28 (2004) 171-180, available at www.sciencedirect.com.

(Continued)

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(57) **ABSTRACT**

According to the invention, configurations of X-windings and Y-windings in a synchronous permanent planar motor are improved, X-windings and Y-windings overlap in the direction normal to the planar magnet array and distribute on the entire surface of the thrust core, such that effective wires in the X-windings and Y-windings are lengthened and increased in number, therefore the electromagnetic force generated by the SPMPM of this invention is increased correspondingly; X-windings and Y-windings are mounted on a thrust core made of iron material, thus the electromagnetic force is further increased; in addition, two separated anti-yawing member are provided on the mover for counteracting yawing of the mover, accordingly interference between anti-yawing torque and the electromagnetic force for propelling is eliminated.

8 Claims, 6 Drawing Sheets

The document above shows the record of the first patent filed by **Shanghai Microelectronics Equipment Co.** with USPTO. We first standardize the company's name by replacing "Co." with "Company", and identify its first application. We then translate the two keywords "Microelectronics Equipment" and "Shanghai" into Chinese ("微电子设备" and "上海"), and search for them in the publicly available business registration database, *Tianyancha*. The search results mainly direct to one company named "上海微电子装备有限公司." To ensure the accuracy of this match, we cross-check the patent information with the company's information on *Tianyancha*. The results indicate that the company has been producing electronic components and was established before 2005, which aligns with the technology field and filing date of the patent. Finally, we use the firm's Chinese name to locate the firm's customs ID in the CCTS database.

Appendix C Illustration of the NLP-based Matching Procedure between Patent Applications and HS Codes

This section illustrates the NLP-based matching procedure used to match patent applications to HS codes. One of the benefits of this approach is that it enables us to identify the relevant products with greater accuracy by analyzing the specific textual descriptions in each patent, as opposed to relying solely on the textual information provided in the patent technology class description.

To begin, we compile the key textual information from each patent application record in our matched dataset, which includes the patent title, abstract, and USPC technology class description. Following Argente *et al.* (2023), we assign a higher weight to the patent title (by a factor of 5) and the USPC technology class description (by a factor of 3), as these fields typically have higher signal-to-noise ratios than the patent abstract. We also extract the textual descriptions of each 6-digit, 4-digit, or 2-digit HS code from the UN Comtrade database.

Next, we concatenate the textual information from the patent applications and preprocess both textual datasets to remove unwanted characters and stop words. To further optimize the text data, we apply the lemmatizing algorithm using the WordNetLemmatizer from the NLTK Python module (`nltk.org`), which reduces words to their base or dictionary forms. This step enables more precise analysis and facilitates easier comparison between documents.[32]

We then encode the preprocessed datasets using the text-embedding-ada-002 model developed by OpenAI. This model is pre-trained on a vast corpus of text data and utilizes a transformer neural network architecture similar to OpenAI's GPT-2 model. The model encodes the textual data into fixed-length vectors that represent the semantic meaning of the input sentences - that is, vectors that capture the meaning and context of words in the input sentences, as well as the relationships between them.[33] We denote the resulting word vector for patent texts as $\mathbf{P}_i \equiv (p_{i1}, p_{i2}, ..., p_{iM})$ and the word vector for HS texts as $\mathbf{H}_j \equiv (h_{j1}, h_{j2}, ..., h_{jM})$. Here, i represents each patent, j represents each HS code, and M represents the total length of the word vector.

