Technological Influence of Inventions: Analyzing Countries in Global Comparison

Elisabeth Mueller* Philipp Boeing◊

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Keywords: technological influence, patents, citations
JEL Codes: O33, O34

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*IESEG School of Management, Univ. Lille, CNRS, UMR 9221 - LEM - Lille Economie Management, F-59000, Lille, France; ZEW – Leibniz Centre for European Economic Research, Mannheim, Germany. E-mail: e.mueller@ieseg.fr

◊Goethe University Frankfurt, Frankfurt am Main; ZEW – Leibniz Centre for European Economic Research, Mannheim; IZA – Institute of Labor Economics, Bonn, Germany; Tsinghua University, Research Center for Technological Innovation, Beijing, China. E-mail: philipp.boeing@zew.de

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1 Introduction

The global economic landscape has fundamentally shifted from the paradigm of globalization to renewed concern regarding the risks and rewards of economic integration and technological interdependence. The technological influence of countries is increasingly interpreted from a geoeconomic perspective, with policy makers seeking to increase technological sovereignty. This concept refers to a country's capacity to provide technologies essential for its competitiveness, either by developing them domestically or by acquiring them from abroad, without being unilaterally dependent on any particular country (Edler et al. 2023). Since new inventions and technological regimes develop globally, technological influence and international cooperation are not antagonistic, but can be pursued at the same time. However, in the absence of reciprocal interdependence that ensures access to foreign knowledge, unilateral dependence can erode the technological influence of more dependent countries.

Recent technological competition and geoeconomic disputes, particularly between the West and China (Lee 2021), have compelled policymakers to balance efficiency and international de-risking strategies. In general, countries seek to cooperate with like-minded and geoeconomically reliable partners while reducing unilateral dependence on less reliable countries. Therefore, evidence-based policymaking increasingly requires quantitative measures of technological influence and an understanding of how this influence shapes countries' technological independence or dependence, both bilaterally and globally. Our study presents a novel empirical approach to measure the independence or dependence of the leading global innovators, making the concept of technological influence empirically assessable.

A country's technological influence can be defined as the degree to which other countries depend on its technology. For example, if a country can influence the trajectory of a technology as a leader, other countries will depend on continued access to that technology in order to build on it. Technological influence can be exerted, for example, by stopping the export of goods needed to build on a particular technology, impeding the mobility of experts, stopping the licensing of critical technology, or imposing secrecy on future critical inventions. Previous research on knowledge spillovers has primarily examined onedirectional knowledge flows, focusing on the extent to which a country benefits from knowledge generated in other countries (e.g. see Eaton and Kortum (1999); Liu and Ma (2023); Melitz and Redding (2022)). Recently, studies have taking a different point of view by focusing on the degree to which inventions are taken up by other countries. Specifically, Aghion et al. (2024) measure how much the influence of an invention in another country increases when the underlying product is exported. For the semiconductor industry, Wong et al. (2024) examine the extent to which semiconductor inventions from

leading countries are adopted by other countries. In our study, we extend these onedirectional approaches to a bidirectional one in order to measure technological influence empirically. We not only consider how a country influences a second country, but we also net out the influence emanating from the second country.

When using patent citations to assess how a pair of countries builds on each other's inventions, ensuring comparability between the units of knowledge flow, i.e., citations, is essential to accurately net out bilateral relationships that mark technological independence or dependence. However, this poses an empirical challenge due to significant heterogeneity in the legal rules followed by national patent offices, which affects both patents and citations.

Building on an approach that was first developed in Boeing and Mueller (2016), we ensure the comparability of the legal framework that underlies patent applications and citations. This is achieved by restricting the analysis to patent applications filed under the Patent Cooperation Treaty (PCT) of the World Intellectual Property Organization (WIPO), and citations generated in the corresponding international search reports (ISRs) during the international phase of PCT applications. In measuring a country's technological influence, we consider only nonself-citations from abroad and are interested in the extent to which inventions in one country provide the basis for inventions in other countries. This approach also ensures that our measure is unbiased and independent of potential distortions through domestic policy.

We contribute to the existing literature by developing empirical measures of technological influence. Our analysis is based on the entire universe of global PCT filings between 2000 and 2020. Consistent with the focus of our study, we first assign all applications to one of the top global innovators, i.e. Europe, the United States (US), China, Japan, and Korea, along with a residual category (covering the remaining countries). We then calculate the number of citations that the inventions of a country receive from another country – and vice versa.[1] In our empirical analysis, we examine three important aspects. First, we analyze the onedirectional technological influence for each country's average invention and provide a rigorous validation of our patent-level measure. Second, we disaggregate each country's technological influence by the geographic direction of influence. Third, we cover the bidirectional technological influence of country pairs by netting out citation flows between a given pair of countries to calculate their respective bilateral and global independence or dependence.

Our main findings are as follows. Throughout our study period, the US shows

[1]The term "country" refers to (i) Europe, (ii) the US, (iii) China, (iv) Japan, (v) and Korea, and the category of residual countries. We consider Europe as a whole because the European Union (EU) is increasingly governing geoeconomic and innovation-related issues of its member countries. One well-known example is the Horizon Europe research program and its predecessors (European Commission 2024). In this study, Europe comprises 30 countries: the EU-27 plus Norway, Switzerland, and the United Kingdom – which was an EU member country until January 2020.

the greatest global independence, outperforming all other countries in the respective bilateral relationships and establishing leading technological influence. However, this conclusion would be far from obvious when looking at simple patent counts. Since 2019, China has surpassed the US, Japan, Korea, and Germany in terms of PCT patent applications, making it the number one country. However, our results show China's continued dependence on all other innovation-leading countries, which is evident across all technologies and future-oriented KETs. Despite the improvement in its global influence during the first decade of the millennium, China's recent growth in global influence is more modest.

Another important finding is the strong integration between the US and Europe in terms of the direction of geographic influence. By comparison, East Asian countries generally show an increasing internal focus over time. This is particularly true of China and Japan. However, despite the ongoing integration between the US and Europe, the US and Europe differ markedly in their respective global positions. While the US has achieved outstanding independence, Europe shows global dependence and bilateral dependence on all countries except China. It is noteworthy, however, that Europe's influence is in fact stronger in KETs than in total technologies. Although our results confirm Japan's global independence and bilateral dependence only on the US, the influence of Japanese inventions has been declining. As a result, despite its strong focus on KETs, Japan's global influence has recently been decreasing, and it is the only country showing a downward trend. Japan's innovations are cited abroad less frequently over time, not just by fewer countries and technology areas, leading to a reduction in its overall influence. For Korea, on the other hand, our results show a moderately positive but sustained global influence. Moreover, Korea receives a larger share of foreign citations than its neighbors Japan and China.

We highlight several implications for policy makers. The growing awareness of the changing global geoeconomic environment has reinforced the use of innovation and industrial policy. However, this may also increase the likelihood of misallocation of public funds. The results of our analysis can help policy makers increase allocation efficiency by addressing the most relevant technological dependencies first, while continuously monitoring countries' individual positions to make necessary adjustments along the way. While the US currently maintains its global technological leadership, it seems crucial for European policy makers to address its global technological dependence. A key aspect of such a policy approach could focus on the promotion of KETs. While European policymakers view the US, Japan and Korea as reliable partners, limiting the need for immediate bilateral intervention, Europe could seek more balanced, long-term bilateral partnerships with these countries, while avoiding future dependency on others. Japan may seek to slow or reverse its recent decline in global technological influence by gen-

erating inventions that translate into more technological influence. For Korea, its relatively high levels of R&D investment may have contributed to continued global influence, but the question remains whether this approach can be adequately sustained in the future. Finally, China's ambitions and activities to become a global innovation leader still exhibit some discrepancy with its actual bilateral and global technological dependence.

The paper proceeds as follows. Section 2 reviews the literature on technological influence, patent citations, and measures of influence. Section 3 introduces background to the PCT system and explains our data and measurements. Section 4 presents the empirical results, while section 5 discusses policy implications. Section 6 concludes.

2 Literature

2.1 Technological influence

In recent years, the global economic order has undergone a fundamental transformation. The paradigm of globalization has given way to new perspectives on the risks and benefits of economic integration and technological interdependence. The world is moving away from a market-based regime in which deeper economic integration was seen as a low-risk path to one in which strategic actors can exploit openness and vulnerability to pursue independent geopolitical objectives.[2] In response, governments are seeking to make their economies more resilient. Against this backdrop, policymakers increasingly need measures of technological influence to assess their countries' bilateral and global independence or dependence. Located at the intersection of innovation studies and geoeconomics, the empirical measurement of technological influence is also related to the theoretical concept of technological sovereignty.

According to March and Schieferdecker (2023), technological sovereignty is different from national autarky or technological self-sufficiency. The authors define technology sovereignty as a country's capability to determine the development and use of technologies and innovations that affect its political and economic sovereignty. Similarly, Edler et al. (2023) define technological sovereignty as the capability to provide the technologies necessary for a country's competitiveness and to develop them domestically or acquire them from abroad without being unilaterally dependent on any particular country.

Therefore, access to the results of research and development (R&D) that is conducted domestically and internationally plays a crucial role in establishing techno-

[2]Exploiting vulnerabilities is not a new phenomenon. For example, in the 1980s to 2000s, developed countries took advantage of developing countries to gain access to their raw materials and resources (Milin 2014).

logical influence. As new innovations and technological regimes develop globally, technological influence and international cooperation are not antagonistic, but interdependent. As documented in Griffith et al. (2004), domestic R&D serves at least two functions from this perspective. First, it facilitates the identification and adoption of R&D results from international sources, which is also referred to as absorptive capacity (Cohen and Levinthal 1989). Second, it is essential for generating domestic research results that other international actors can use and build upon. Overall, domestic R&D is crucial for benefiting from international knowledge and avoiding unilateral dependence.

When analyzing technological influence, so-called key enabling technologies (KETs) play a critical role because they are contributing to economic growth and development, while also fostering dynamic application of other technologies. KETs have three defining characteristics (EFI 2022). (1) They have diverse applications in different technological fields and economic sectors. (2) They exhibit strong, non-substitutable complementarities with several other technologies. (3) Both the KET itself and its application areas have a high potential for performance improvement. Interpreted from a global perspective, economies could specialize in certain KET areas and develop comparative advantages over other economies. This portfolio perspective suggests that economies may specialize in certain KETs, leading to interdependencies among each other, which makes unilateral dependence less probable. Using innovation to support economic development, catching-up economies can pursue loose IPR regimes, move up global value chains, and transition from short-cycle to long-cycle technologies (Lee 2024b). However, once a certain level of development has been reached, it may be more beneficial to pursue long-term rather than short-term innovation strategies (Lee 2021). For example, such economies may focus on specific KETs that require more upfront investment but will enhance future competitiveness. This approach still emphasizes the importance of global integration, which differs markedly from technological self-sufficiency strategies.

In the absence of reciprocal interdependence that ensures access to foreign knowledge, however, unilateral structural dependence can erode the technological influence of the more dependent country; therefore, a country's strategic positioning between full global integration and national self-sufficiency is crucial in defining the limits of dependence and independence (Eaton and Kortum 1999). Recent technological competition and geoeconomic disputes, particularly between the US and China, but also between Europe and China, compelled a balancing act between prioritizing efficiency and implementing risk mitigation strategies, which may also require the development of domestic redundancy. Overall, policymakers are now seeking to rebalance collaboration toward like-minded and geoeconomically reliable partners, while reducing unilateral dependence. At the

global level, this involves navigating technological independence and dependence among countries and regions (Van der Pol and Virapin 2022).

Technological influence is related to but different from commodity trade. Interdependencies between countries can also be observed through trade; for example, when considering global value chains (Felbermayr et al. 2023). The flow of commodities represents trade in semi-finished or finished products, while the production of knowledge precedes that of commodities and is often an early determinant of subsequent product specialization. Against this background, we are particularly interested in examining the degree to which the knowledge of one country is taken up elsewhere. In this sense, the two phenomena are related but distinct. For example, Gong et al. (2023) investigate the patenting and exporting activities of Chinese firms in the US, determining that the first US patent grant has a positive impact on the subsequent export performance of Chinese firms, demonstrating that knowledge creation and the protection of inventions precede the production and shipment of goods. Similarly, Liu and Ma (2023) measure the correlation between knowledge flows and input-output production networks across industries in 40 countries, revealing that these activities are only moderately correlated. Specifically, knowledge spillovers from upstream industries are more influential in driving innovation in the focal industry than knowledge spillovers within the focal industry or international commodity trade. Han et al. (2023) show that domestic upstream innovation is important for counteracting negative sanction-induced shocks to a downstream industry because it is possible to substitute the required intermediates through domestic production. In general, upstream innovation capacity is crucial for mitigating downstream geoeconomic risks. It follows that KETs, which are often located in upstream sectors, are of considerable strategic importance.

Technological influence is also related to knowledge spillovers. The literature on knowledge spillovers has long recognized that inventions do not take place only within national borders, but depend on knowledge flows from abroad. Prior research shows that such knowledge spillovers can directly affect countries' productivity and output growth (Melitz and Redding 2022). While the literature on knowledge spillovers is concerned with the use of international knowledge and its economic consequences, our study is interested in measuring the influence of one country's inventions on other countries. This latter perspective is also covered by Aghion et al. (2024). The study focuses on onedirectional knowledge flows and considers the extent to which a country's technology is taken up by other countries. More specifically, the paper finds that trade facilitates knowledge spillovers in the destination country of the exports. Empirically knowledge flows are measured based on triadic patent citations. Wong et al. (2024) investigate technological power as onedirectional knowledge flows for five countries and five sub-

technologies in the semiconductor industry. The study is based on the analysis of US patents. We extend these approaches by measuring knowledge flows as bidirectional, using patent citations to measure how a pair of countries builds on each other's inventions. Importantly, ensuring the comparability of the units of knowledge flow (citations) is crucial for netting out bilateral and global independence or dependence. This endeavor poses an empirical challenge due to the considerable heterogeneity in the national legal frameworks of patent offices, which is influencing the measurement of both patents and citations. In the next section, we discuss the issues surrounding the use of citations in cross-country analysis and our approach to addressing them.

2.2 Analysis of citation data

Forward citations of a published patent are a well-established measure of the cumulative nature of inventions (Jaffe et al. 1993). This measure is observable since subsequently filed patents refer to prior art (Higham et al. 2021). As such, forward citations are an appropriate measure for the global influence of inventions, and are often used to measure economic value (Harhoff et al. 1999; Lanjouw and Schankerman 2004). Gambardella et al. (2008) show that forward citations have a closer relationship to patents' actual economic value than references, claims, or family size. Moreover, variation in forward citations is used to account for other margins of patent heterogeneity; see the survey by Jaffe and De Rassenfosse (2017), including technical value (Trajtenberg 1990) and technological impact (Corredoira and Banerjee 2015). Recent studies also use citations in network settings, going beyond measuring knowledge flows between two patents. For example, citations are used to examine the diffusion of knowledge (Rosell and Agrawal 2009) or to determine centrality of specific patents (Funk and Owen-Smith 2017; Park et al. 2023). Nevertheless, working with citation data is subject to empirical challenges as it is necessary to control for multiple, unrelated changes in patent and citation data-generating processes to obtain unbiased estimates of economic phenomena. To address these challenges, Kuhn et al. (2020) recommend selecting appropriate patent and citation types and employing a fixed effects approach to control for remaining differences (e.g., across technology areas and time) in the patenting process.

A well-known challenge to using forward citations is their application to cross-country comparisons. This is because heterogeneity across the legal frameworks of national patent examination leads to significant variation in forward citations generated across patent offices. For a set of triadic patent families following national standards, Michel and Bettels (2001) show that the US Patent and Trademark Office (USPTO) applies three-times more patent references than the European Patent Office (EPO) and patent examiners are more likely to cite domestic patents, which

is also known as "home bias" (Bacchiocchi and Montobbio 2010). Thus, naïve comparisons of international citation measures across (and within) countries may be biased. When examining international knowledge flows, some studies have avoided citations and instead relied on counting patent applications by foreign applicants (Eaton and Kortum 1999) or international co-applicants (De Rassenfosse and Seliger 2020).

Although foreign filings tend to be a positive and more homogeneous selection compared with domestic filings because it is more costly to file in more than one patent office, considerable heterogeneity remains within selected samples. To address this issue, several studies investigating international knowledge flows have used forward citations while attempting to control for potential differences in the data-generating process. A typical approach restricts the data-generating process of citations to a single patent office. For example, the studies by Lee and Yoon (2010) and Wu and Mathews (2012) compare forward citations received by USPTO applications filed by applicants from the US, Japan, Korea, and Taiwan. While focusing on a single patent office can increase the comparability of the citations generated, allocation of these citations may still be subject to the aforementioned home bias, favoring US patents, while those of other countries represent a positive selection. A second limitation of this approach is its narrow focus on patenting in one country, which limits its global relevance (De Rassenfosse et al. 2014).

Another set of studies on international knowledge flows increases the number of analyzed countries but faces the limitation of differing data-generating processes for patents and citations across countries.[3] Examining 40 major countries between 1976 and 2020, Liu and Ma (2023) investigate whether patents filed in a given country cite other patents filed in that country or abroad. Patents are either assigned by the country of inventors, applicants, or patent office (in that order). As an invention can generate patent applications in more than one country, all related patents are grouped by patent family and the information is attributed to the priority application. Eugster et al. (2022) introduce further refinements by only selecting patent families with a minimum of two national applications, for which the country is identified according to the address of the first inventor, and excluding self-citations between patents with the same inventors.[4] The authors set the

[3] A well-documented historical example is Japan's single-claim patent before 1989 (Goto and Motohashi 2007). Although the introduction of multiclaim patents and more stringent selection criteria in patent applications reduced the number of patents (Motohashi 2004), ceteris paribus, such patterns may have some persistence over time. Additional differences between patent offices include divergent rules for applicant citations. Whereas in the US the applicant needs to provide references to all relevant prior art that they are aware of, the EPO requires only the examiner and not the applicant to provide references to prior art (Michel and Bettels 2001).

[4] Self-citations account for about 10% of citations received (Higham et al. 2021). The exclusion of self-citations is a common practice because larger firms typically have more patents from which to potentially cite their own prior art. To address this concern, it is instrumental to define self-citations at the applicant level rather than the inventor level.

citation window, referring to the time period in which a cited patent can receive citations from a citing patent, to four years after the publication of the cited patent.[5] While excluding most recent years from the analysis due to truncation issues, this practice ensures comparability between patents filed at different points in time.

The rise of China has significantly contributed to global patenting activities, but numerous pro-patent policies have also led to an increase in marginal patents and related citations. While China is globally leading in terms of patent output in both national applications by residents and PCT applications since 2011 and 2019 (WIPO 2023), respectively, in 2020 Chinese examiners were handling 47% more patents than examiners in the US and 136% more than those in Europe (Branstetter et al. 2023; Yin and Sun 2023). Excessive workload, reduced examination time, and low salaries for examiners[6] can potentially degrade the quality of examinations, subsequently introducing measurement error regarding the citations made by such patents (Branstetter et al. 2023).

Citation data from China's patent office have only recently become available; however, national patenting targets (Sun et al. 2021), subsidies (Branstetter et al. 2023), and tax cuts (Wei et al. 2023) have all contributed to distorted patenting activities, which makes the interpretation of citations emanating from the Chinese patent office more difficult. Several studies substantiate this concern by relating citations to economic measures. For example, Yin and Sun (2023) show that forward citations are not correlated with initial patent auction prices in China, which contradicts results in other countries. Wu et al. (2022) only find a significant relationship between patent citations and firms' total factor productivity after restricting their sample to patents that incurred higher filing costs because they exceeded the threshold of 10 claims. Boeing and Mueller (2019) restrict their analysis to citations generated by ISRs of PCT applications. Investigating the correlation between R&D expenditure and citation-weighted patents, the authors find that only foreign citations, but not domestic and self-citations (which may be partially policy-driven), have a significant and positive relationship with R&D stocks in China. Referencing Germany as a country without domestic policy support for patenting, they show that all three citation measures have the expected positive correlation with R&D inputs. Taking a broader international perspective, Schmoch and Gehrke (2022) compare non-Chinese and Chinese PCT applications and demonstrate that subsequent to the international phase, 79% of non-Chinese applications are transferred to the national phase (in patent families with three or more national applications), whereas the corresponding rate for China is only 66%. This indicates lower average patent value, which is associated with China's subsidies and targets related to

[5] Previous research shows that patents reach the highest probability of citation around three years after publication (Hall et al. 2005).

[6] Anecdotal evidence implies a monthly salary of around 10,000 RMB, which is equivalent to USD 1,600 (Branstetter et al. 2023).

PCT applications.

Despite heterogeneity in the data-generating process of forward citations across national patent offices, some studies use forward citations in international comparison. Han et al. (2023) observe patents filed in the US that cite patents filed in China and vice versa, to measure decoupling and dependence. Bergeaud and Verluise (2022) divide global patenting activity into five geographic areas to investigate the rise of China in terms of six frontier technologies. In the most conservative analytical setting, they observe forward citations originating in PCT applications and received by the top 10% most cited (considering all citation types) patents in each technology, year, and country. While citations from PCT applications are a more homogeneous set, the mixture of citations generated in the international and subsequent national phase of the PCT process still introduces heterogeneity. Furthermore, the selection of cited patents is endogenous to the citation intensity of national processes.