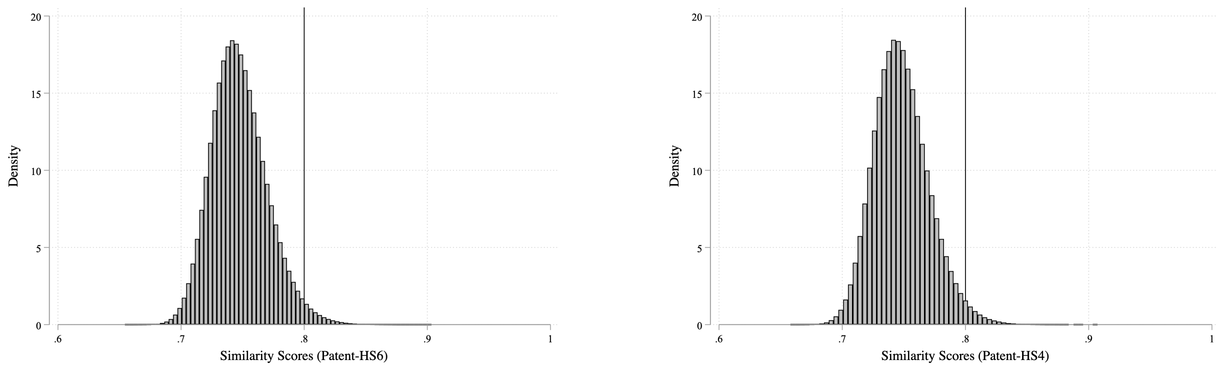
We compute the cosine similarities between each patent word vector, $\mathbf{P}_i$ and all HS word vectors, $\mathbf{H}_j, \forall j$. Specifically, for each pair of $\mathbf{P}_i$ and $\mathbf{H}_j$, we compute the cosine similarity as following:

$$S_C(\mathbf{P}_i, \mathbf{H}_j) = \frac{\mathbf{P}_i \cdot \mathbf{H}_j}{\|\mathbf{P}_i\|\|\mathbf{H}_j\|} = \frac{\sum_{m=1}^{M} p_{im} h_{jm}}{\sqrt{\sum_{m=1}^{M} p_{im}^2}\sqrt{\sum_{m=1}^{M} h_{jm}^2}}$$

[32]For example, the word "running" will be reduced to "run," and the word "mice" will be reduced to "mouse."

[33]For a detailed description of the text-embedding-ada-002 model, please see `https://openai.com/blog/new-and-improved-embedding-model`.

Figure C1: Distributions of Similarity Scores



Note: This figure plots the distributions of similarity scores between the patent texts and HS descriptions. The left panel shows the distribution of similarity scores between patent texts and descriptions of HS 6-digit codes, and the right panel shows the distribution of similarity scores between patent texts and descriptions of HS 4-digit codes.

The cosine similarity score ranges in $[0, 1]$ and reflects the semantic similarity between the patent texts and the HS descriptions. A higher score indicates greater contextual similarity between the two documents. This technique has been the standard practice in the literature, see, for example, Hoberg and Phillips (2016).

Finally, we set a similarity score threshold of 0.8, which is approximately the 99 percentile of the distribution of similarity scores between patents and HS6 codes. This threshold ensures that only HS codes with a similarity score above 0.8 are deemed technologically relevant. (the density distribution of similarity scores is shown in Figure C1). In cases where a patent has less than five HS codes that meet this condition, we follow Argente *et al.* (2023) and include the top five HS codes based on their similarity scores. We apply the same algorithm for patent-HS6 pairs and patent-HS4 pairs.

To verify the accuracy of our matching results, we manually review four patent applications and their matched HS codes with the highest similarity scores. We further use OpenAI's chatbot, ChatGPT-3.5, to examine whether our matched results overlap with ChatGPT-3.5's answers. We list the details of the validation checks below. Overall, we find that our matching results are reasonably well in identifying the HS codes that are most closely associated with the technical content of the matched patent applications.

Examples of Validation Checks:

1. Application number: 11986526
    - <u>Patent title</u>: fluorescent lamp driver
    - <u>Patent abstract</u>: the present invention discloses a kind of fluorescent lamp driver, which consists of the multi-switch converting circuit, power transformer (t1), resonant inductor (l1), resonant capacitor (c3) and step-up transformer (t2). it features the followings: the primary winding (pw) of t1 connects with the ac output of multi-switch converting circuit. l1 and c3, after series connection, connect

with the secondary winding (sw) of t1 through the pw of t2. the sw of t2 connects with the load output. in this invention, a resonant inductor is connected in series on the resonant loop to realize frequency and voltage modulation as well as the soft switch function of the primary power switch of the power transformer.