To provide a rigorous assessment regarding the quality and global influence of inventions, analyses must consider differences in examination rules and types of patents filed. We follow Boeing and Mueller (2016) by including these aspects as, to the best of our knowledge, their approach provides the most rigorous setting for cross-country comparison of patent quality. The authors only examine PCT applications, which can make references or receive forward citations, and restrict such references (generated by ISRs) to foreign origin (i.e., the citing patent is foreign, while the cited patent is domestic), which also avoids potential upward bias in citations due to domestic policies.

2.3 Measures of influence

The global influence of countries can be measured in several ways. In this section, we first review literature that compares countries' innovative performance based on patent indicators. We then examine the bilateral influence between countries, as observed through patents and scientific publications, and finally consider the influence of policy on such relationships. At the most basic level, researchers have been interested in raw patent counts to measure influence. Traditionally, the US and Europe were the most significant patent applicants; however, they lost their leading position to East Asian countries in more recent years. In 2020, China filed 16.1% of global PCT applications (WIPO 2023), making it the world leader in patenting, followed by the US, Japan, Korea, and Germany. However, a simple comparison of patent counts, even if adjusted by conventional measures of patent quality, will most likely be misleading due to substantial heterogeneity across patents.

Addressing the concern of international comparability, Boeing and Mueller (2016) use foreign ISR citations, which are independent from domestic policy, to

investigate the technological capacity of the top-five innovative countries. Technological capacity is measured as annual patent counts weighted by average quality. The authors' analysis covering 2001 to 2009 shows that the US is leading in overall technological capacity, followed by Japan, Germany, and Korea, while China takes the last position.

Analyzing more recent patent data up to 2019, Breitinger et al. (2020) identify the top 10% patents in force for 58 forward-looking technology areas, which is measured by family size and forward citations. After attributing patents to countries according to inventor addresses, the findings demonstrate the dominant position of the US while also highlighting growing patenting activities in East Asia, notably China, in recent years. The US leads in 50 of the 58 technologies evaluated in the study. In contrast, European countries appear to be lagging behind, leading only in the two technology areas of wind energy and functional foods. However, the results also highlight the inventiveness and dynamism of East Asia, which has surpassed the US in some areas and is closing the gap in others. China has gained considerable momentum in recent years and is advancing more rapidly than the US and Europe in almost all sectors. Additionally, countries outside of the three leading innovation regions find it challenging to obtain a significant role.

Using an alternative approach, Bergeaud and Verluise (2022) measure countries' global influence based on the number of patent applications, forward citations, and the radicalness inferred from patents' semantic content. Focusing on six frontier technologies from 1974 to 2019, the authors observe that the US maintains a relatively high position in all technologies when considering the quantity of applications, while Europe's significance is limited to fewer technologies. The steady growth of China's influence is also confirmed, while the proportion of Japanese patents drops to a lower level by 2019, indicating Japan's declining significance as an innovation hub (Criscuolo and Timmis 2018; Ito et al. 2019). Notably, Bergeaud and Verluise (2022) confirm that Chinese patents are of lower quality compared with European, US, and Japanese counterparts. Nonetheless, this gap is narrowing over time. In general, the patenting activities in frontier technologies are increasingly polarized between the US and China as the main players.

Other studies investigate the bilateral influence between countries. Cerdeiro et al. (2021) analyze the impact of global knowledge flows on countries' economic performance from 2000 to 2013. For China and other countries, the primary sources of knowledge spillovers are the US and, to a lesser extent, Japan. China's contribution to other countries is substantial and exceeds that of the traditional technological leaders in Europe. All countries, including the US, appear to have increasingly benefited from China's innovation drive. Han et al. (2023) examine the bilateral relationship between the US and China, developing measures for technology decoupling and dependence. The authors reveal a consistent rise in technological

integration (as opposed to decoupling), with China's reliance on the US increasing in the first decade and subsequently reducing in the second decade of the millennium.

A related literature examines global influence through scientific publications. According to the Nature Index 2023, China has overtaken the US for the first time in the natural sciences, which include the physical sciences, chemistry, earth and environmental sciences, and biological sciences (Nature 2023). The metric considers each author's share of articles published in 82 scientific journals between 2015 and 2022. However, recent studies provide a more nuanced picture of China's scientific prowess. Qiu et al. (2022) demonstrate that the high impact of US-based research on Chinese scientific publications persists. Nonetheless, Chinese scientists working in China and abroad are now significant contributors to the global knowledge frontier; however, cross-border frictions to knowledge spillovers persist in both directions (e.g., Qiu et al. (2022) and Xie and Freeman (2021)).

Policymakers who are conscious of the need to strengthen technological influence also implement measures to impede the free flow of ideas by restricting scientific collaborations. For example, the 2018 China Initiative in the US aimed at limiting scientific cooperation between US and Chinese researchers. Aghion et al. (2023) find a negative effect of the initiative on average publication quality and on US researchers with Chinese coauthors with prior US collaborations. Jia et al. (2023) find that the research conducted since the China Initiative coincides with a decline in the productivity of US scientists with previous collaborations with scientists in China relative to those with international collaborators outside of China, particularly when considering the impact of publications, proxied by citations.

In summary, the literature underscores the enduring role of the US as a global knowledge source as well as China's ascent as a substantial knowledge contributor and user. However, the intensifying competition between these two major powers also has implications for other regions, in terms of innovation and research activities and the degree to which countries bilaterally influence one another. In addition, more studies are needed to investigate how these factors impact countries' technological influence. In the next section, we describe how this paper measures the global technological influence of countries.

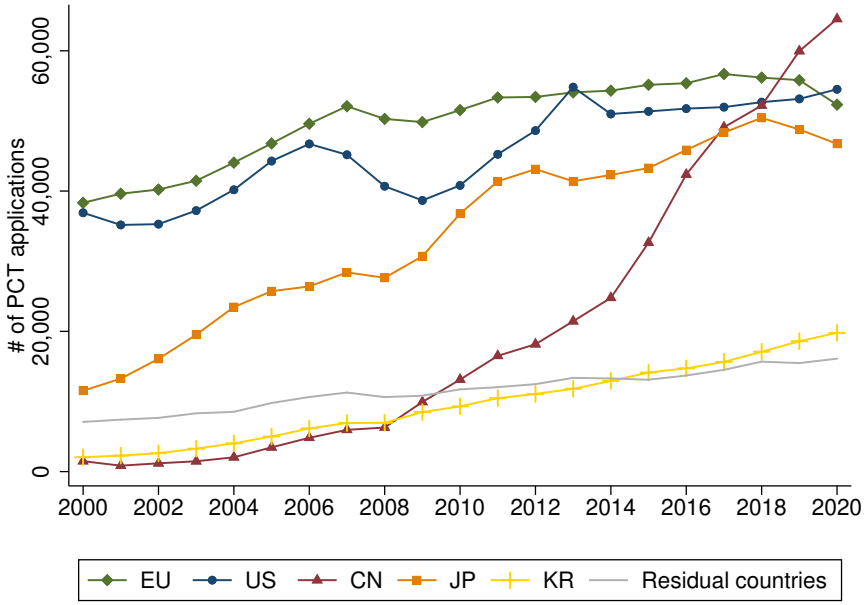
3 The PCT System, Data and Measurement

3.1 Usage of the PCT system

The PCT system, which is administered by United Nations' (UN) WIPO, allows applicants to simultaneously protect intellectual property in up to 157 countries. Figure 1 demonstrates that use of the PCT system has significantly expanded throughout the years, increasing from 97,414 filings in 2000 to 254,008 filings in

2020. Specifically, this growth is largely influenced by East Asian countries, particularly China, Japan, and Korea, which experienced larger growth rates than Western countries such as the US and European nations. China has been the number one ranked PCT applicant country since 2019, surpassing the US, Japan, Korea, and Germany. The shift in innovation activity from the West to the East is also reflected in Figure 2. In 2000, more than three-quarters of PCT applications originated from the US and Europe; however, Western dominance gradually decreased in the following two decades. By 2020, more than half of the global PCT applications originated from China, Japan, and Korea. In recent years, China and Korea's global shares have expanded, while those of the US, Japan, and Germany have contracted.

Figure 1: Number of PCT applications by countries

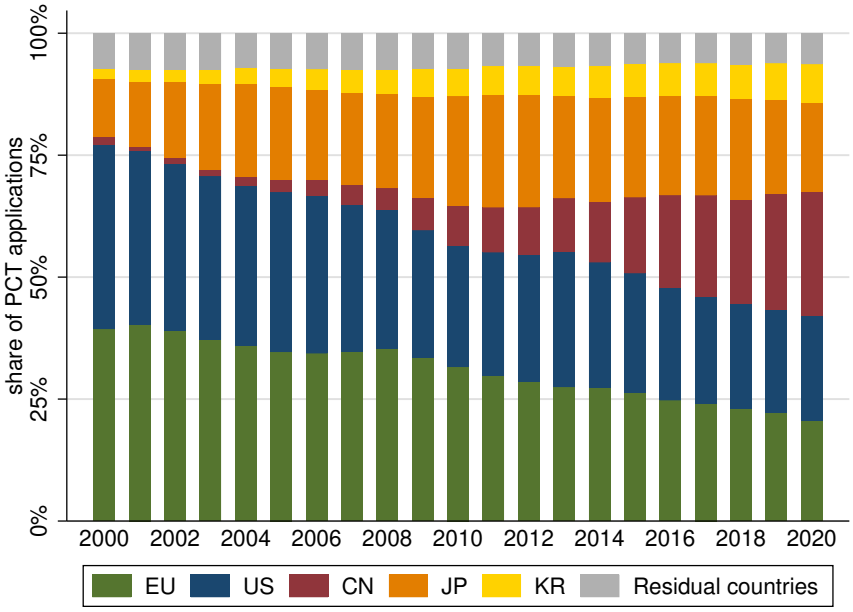


3.2 Legal background of the PCT system

A PCT patent application passes first through the international phase. During the international phase the search authority is designated and the international search report (ISR) is published. The ISR contains the prior art on which the technology in the patent application builds. Typically 30 months after the priority date the national phase starts. For this phase the applicant selects all countries or regions in which patent protection is sought. The designated national patent offices are then responsible for the grant decision (WIPO 2024).

The search for prior art of patent applications under the PCT system follows a strict legal framework. Prior art searches are conducted during the international

Figure 2: Share of PCT applications by countries



search phase within 30 months of filing the application. Designated national patent offices act as International Searching Authorities (ISAs), with all examiners following the same WIPO examination rules when preparing an ISR (WIPO 2022a). Confirming the influence of identical regulations, Michel and Bettels (2001) provide empirical evidence of highly similar citation rates for the USPTO, the EPO, and the Japan Patent Office (JPO) when the patent offices prepare ISRs as ISAs. Regarding applicant citations, the rules of the PCT system state that the application should "indicate the background art which, as far as known to the applicant, can be regarded as useful for the understanding, searching and examination of the invention, and, preferably, cite the documents reflecting such art" (WIPO 2022b, Rule 5). Notably, the examiner ultimately decides which references are included in the ISR.

The selected references measure the technical and legal relationships among patents and are the appropriate measures of an invention's influence for our analysis. Restricting our analysis to citations from the ISR offers several important advantages. The PCT system applies common standards for searching prior art, which makes citations internationally comparable regardless of the nationality of the ISA conducting the search. The search guidelines explain in detail how citations should be selected by the examiners (WIPO 2022a, §15.63-§15.72). For example, examiners are encouraged to cite only the most relevant documents and to cite documents in the application's language, if several members of one patent family are available (WIPO 2022a, §15.69). As we aggregate citations at the family level, our measure is not influenced by which family member is actually cited.

International comparability is further enhanced because the search for prior art is highly concentrated among few ISAs. According to WIPO (2023, p. 75), the top-five ISAs were responsible for more than 90% of ISRs in 2022 (EPO, 37.8%; JPO, 21.1%; Korean Patent Office (KPO), 15.6%; USPTO, 9.7%; and China National Intellectual Property Administration (CNIPA), 9.5%).

PCT applications move from the international to the national phase 30 months after priority. National patent offices conduct additional searches and examine the application prior to their grant decision. Citations in the national phase can differ from ISR citations as they follow national guidelines. To restrict the citations originating from only one data-generating process, we do not consider those generated during the national phase.

In international comparisons, it is essential to account for potential language barriers that deter patent examiners from identifying prior art from a specific country. Patent examiners typically begin their search for prior art with a keyword search in English. The PCT system provides an English translation of the main portions of PCT applications, including title, abstract, international search report, and any text related to figures for all PCT applications not published in English (WIPO 2022b, Rule 48.3 (c)). Abstracts have a key role in the search. According to Rule 8.3 (WIPO 2022b) "The abstract shall be so drafted that it can efficiently serve as a scanning tool for purposes of searching in the particular art, especially by assisting the scientist, engineer or researcher in formulating an opinion on whether there is a need for consulting the international application itself." Therefore, even if a PCT application is not originally published in English, it is easily identifiable as potentially relevant prior art. To account for additional language heterogeneity across patents, in the empirical analysis we also control for the date when the English full text patent document becomes available.

According to further guidelines of the PCT system, patent examiners conducting the international search have access to the minimum documentation standard, which specifies which prior art needs to be searchable for examiners. Regardless of the publication language used, PCT applications are part of this minimum standard. As such, all PCT applications are fully available during the search process.

3.3 Measurement

Following Boeing and Mueller (2016), we ensure comparability in the legal framework underlying the studied patent applications and citations by restricting our sample to PCT applications and citations generated in ISRs during the international phase. We only consider nonself-citations from abroad when measuring technological influence because we are interested in the degree to which the inventions of one country serve as the foundation for inventions in other countries. This approach also alleviates concerns about potential bias through domestic pol-

icy. The priority year indicates the year in which the first patent application for a given invention was filed. Country assignment of applications is based on the address of the first applicant, and we only consider citations from unique pairs of citing and cited patent families.[7] [8] Self-citations are determined based on DOCDB standard names from PATSTAT and EEE-PPAT application name harmonization (Magerman et al. 2006). We set the citation window to three years to ensure comparability between patent families with different priority years and a high degree of timeliness.

We contribute to the literature by constructing empirical measures of technological influence that are calculated based on PCT filings with priority years between 2000 and 2017.[9] Consistent with the focus of our analysis, we first assign all filings to the world's five leading innovators, i.e. (i) Europe, (ii) the US, (iii) China, (iv) Japan, (v) and Korea, plus a residual (the rest of the world).[10] We also identify the main technology class of each application based on the International Patent Classification codes. We use the classification by Schmoch (2008), which defines 35 technology classes. Because a country's patent citations received from another country is related to the technological influence of this country, we quantify the number of citations a country receives from another country and vice versa. Our empirical analysis focuses on three aspects of technological influence.

First, we assess the *onedirectional influence* of each invention at the patent level using ISR citations to measure the average onedirectional technological influence of a country's inventions. Let i denote an individual invention, represented by a patent family, and K the set of PCT applications eligible to cite it (i.e., those with a priority date within three years of invention i's priority date). The indicator $\text{ISR citation}_{i,k,j,j'}$ equals 1 if invention i from country j is cited by invention k from country j' within this window, and 0 otherwise, considering only non-self citations

[7] Because we use the address of the first applicant for the geographic assignment of the invention, our empirical measures aren't influenced by the countries that are chosen for patent protection. E.g., if a Korean firm is only seeking protection in the US and in Europe, the invention would still be classified as belonging to Korea.

[8] When a patent is filed by applicants from different countries, we allocate the patent to the country of the first applicant. Because PCT rules don't stipulate a specific order, applicants may indicate the more important applicant first or choose a random order. In both scenarios the use of the first applicant will cover on average the influence that the countries receive from international co-applications.

[9] The inclusion of more recent years would introduce truncation to our citation measure. We can't use PCT patents after 2017 as we require full data coverage for our three-year citation window. When considering the data availability for the citation count, we also need to take the publication lag into account with which influences when data becomes available in PATSTAT. Given the PATSTAT version from March 2021, with which we work, 2017 is the last year for which we have full citation data. We decided not to start our analysis before 2000 in order to have a meaningful minimum number of Chinese PCT applications. Even considering these restrictions, we can base our analysis on a long time period.

[10] Taiwan is excluded from the PCT system because it is not a member of the UN. Taiwanese applicants can only submit PCT applications indirectly through PCT member countries, which may involve additional administrative steps and costs compared to applicants from member countries.

from abroad $k \in K_{j'}$, where $j' \neq j$. We omit the time dimension in the notation for brevity. The *onedirectional influence* for invention i from country j is then defined as:

$$\textit{Onedirectional influence}_{i,j} = \sum_{k \in K_{j'}, j' \neq j} \text{ISR citation}_{i,k,j,j'} \tag{1}$$

Second, we analyze each focal country's direction of *geographic influence*, assessing its impact on other countries' inventions within the PCT application universe K. To provide a complete picture, we include both foreign and domestic ISR citations $k \in K$ for the calculation of this measure. By identifying the origin j' or j of each citing application k, we attribute citations to the focal country j, mapping the geographic distribution of ISR citations it receives. For example, for European patents, we calculate the percentage of ISR citations originating respectively from Europe, the US, China, Japan, Korea, and other countries. In equation (2) the denominator corresponds to all citations that the patents of country j receive and the nominator corresponds to the number of citations received from one of the six possible geographical origins.

$$\textit{Geographic influence}_{j,j'} = \frac{\sum_{k \in K_{j,j'}} \text{ISR citation}_{i,k,j,j'}}{\sum_{k \in K} \text{ISR citation}_{i,k}} \tag{2}$$

Third, to quantify *bilateral influence*, we calculate the difference in citation counts between the focal country j and a partner country j'. Specifically, we compute the number of citations that country j receives from country j' ($\text{ISR citations}_{j,j'}$) and subtract the number of citations that country j' receives from country j ($\text{ISR citations}_{j',j}$). To ensure comparability across different country pairs, we scale this measure by the sum of the two citation counts. This metric ranges from -100 to +100, where 0 indicates reciprocal influence, positive values suggest independence from country j', and negative values suggest dependence on country j'.

$$\textit{Bilateral influence}_{j,j'} = 100 \times \frac{\text{ISR citations}_{j,j'} - \text{ISR citations}_{j',j}}{\text{ISR citations}_{j,j'} + \text{ISR citations}_{j',j}} \tag{3}$$

Furthermore, to calculate the *global influence* of a focal country j, we compute the weighted average of its bilateral influence with respect to the five other countries j'. Bilateral influence measures the directional relationship between j and j', capturing the balance of technological influence between the two countries. The weights are derived from the time-variant global patent shares of partner countries j', ensuring that countries contributing a larger share of global inventions

have proportionally greater influence. This measure is also scaled between -100 and 100, where positive values indicate independence, negative values indicate dependence, and 0 represents reciprocity in global technological influence.

$$\textit{Global influence}_j = \sum_{j' \neq j} \left(\frac{\text{Patent share}_{j'}}{\sum_{j' \neq j} \text{Patent share}_{j'}} \right) \cdot \text{Bilateral influence}_{j,j'} \tag{4}$$

The measure of *global influence* serves as our most comprehensive indicator of a country's technological influence. It captures the extent to which the inventions of a focal country receive more citations from all other countries than they provide in return. If a focal country's inventions are more frequently utilized by other countries than vice versa, it exhibits a higher degree of technological influence. Intuitively, this influence is expressed through technological relationships: a country whose inventions underpin subsequent inventions in other countries holds greater global influence.[11]

3.4 Descriptive statistics

We separate the time period 2000-2017 into three time spans of 2000–2005, 2006–2011, and 2012–2017. Table 1 presents the descriptive statistics for 1,252,148 PCT applications filed in the most recent period between 2012 and 2017. Among all applications, 10.1% received at least one and up to 68 ISR citations from other countries. Among all cited applications, the mean and median values are 1.477 and 1, respectively, indicating a right-skewed distribution, which is commonly observed for patent citation data. Citations are from up to five other countries, with mean and median values of 1.173 and 1, respectively, and from a maximum of 10 technology areas, with mean and median values of 1.098 and 1. The distribution of PCT applications by origin, in descending order, is as follows: Europe accounts for 26.3%, the US for 24.7%, Japan for 21.1%, China for 15.1%, Korea for 6.4%, and the remaining countries for 6.4%.

[11] Following Griliches (1990), we acknowledge that not all inventions are patentable and not all inventions are patented. However, the homogeneous design of the global PCT system precludes systematic cross-country bias in the selection of inventions for patenting.

Table 1: Descriptive statistics

	Mean	Median	Std. Dev.	Min.	Max.
ISR citations	0.152	0	0.653	0	68
ISR citations > 0 #	1.477	1	1.478	1	68
Citing countries	0.121	0	0.388	0	5
Citing countries > 0 #	1.173	1	0.473	1	5
Citing technology areas	0.113	0	0.352	0	10
Citing technology areas > 0 #	1.098	1	0.345	1	10
Europe (0/1)	0.263	0		0	1
US (0/1)	0.247	0		0	1
China (0/1)	0.151	0		0	1
Japan (0/1)	0.211	0		0	1
Korea (0/1)	0.064	0		0	1
Residual countries (0/1)	0.064	0		0	1

Note: PCT applications between 2012 and 2017 are observed. The number of observations is 1,252,148. #125,956 PCT applications receive > 0 citations.