- USPC Description: electric lamp and discharge devices: systems
- Matched HS6 codes
  (a) 850410* - Discharge lamps or tubes; ballasts therefor
  (b) 900661 - Photographic flashlight apparatus; discharge lamp (electronic)
  (c) 850490 - Electrical transformers, static converters and inductors; parts thereof
  (d) 853941 - Lamps; arc-lamps
  (e) 853931 - Lamps; discharge, (excluding ultra-violet), fluorescent, hot cathode

2. Application number: 13006944
   - Patent title: safety socket
   - Patent abstract: a safety socket includes a first conductive clamp seat and a second conductive clamp seat in alignment with a first insertion hole and a second insertion hole. in normal state, the first and second conductive clamp seats are spaced from a first power terminal and a second power terminal in an open state. when a plug is plugged into the safety socket, the prongs of the plug outward bias spring limbs of the first and second conductive clamp seats into contact with the corresponding first and second power terminals respectively. only under such circumstance, the first and second conductive clamp seats electrically contact the first and second power terminals to close the circuit and provide power for an electric appliance. if a child inserts a conductive article into the first or second insertion hole, the danger of electrical shock can be avoided to ensure safety in use of electricity.
   - USPC Description: electrical connectors
   - Matched HS6 codes
     (a) 853669* - Electrical apparatus; plugs and sockets, for a voltage not exceeding 1000 volts
     (b) 854451 - Insulated electric conductors; for a voltage exceeding 80 volts but not exceeding 1000 volts, fitted with connectors
     (c) 854441 - Insulated electric conductors; for a voltage not exceeding 80 volts, fitted with connectors
     (d) 854459 - Insulated electric conductors; for a voltage exceeding 80 volts but not exceeding 1000 volts, not fitted with connectors
     (e) 853540 - Electrical apparatus; lightning arresters, voltage limiters and surge suppressors (for a voltage exceeding 1000 volts)

3. Application number: 11910738
   - Patent title: automatic tv standard determination method and apparatus thereof

- Patent abstract: an apparatus for automatically determining a tv standard of a tv channel comprises a frequency identification module and a determination module. the frequency identification module identifies a carrier frequency of an audio if signal of the tv channel to generate a frequency identification result. the determination module, which coupled to the frequency identification module, determines the tv standard of the tv channel according to the frequency identification result.
- USPC Description: television
- Matched HS6 codes
  (a) 852510 - Transmission apparatus; for radio-telephony, radio-telegraphy, radio-broadcasting or television, whether or not incorporating reception or sound recording and reproducing apparatus
  (b) 852520* - Transmission apparatus; for radio-telephony, radio-telegraphy, radio-broadcasting or television, with reception apparatus, with or without sound recording or reproducing apparatus
  (c) 852813 - Television receivers; black and white or other monochrome, whether or not incorporating radio broadcast receivers or sound or video recording or reproducing apparatus
  (d) 852692 - Radio remote control apparatus
  (e) 852691 - Radio navigational aid apparatus

4. Application number: 11975091
   - Patent title: equal phase two-dimensional array probe
   - Patent abstract: an ultrasonic image scanning system for scanning an organic object includes a 2d array probe constructed with transducer elements in both azimuth and elevation dimension. there is a multiplexer disposed in one dimension to route the transducer elements to system front-end channels, while the other dimension can sum into the first dimension with various element number.
   - USPC Description: surgery
   - Matched HS6 codes
     (a) 901812* - Medical, surgical instruments and appliances; ultrasonic scanning apparatus
     (b) 901540 - Surveying equipment; photogrammetrical surveying instruments and appliances
     (c) 901813 - Medical, surgical instruments and appliances; magnetic resonance imaging apparatus
     (d) 901520 - Surveying equipment; theodolites and tacheometers
     (e) 845620 - Machine-tools; operated by ultrasonic processes

Note: HS codes with asterisk superscript are the codes chosen by ChatGPT-3.5 as the closest matches to the patent applications. To obtain this information from ChatGPT-3.5, we use the prompt "Can you list the most closely associated HS code for the given patent abstract description?"