Table 2 presents an overview of patent statistics by country and also by the three time spans of 2000–2005, 2006–2011, and 2012–2017. When observing the entire time period between 2000 and 2017, Europe contributed 31.1% of global PCT applications, closely followed by the US (28.0%), Japan (19.6%), China (9.0%), and Korea (5.2%). This emphasizes the traditional importance of European and US invention. However, contrasting the number of patent applications from 2000 to 2005 with those from 2012 to 2017 reveals that China's contribution has increased 17.9-fold, while Korea and Japan experienced a 4.2- and 2.4-fold increase, respectively. In comparison, the US and European contribution increased only 1.3- and 1.4-fold. Notably, the strong rise in East Asia's patent quantity has resulted in some decline in average ISR citations per patent: the US has the highest average overall, followed by Korea and Europe, with Japan and China coming last. Remarkably, average citations for China and Japan decreased by about a quarter or more, while those of Europe, the US, and Korea have remained stable. The average number of citing countries and technology fields follows a similar pattern, with Korea positioned in between.

Table 2: Invention characteristics by country

	Europe	US	China	Japan	Korea	Residual countries	Total
PCT applications (count)							
2000-2005	250,496	229,051	10,506	109,576	19,284	48,784	667,697
2006-2011	306,716	257,312	56,619	191,327	48,324	67,140	927,438
2012-2017	329,038	309,537	188,480	264,320	80,328	80,445	1,252,148
2000-2017	886,250	795,900	255,605	565,223	147,936	196,369	2,847,283
ISR citations (mean)							
2000-2005	0.134	0.237	0.115	0.128	0.244	0.269	0.181
2006-2011	0.120	0.219	0.103	0.101	0.218	0.238	0.156
2012-2017	0.128	0.242	0.084	0.083	0.230	0.215	0.152
2000-2017	0.127	0.233	0.090	0.098	0.228	0.236	0.160
Citing countries (mean)							
2000-2005	0.109	0.189	0.099	0.108	0.198	0.210	0.146
2006-2011	0.100	0.176	0.087	0.087	0.175	0.188	0.128
2012-2017	0.105	0.187	0.068	0.072	0.167	0.170	0.121
2000-2017	0.105	0.184	0.074	0.084	0.174	0.186	0.129
Citing technology areas (mean)							
2000-2005	0.110	0.188	0.095	0.107	0.183	0.207	0.145
2006-2011	0.098	0.168	0.079	0.084	0.157	0.183	0.123
2012-2017	0.101	0.174	0.063	0.069	0.145	0.163	0.113
2000-2017	0.102	0.176	0.068	0.082	0.153	0.181	0.124

Note: The absolute number of PCT applications and mean values of citations are displayed. Citations only consider ISR citations received from other countries.

4 Empirical Results

In this section, we first analyze the ondirectional influence of each county's inventions at the patent level and provide a rigorous validation of this measure. Second, we examine the geographic influence for each country. Third, we calculate the bilateral influence between a specific set of two countries. Finally, we obtain each country's global influence as the average weighted bilateral influence for that country relative to the aggregate of all other countries.

4.1 Onedirectional influence

We proceed to present our regression specification, depicted in Eq. (5). Let y_{it} represent patent i filed in year t. For each patent, the main outcome is the number of ISR citations received from other countries, as specified in Eq. (1). Variations in the outcome are assumed to depend on the country (j) which the cited patent is originating from (e.g. the US, China, Japan, Korea, and residual countries), with Europe

as the reference category. Additional variables that capture patent-specific heterogeneity are summarized in X_{it}. Unobserved time and technology-specific factors are controlled for through year (φ_t), technology area (φ_a), and year-technology area (φ_{ta}) fixed effects.[12] ε_{it} is an i.i.d. error term with a mean of 0 and variance of σ_ϵ^2.

$$y_{it} = \alpha_0 + \gamma \sum_{j=1}^{J} \text{country}_{\ j} + X_{it}\beta + \varphi_t + \varphi_a + \varphi_{ta} + \varepsilon_{it} \tag{5}$$

The main parameter of interest in Eq. (5) is γ, which measures the average effect of a patent's geographic origin on outcome y_{it} (i.e. the number of ISR citations received from other countries over a three-year period). In this setting, a significant γ would reject the null hypothesis of no correlation of patents' geographic origin on the extent of influence of the focal patent to other countries. To broaden our analysis of influence, we also investigate two additional margins for each patent. First, we consider the number of citing countries to capture the spatial dimensions of influence. Second, we consider the number of citing technology areas to measure the technological diversity in a patent's influence.

Table 3 presents our main regression results. We start by estimating Eq. (5) with the number of ISR citations as the outcome, considering the three time periods 2000–2005, 2006–2011, and 2012–2017 in columns, (1), (2), and (3), respectively. The number of ISR citations corresponds to our measure of ondirectional influence in Eq. (1). In comparison to Europe, US patents receive significantly more citations. In contrast, Chinese patents are associated with fewer citations. The results for both countries remain relatively persistent over the three periods and become a bit more pronounced over time. Japanese patents initially start off similar to European ones, but weaken significantly over time. In contrast, Korean patents receive significantly more citations, albeit with some decrease over time.[13] The coefficient of 0.095 for the US in column (3) indicates a level of influence that is 62.5% higher than the mean of the dependent variable, which corresponds to 0.152 citations. In contrast, for China we calculate a level of influence that is 63.8% lower than the mean. The corresponding values for Japan and Korea are -26.3% and 48.7%, respectively. Thus, the average onedirectional influence varies widely between countries. In column (4)–(7), we focus on the most recent time period and change the outcome to the number of citing countries and technology areas. The results reveal a similar pattern as that of the number of citations. Notably, the results also remain qualitatively robust to the inclusion of the number of citations

[12] The technology fixed effects control for differences between long- and short-cycle technologies (see, e.g., Lee (2024a)) in the time dimension in which citations accumulate. Within the 3-year citation window long-cycle technologies may receive fewer citations because their citations may be spread out over the longer time period during which the invention has economic value. The technology-year fixed effects control for time-variant differences in the average citation count by technology.

[13] Because residual countries collectively account for only 6.9% of global PCT applications, we omit them from the discussion.

as an additional control variable. This finding demonstrates that over and above receiving more citations, US patents also have a stronger influence across countries and technology areas. Overall, these results underscore that, in comparison to Europe, US and—to a lesser extent—Korean inventions, have a distinct influence through multiple channels. Conversely, the influence of China and Japan is shown to be weaker.

Table 3: Onedirectional influence

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Time period	2000-2005	2006-2011	2012-2017	2012-2017	2012-2017	2012-2017	2012-2017
Dependent variable	ISR citations	ISR citations	ISR citations	Citing countries	Citing countries	Citing tec. areas	Citing tec. areas
US (0/1)	0.089***	0.087***	0.095***	0.068***	0.023***	0.062***	0.024***
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
China (0/1)	−0.067***	−0.105***	−0.097***	−0.070***	−0.023***	−0.061***	−0.022***
	(0.005)	(0.003)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Japan (0/1)	−0.003	−0.020***	−0.040***	−0.030***	−0.010***	−0.028***	−0.012***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Korea (0/1)	0.105***	0.072***	0.074***	0.044***	0.008***	0.030***	0.001
	(0.005)	(0.003)	(0.003)	(0.002)	(0.001)	(0.002)	(0.001)
Residual countries (0/1)	0.131***	0.114***	0.085***	0.063***	0.022***	0.059***	0.025***
	(0.003)	(0.003)	(0.003)	(0.002)	(0.001)	(0.002)	(0.001)
ISR citations					0.483***		0.402***
					(0.010)		(0.009)
Year FE	Y	Y	Y	Y	Y	Y	Y
Technology area FE	Y	Y	Y	Y	Y	Y	Y
Year-technology area FE	Y	Y	Y	Y	Y	Y	Y
Observations	667,697	927,438	1,252,148	1,252,148	1,252,148	1,252,148	1,252,148
R-squared	0.034	0.029	0.029	0.038	0.681	0.031	0.571

Note: OLS regressions with robust standard errors in parentheses. ***p <0.01, **p<0.05, *p<0.1. The reference category is "Europe (0/1)".

We aim to estimate parameter γ (the relationship between a patent's geographic origin and its influence), which is measured by the number of ISR citations received from other countries; however, bias may be introduced by omitted variables that confound origin and influence. To assess the robustness of our results, we compare our main results in column (1) of Table 4 which is identical to column (3) in Table 3, with results obtained after augmenting Eq. (5) with potential confounders. As a first step we control for the number of claims. While the average number of claims per patent may vary across countries; for instance, Japan is known to traditionally have fewer claims per patent (Goto and Motohashi 2007), the number of claims—and thus the inventive content of the patent—may positively influence the number of citations received. While a positive and significant relationship between claims and citations is confirmed in column (2), the magnitude of γ drops for Japan, confirming a lower average number of claims. Importantly, the baseline results remain robust. Second, we control for patenting by

universities because the average number of citations received by science-oriented patents may be lower, introducing a negative bias for countries with more patents coming from universities. Indeed, column (3) shows a negative correlation between patent applications by universities and the number of citations received; however, parameter γ remains virtually unchanged across countries.

Table 4: Robustness tests (2012-2017)

	(1)	(2)	(3)	(4)	(5)	(6)
	Comparison	Claims	Universities	Authority	English	All
Dependent variable	ISR citations	ISR citations	ISR citations	ISR citations	ISR citations	ISR citations
US (0/1)	0.095***	0.072***	0.096***	0.070***	0.078***	0.045***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
China (0/1)	−0.097***	−0.072***	−0.096***	−0.044***	−0.065***	−0.014***
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)
Japan (0/1)	−0.040***	−0.013***	−0.040***	−0.033***	−0.024***	−0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Korea (0/1)	0.074***	0.093***	0.075***	0.031***	0.099***	0.058***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Residual countries (0/1)	0.085***	0.099***	0.086***	0.083***	0.078***	0.086***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Number of claims (log)		0.106***				0.087***
		(0.002)				(0.002)
University applicant (0/1)			−0.032***			−0.010***
			(0.002)			(0.002)
Chinese receiving office (0/1)				1.872***		1.855***
				(0.014)		(0.014)
English full text (0/1)					0.105***	0.057***
					(0.001)	(0.001)
Year FE	Y	Y	Y	Y	Y	Y
Technology area FE	Y	Y	Y	Y	Y	Y
Year-technology area FE	Y	Y	Y	Y	Y	Y
Observations	1,252,148	1,252,148	1,252,148	1,252,148	1,252,148	1,252,148
R-squared	0.029	0.037	0.029	0.213	0.033	0.219

Note: OLS regressions with robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The reference category is "Europe (0/1)". In model (2) we include a dummy variable for missing claims information.

Next, in column (4) we control for ISR citations generated at the Chinese receiving office, which recently has become the largest ISA in terms of examined PCT patent applications (WIPO 2023). China introduced national subsidies for patenting through the PCT system in 2009.[14] Cost reductions from subsidies disproportionately incentivize the production of patents of marginal value and the additional citations generated by such patents may inflate the outcome variable

[14] In 2009 China's Ministry of Finance introduced subsidies for PCT patenting. Applications in up to five countries are subsidized with a maximum of 100,000 RMB each (ca. 14,600 USD at an exchange rate of 31.12.2009) but more support is possible for projects involving significant innovation (Boeing and Mueller 2019).

(see the discussion in Section 2.2).[15] By construction, our measure of onedirectioal influence prohibits patents receiving citations from their country of origin, but non-Chinese patents could still receive Chinese citations. Our results remain robust after including a dummy variable to control for citations of Chinese origin. In column (5), we address the concern that variation in the availability of a patent's full text in English confounds the cited patent's origin and the number of citations received by including a dummy variable that takes the value of 1 if the full text became available in English during the citation window. Unsurprisingly, the availability of a full text in English is associated with more citations received; however, our main results remain robust. Finally, in column (6) we include the full vector of control variables and once again obtain robust results.

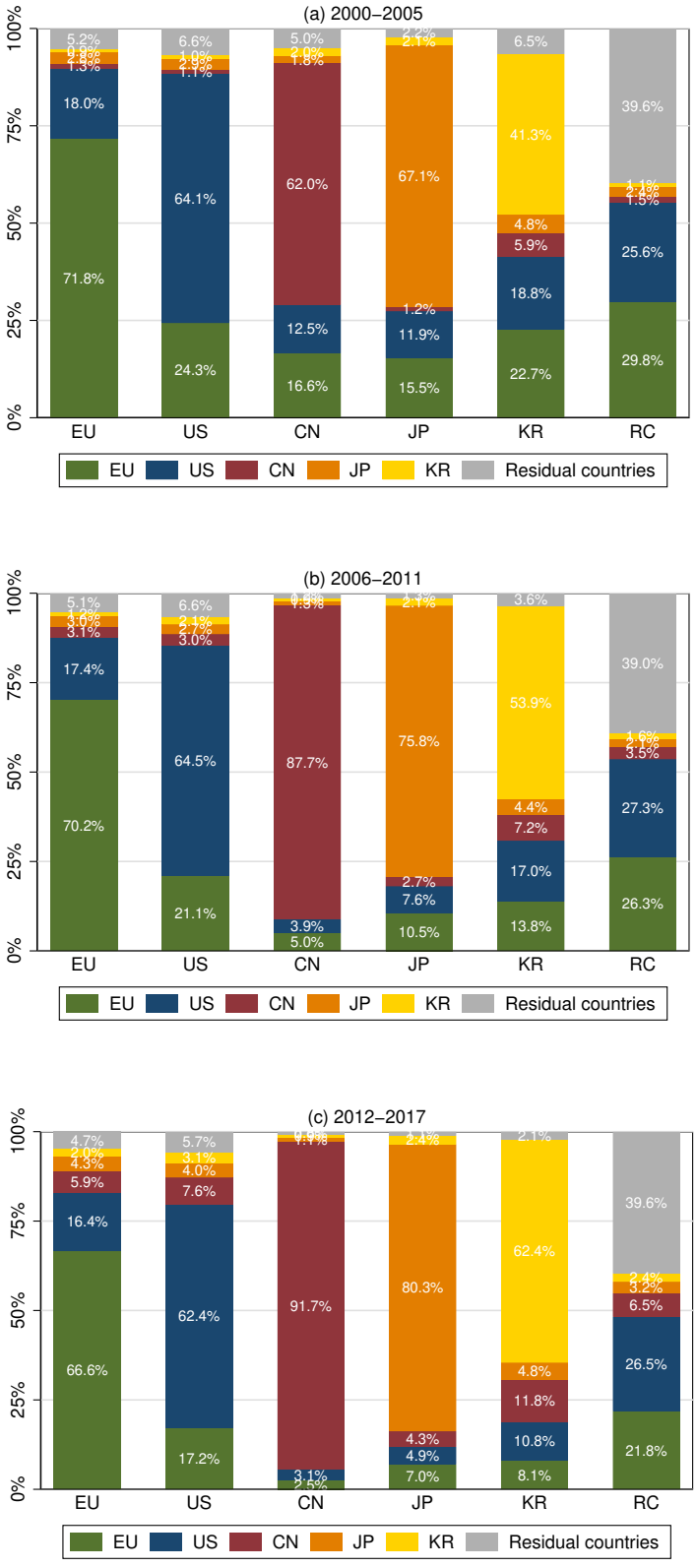
4.2 Geographic influence

We proceed with our analysis by considering the geographic direction of influence, which allows us to assess one country's specific influence on other countries. To analyze both the international and domestic dimensions of influence, in this section we relax our strict selection criteria and also include domestic ISR citations. Although such citations may be inflated by domestic policies, which amounts to an upward bias in China's case, this comparison is yet indicative of the level of technological self-reliance in a given country. To analyze changes over time, in Figure 3 we examine the periods 2000–2005, 2006–2011, and 2012–2017. For the early time period, Panel (a) shows PCT patents originating in Europe receive 72% of citations from within the immediate geographic area. European patents receive 18% of citations from the US, 1% from China, 3% from Japan, 1% from Korea, and 5% from residual countries. The economic implication is that European inventions are predominantly important for subsequent inventions in Europe. Despite a notable European influence on inventions in the US, the influence on other countries in the earlier years is more marginal.

Several insights stand out when focusing on Panel (c) for the time period 2012-2017. Building on self-generated inventions is critical, as demonstrated by the fact that between 62% and up to 92% of citations are of domestic origin. A notable degree of integration also occurs between Europe and the US, with 16% to 17% of citations coming from the respective partner, highlighting the depth of international cooperation. In addition, the share of citations from other countries to Europe and the US grew from 10% and 12%, respectively, in the early time period

[15] We follow Abadie (2021) and employ a synthetic control group to assess the impact of China's national PCT subsidies. The results show that subsidies not only increase the number of Chinese PCT applications after 2009, but also increase (decrease) the average number of domestic (foreign) non-self ISR citations received by Chinese PCT applications. This confirms that patent subsidies not only result in an disproportionate increase in the number of marginal patents, but also in an upward bias of domestic citations received by prior patents. Conversely, the reduction in foreign citations, which are independent of domestic policy, shows the expected inflation of Chinese patents.

Figure 3: Geographic influence



Note: The figure shows the geographic distribution of the origin of ISR citations received by the respective country.

to 17% and 20% in the late time period. The rationale for this increase is that the number of PCT applications strongly increased in East Asia; thus, these countries produced more inventions that refer to Western inventions. Overall, this illustrates that inventions from Western countries continue to exert broad international influence.

In contrast, the proportion of domestic ISR citations received in China and Japan increased to 92% and 80%, respectively. Although China's domestic ISR citations are biased upward by subsidy policy, our analysis still suggests an increasing degree of technological self-sufficiency combined with a declining international geographic influence of Chinese innovations in relative terms. In recent years, only 20% of citations in Japan and 8% in China came from abroad, compared to 38% in the US and 32% in Europe. These patterns highlight a strong domestic orientation of East Asia, with lesser influence on innovations developed elsewhere. As a noteworthy exception, Korea received 38% of its citations from abroad, confirming a stronger international geographic influence than Japan and China.

4.3 Bilateral influence

Technological influence positions countries heterogeneously in terms of dependence on other countries. Considering the time period 2012–2017, Table 5 presents the bilateral influence of the focal country indicated in the top row in relation to the countries noted in the column below. This measure considers both the quantity and the onedirectional influence of inventions. A value of 0 indicates full reciprocity between the two countries, while an upper (lower) bound of 100 (-100) implies full independence (dependence) of the focal country in relation to the other country. For this measure, we quantify the number of ISR citations that the patents of one country obtain in one year from the other country. If the focal country obtains more citations than it gives to that country, then the focal country is deemed more independent.[16] For instance, a value of -22 for Europe suggests that Europe depends more on the US than the US does on Europe, whereas a value of 27 for Europe indicates that Europe depends less on China than China does on Europe. Europe's global influence has a value of -8 and indicates modest reliance on foreign innovation overall, placing the continent at a disadvantage in its global technolog-

[16]The measurement of bilateral influence is described in more detail in the Appendix, where the full details of our measure calculation are presented in Table A1.

ical influence, except in comparison to China.[17] [18]

Table 5: Bilateral influence (2012-2017)

	Europe	US	China	Japan	Korea	Residual countries
Europe		22	-27	16	9	6
US	-22		-48	-19	-21	-14
China	27	48		39	54	18
Japan	-16	19	-39		-11	-8
Korea	-9	21	-54	11		1
Residual countries	-6	14	-18	8	-1	
Global influence	-8	26	-37	8	3	-1

Note: Columns show the bilateral influence of the focal country with respect to the other country: 0 refers to reciprocity between two countries, 100 refers to full independence, and -100 refers to full dependence.

Notably, the US consistently shows higher levels of independence in relation to all other countries, as demonstrated by its global influence value of 26, and exhibits its strongest position in relation to China. Conversely, China has the weakest overall position, with an global influence of -37. At the country level, China exhibits significant dependence on Korea (-54), the US (-48), and Japan (-39), while its dependence on Europe is relatively lower (-27). Japan and Korea exhibit independence in relation to almost all other countries, as evidenced by a value of global influence of 8 and 3, respectively. While both countries are dependent on the US, Korea also depends on Japan.

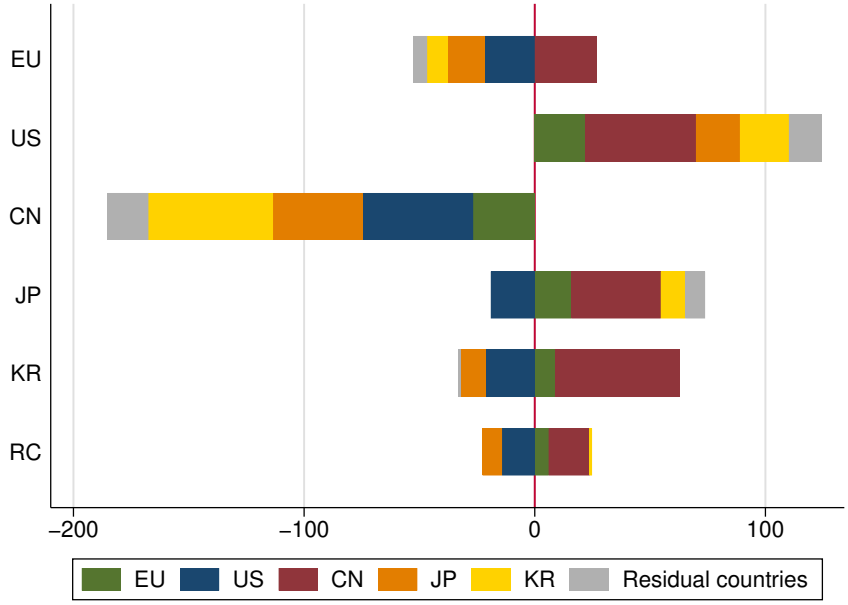
For a more comprehensive international perspective, in Figure 4 we illustrate the stacked bilateral influence for each country. Because we are quantifying the bilateral influence over all five partner countries, upper and lower bounds expand from 100 and -100 to 500 and -500, respectively. While individual values for bilateral influence are presented in Table 5, Figure 4 allows for a more comprehensive representation, both indicating variation within and across countries. Notably, the US is the only country with consistent bilateral independence (124), while China is the only country with consistent dependence (-185). Europe (27 and -53), Japan (74

[17] It can be numerically shown that our measure is not influenced by the size of a country. The intuition is that a smaller country would receive fewer citations from abroad but, because it has also fewer inventions, it would refer less often to the inventions of other countries.

[18] We tested whether our results are robust to the exclusion of patents with international co-applicants. On average only 7.1% of patent families entail international co-applicants in the period 2012-2017. The share ranges from 9.8% for the US to 1.8% for Korea. Our main results, see tables 1-3 and figure 3, remain robust if we exclude families with international co-applicants. Our calculations confirm that patents with international co-applicants have a higher onedirectional influence as they receive more citations. Excluding patents with international co-applicants improves the position of Korea with respect to bilateral influence in Table 5, because the other countries lose relatively more patents with high citation counts. However, as patents with international co-applicants also belong to a country's invention base that confers technological influence, these patents shouldn't be excluded from our calculations.

and -19), and Korea (63 and -33) have mixed accounts of stacked bilateral influence, with more moderate respective upper and lower values.

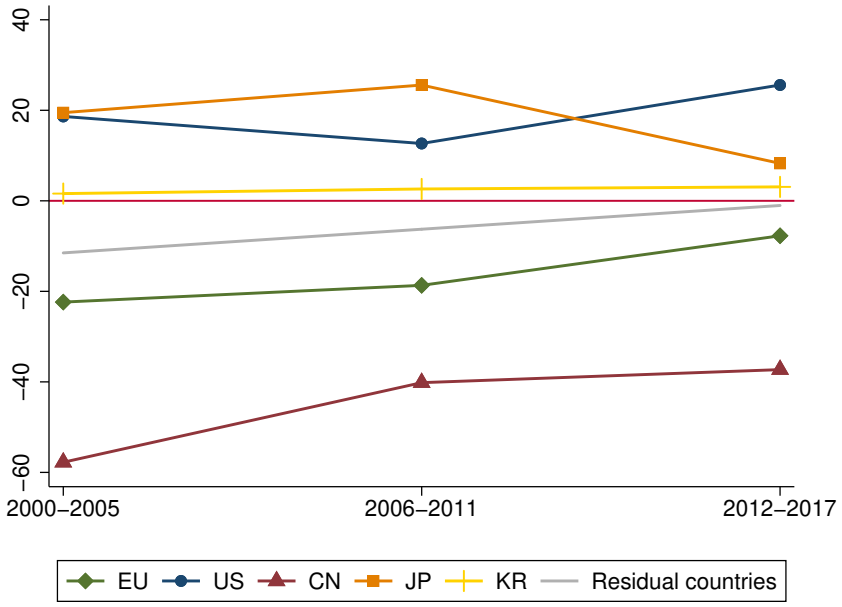
Figure 4: Stacked bilateral influence (2012-2017)



Notes: Each country's bar shows its stacked bilateral influence with respect to the other five countries. 0 refers to reciprocity, 500 refers to full independence, and -500 refers to full dependence.

Figure 5 displays each country's global influence. This is calculated as the average weighted bilateral influence for each country with respect to all other countries. Again, a value of 0 indicates reciprocity, 100 indicates full independence, and -100 indicates full dependence. Notably, Europe and the US exhibit similar positive long-term trends. Specifically, the US fluctuates between 12.7 and 25.6, whereas Europe ranges from -22.4 to -7.7. Korea remains very stable between 1.6 and 3.1. Japan has first improved to 25.6 and then declined to 8.3. In contrast, China shows the greatest continuous increase from -57.8 to -37.3, which still positions it below other countries. In summary, the traditional innovation countries of Europe and the US have remained stable over the last two decades, considering both the influence and quantity of inventions; however, the rise of China and the recent decline of Japan are also evident. The decrease in the average influence of China's PCT applications is outweighed by increased quantity. In contrast, Japan is experiencing a decline in average influence without a sufficiently robust rise in patent quantity, leading to a decrease in its global influence. Korea accounts for the lowest number of PCT applications, however, its persistent and high rate of citations amounts to a modest but stable global influence.

Figure 5: Global influence over time (2000-2017)



Notes: Each country's global influence is displayed. 0 refers to reciprocity, 100 refers to full independence, and -100 refers to full dependence.

4.4 Key enabling technologies

Key enabling technologies (KETs) are crucial for the development and continuation of technological influence. Such technologies have versatile applications across numerous technology fields and economic sectors, possess strong, nonsubstitutable complementarity with multiple other technologies, and have a considerable potential for performance enhancement. Therefore, we conduct an additional analysis focusing on KETs from 2012 to 2017. Empirically, KETs are classified referencing the criteria outlined in Van de Velde et al. (2013), encompassing nanotechnology, photonics, industrial biotechnology, advanced materials, micro and nanoelectronics, and advanced manufacturing technologies.[19] Besides the economic importance, the focus on KETs also offers a methodological advantage. While countries' actual technological influence is partly determined by their endogenous selection of technologies, KETs are a rather exogenous selection of technologies that could be considered as similarly relevant for all countries.

From 2012 to 2017, 17.8% of PCT patent applications were classified as KETs. Notable heterogeneity is evident in the share of KETs across countries. In decreasing order, Japan has 22.1%, the US 19.5%, Korea 18.4%, Europe 16.9%, and China 10.9%. Considering the onedirectional influence based on average ISR citations received per patent (compare with Table 2), the US leads with a mean value of 0.257

[19] As the widespread use of artificial intelligence is still a very recent phenomenon, these patents are not considered separately.

for KETs, compared to a mean value of 0.242 for all PCT applications. The corresponding values are 0.171 and 0.128 for Europe, 0.167 and 0.230 for Korea, 0.099 and 0.084 for China, and 0.079 and 0.083 for Japan. Notably, Europe shows the highest positive difference for KETs patents (33.6%) whereas a negative difference is found for Korea (-27.4%) and Japan (-4.8%), suggesting disadvantages in these technologies. Regression analysis corroborates this finding. When we replicate our benchmark model (Table 3, column (3)) with a restriction to KETs and compare it to the original results, the more negative finding for Japan and Korea stand out. Japan's coefficient is -0.075 for KETs, while it is -0.040 for all technologies. For Korea, the coefficient for KETs turns zero and insignificant, compared with 0.074 for all technologies. For the US, the respective coefficients are 0.066 and 0.095. These changes in coefficients confirm Europe's relative advantage in KETs towards the US, Japan, and Korea. Only for China we see a relative strengthening with respect to KETs with coefficients of -0.071 compared to -0.097.

The geographic influence reveals only minimal differences for KETs compared to all technologies (compare Figure 3). However, Japan and Korea substantially increase their share of own ISR citations, rising from 80.3% to 86.2% and 62.4% to 69.9%, respectively. This also suggests that these KET inventions have a lesser influence on other countries. Finally, replicating the results for bilateral and global influence restricted to KETs (compare Table 5), reveals the following notable results. Europe improves its global influence from -8 to -3, while Japan drops from 8 to -7 and Korea from 3 to -10. Japan and Korea show a lower bilateral influence in particular towards Europe (-3 for Japan, 0 for Korea) and the US (-29 for Japan, -35 for Korea). Japan's overall decline is attributable to a very low rate of foreign ISR citations, which cannot be compensated by the high absolute number of KET patents.

4.5 Country and region

Technological influence is often understood as a national concept. In addition to the US, China, Japan, and Korea, we so far considered the whole of Europe as another country. In this section, we deviate from this perspective and include Germany as the single most important European country in terms of PCT patent applications. However, for measurement reasons we also keep patents from Europe (without Germany) included, allowing for a comparison of Germany with the rest of Europe. Specifically, when counting ISR citations that build upon German inventions, we count only citations that come from outside Europe. We keep the citation measure as previously employed in the analysis but allow for a separation of European inventions into German and European but non-German. This setting

ensures direct comparability with our prior results.[20] [21] Below we briefly report our findings for Germany in comparison to Europe. Between 2012 and 2017, Germany accounted for 105,923 patents, approximately one third of the 329,038 European patents. The average number of citations for a German patent is 0.077, about half of the average of 0.152 citations for the rest of Europe. The difference in citations may be due to the fact that Germany receives a significant portion of its citations from within Germany (59%) and other European countries (17%), amounting to 76% of internal citations from within Europe. The rest of Europe, on the other hand, receives 55% of its citations from other European countries and 7% from Germany, amounting to 62% of internal citations. The 14 percentage point difference in internal citations between Germany and the rest of Europe may be attributed to Germany's central geographic location in Europe as well as its high technological concentration-which conversely explains fewer citations from outside of Europe.

Following from this, Germany's global influence is about five times lower than that of the rest of Europe. Comparable to the rest of Europe though, Germany still shows bilateral independence with respect to China. The findings for Germany in comparison to the rest of Europe regarding KETs are consistent. Between 2012 and 2017, both Germany and the rest of Europe filed 16.9% of their PCT applications in KETs, resulting in Germany's patent count being approximately one third of Europe's. The average number of citations for a KET patent from the rest of Europe is 0.192, while the average number of citations for a German KET patent is 0.126, indicating a smaller relative citation gap compared to all technologies.

5 Discussion and Policy Implications

In the context of increasing geoeconomic uncertainty, policy makers have to balance economic efficiency and de-risking strategies. It is therefore important for policy makers to understand their country's position in terms of technological influence and to avoid technological dependence. In general, countries have two policy levers with which they can strengthen their technological influence. They

[20] We use the same definition for ISR citations when evaluating inventions from other European countries excluding Germany. E.g., for inventions originating in France or in the Netherlands, we only count non-European ISR citations, which excludes German citations.

[21] There are potentially alternative settings that allow a separate analysis of Germany. Alternative settings could, for example, (i) allocate all remaining European countries to the residual country group or (ii) exclude all non top-five countries from the analysis altogether. However, results from these settings would not be directly comparable to our previous results. In alternative (i), Germany would receive foreign ISR citations from France, the Netherlands and other European and non-European countries. However, France, for example, would only receive German citations from the European countries but, for example, no Dutch citations. This different treatment of France and Germany seems implausible given that both countries often act in accord with the European Union. In alternative (ii), when excluding all non top-five applicant countries from the analysis, we would disregard 24.2% of PCT applications. With our chosen analysis we are able to cover all PCT applications and need only relegate 6.4% of PCT applications to the category "Residual countries", a category which isn't further analyzed.

can pursue home shoring, i.e. reinforcing domestic R&D and also production in technological areas that are critical for the country's future competitiveness. Also, in case of larger gaps to technology leaders, they can seek collaboration with reliable partners. In this case, countries can accept a situation of mutual dependence, but they need to be aware that who is considered to be a reliable partner can change over time. However, while it is in a country's general interest to avoid technological dependence, gaining technological influence is a zero-sum game: if one country gains influence, another country loses it. Therefore, in a global geoeconomic environment, it is important for policy makers also to understand the position of other countries. In Section 5.1, we first discuss our main findings that are relevant for evidence-based policy making. Then, in Section 5.2, we go beyond our direct results in discussing concrete policy implications for each country in the light of recent policy trends.

5.1 Discussion of results

In this section we review our main findings of particular importance to policy makers. Across all results, the US shows the greatest global independence and outperforms all other countries in the respective bilateral relationships, establishing leading technological influence. Another important insight is the strong mutual relationship between the US and Europe in terms of the direction of geographic influence. By comparison, East Asia generally shows an increasing internal focus over time. This is particularly true for China and Japan. Despite the ongoing integration between the US and Europe, however, the US and Europe differ markedly in their respective global positions. While the US has achieved outstanding independence, Europe shows global dependence and bilateral dependence on all countries except China. It is noteworthy, however, that Europe's influence in KETs is actually stronger than in total technologies.

The results for China demonstrate that leadership in patent quantity does not directly translate into technological influence. While China has overtaken the US, Japan, Korea, and Germany as the number one country in terms of PCT patent applications since 2019, our results show China's continued dependence on all other innovation-leading countries, which is evident across all technologies and future-oriented KETs. Despite the improvement in its global influence during the first decade of the millennium, China's recent growth in global influence is similar to Korea's, albeit at a lower level. Although our results confirm Japan's global independence and bilateral dependence only on the US, Japanese inventions have experienced a declining influence. As a consequence, Japan's global influence is recently weakening, despite its strong focus on KETs, and it is the only country showing a downward trend. Innovations from Japan are cited less frequently abroad over time, not just from fewer countries and technology areas, resulting in

a reduction in its overall influence. For Korea, on the other hand, our results show a moderately positive but sustained global influence. Moreover, Korea receives a larger share of citations from abroad than neighboring Japan and China.

5.2 Policy implications

In this section we discuss concrete policy implications for each country that go beyond our direct results in the light of recent policy trends. Overall, the US has maintained its influential position as the world's technological superpower. Europe's position, on the other hand, is mainly determined by global and bilateral dependencies. While China has experienced the largest increase in global technological influence over the past two decades, although from a low level, our results do not suggest that China is on the verge of overtaking the US in the short- to medium-term. Contrary to growing anecdotal evidence that China has made substantial progress in certain future-oriented technology areas, such as batteries (Breitinger et al. 2020), our analysis suggests that China's focus on quantitative patent targets combined with industrial and innovation policies has not yet resulted in inventions with overwhelming global influence on average. Japanese inventions have recently shown a declining influence, albeit from a high level, consistent with Japan's decline to fourth place among the world's largest economies.[22] For Korea, its sustained global influence is accompanied by relatively high R&D investment.[23]

To date, all countries have policies that support domestic R&D activities and, to varying degrees, technological sovereignty. Since the mid-2000s, China's policies have been explicitly focused on the long-term goal of reducing reliance on foreign technologies (Naughton 2021, p.51). Key policies include the Mid- to Long-term Science and Technology Development Plan (2006–2020), Made in China 2025 (2015), and the 14th Five-Year Plan (2021–2025), which prioritize domestic invention and technological self-sufficiency. More recently, other countries have responded with similar policies, while still emphasizing cooperation among partners. For example, Japan has introduced the Integrated Innovation Strategy (2018), Korea has implemented the Materials, Parts, and Equipment Strategy (2019), and the US has initiated the CHIPS and Science Act (2022) and the Inflation Reduction Act (2022). While the European Commission has been somewhat slower to adopt similar policies, its 2024 report, The Future of European Competitiveness – A Competitiveness Strategy for Europe, highlights the need to invest in key technologies, reduce reliance on foreign supply chains, and foster cross-border R&D collaboration among member states.

Policy makers' growing awareness of the changing global geoeconomic envi-

[22] The 2023 GDP figures in current trillion USD are as follows: U.S. (27.4), China (17.8), Germany (4.5), Japan (4.2), and Korea (1.7) (Worldbank 2024).

[23] Korea's R&D-to-GDP ratio of 4.9% in 2023 exceeds the US (3.6%), Japan (3.4%), Germany (3.1%), and China (2.6%) (Eurostat 2023).

ronment has reinforced the use of innovation and industrial policy. However, this may also increase the likelihood of misallocation of public funds. The results of our analysis can help policy makers increase allocation efficiency by addressing the most relevant technological dependencies first, while continuously monitoring countries' individual positions to make necessary adjustments along the way.[24] While the US currently maintains its global technological leadership, it seems crucial for European policy makers to address their global technological dependence. A key aspect of such a policy approach could focus on the promotion of KETs. While European policymakers view the US, Japan and Korea as reliable partners, limiting the need for immediate bilateral intervention, Europe could seek more balanced, long-term bilateral partnerships with these countries, while avoiding future dependency on others. Japan may seek to slow or reverse its recent decline in global technological influence by generating inventions that translate into more technological influence. For Korea, its relatively high levels of R&D investment may have contributed to continued global influence, but the question remains whether Korea's comparatively high levels of R&D investment can be adequately sustained in the future. Finally, China's ambitions and activities to become a global innovation leader still exhibit some discrepancy with its actual bilateral and global technological dependence.

6 Conclusion

Using citations from the universe of PCT patent applications, we develop a novel empirical measure of technological influence that assesses the bilateral and global influence of inventions across countries. We examine the technological influence of Europe, the US, China, Japan, and Korea between 2000 and 2020 and highlight four insights. First, the US shows technological independence through its leadership in bilateral and global influence. Second, the US and Europe are highly integrated, but their global positions differ due to Europe's bilateral dependence on all countries except China. Third, while Japan has recently declined from its former leading position, Korea has maintained a moderate global influence. Finally, although China has filed the most patents in recent years, its dependence on all other countries amounts to the highest global dependence.

Several directions for future research are promising. First, an important direction is studying specific technologies. Although our work starts by examining all technologies and KETs, future research may select specific technologies and examine them in detail. Second, instead of studying global influence, analyzing techno-

[24] It is important to recognize that our measure is limited to evidence generated by patents and citations. While this captures an important dimension, there are other factors in international relations that can determine a country's technological influence, such as the size of the economy or the strength of political relationships (Waltz 1979).

logical influence within certain regions, e.g. an analysis for the individual countries of the European Union, may be insightful. Third, our approach to measuring the influence of patents can also be extended to using ISR citations to scientific publications. This will be helpful for examining the underlying dependencies of countries' basic research. Similarly, extending the direction of research to measuring technological influence with non-patent indicators would be complementary. Fourth, understanding the drivers of technological influence, e.g. domestic R&D and other factors, will be important next steps for identifying how countries can adjust their respective position.

During the preparation of this work the authors used ChatGPT in order to check spelling and grammar in the text. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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Appendix

Calculation of bilateral influence

Table A1 contains the figures that underlie the calculation of the measure of bilateral influence as shown in Table 5. A value of 0 refers to reciprocity between two countries, 100 to full independence, and -100 to full dependence. The measure of bilateral influence is calculated as the total number of citations received by country j from country j' minus the total number of citations provided by country j to country j' divided by the sum of the two citation counts.

To illustrate the calculation, we provide two concrete examples. First, we explain the calculation of the value of bilateral influence of -22 that Europe (country j) has with respect to the US (country j') as reported in the first entry of the first column of Table 5. The value of -22 marks a slight dependence of Europe on the US. The value is calculated by taking the total citations that Europe received from the US, 20,791, and subtracting the total citations that the US received from Europe, 32,384. Both values are displayed in Table A1. The value of the obtained difference is -11,593. This value is divided by the sum of the respective citation counts, 20,791 plus 32,384, which equals to 53,175. The ratio of the two terms, -11,593 divided by 53,175, equals to -22%, which is the final measure of the bilateral influence of Europe on the US.

Second, when it comes to the bilateral influence of Europe with respect to China, the respective calculation is (7,788-4,505)/(7,788+4,505) = 27%. The value of 27 can be found in the second entry of the first column of Table 5.

Table A1: Number of ISR citations received (2012-2017)

	Europe	US	China	Japan	Korea	Residual countries	Total
Europe	80,422	32,384	4,505	7,471	3,553	6,039	134,374
US	20,791	118,094	5,823	5,486	5,167	7,703	163,064
China	7,788	16,603	138,655	4,912	6,599	1,952	176,509
Japan	5,419	8,071	2,171	96,418	2,394	940	115,413
Korea	2,970	7,953	1,970	2,974	26,899	814	43,580
Residual countries	5,353	10,249	1,363	1,113	797	10,610	29,485
Total citations	122,776	193,433	154,567	118,380	45,416	28,073	662,425
Total citations (%)	18.5	29.2	23.3	17.9	6.9	4.2	100.0
Total patents	329,038	309,537	188,480	264,320	80,328	80,445	1,252,148
Total patents (%)	26.3	24.7	15.1	21.1	6.4	6.4	100.0

Note: The table shows the number of ISR citations received by a country, i.e. its influence. E.g., the US obtained 16,603 citations from China whereas China obtained 5,823 citations from the US.