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# Standard essential patents and global ICT value chains with a focus on the catching-up of China

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ABSTRACT

Patents, standards and their combination, standard-essential patents (SEPs), are important in the information and communication technology (ICT) sector, in particular in mobile communication. We argue that SEPs are relevant in macroeconomic development and estimate the effect of a country's SEP portfolio on its value-added trade in global ICT value chains (GVC). We find that SEPs retain a higher share of value-adding domestically and that absorptive capacity is needed to join GVCs. China entered the SEP market late and is catching up rapidly. The trade effect of SEPs on China is different from that on matured economies because of the initially low value of its SEPs.

## 1. Introduction

The standards for information and communication technology (ICT) products can refer to patent-protected technologies (Bekkers et al., 2014; Blind et al., 2011). Owing to the globally intermingled structure of the ICT sector, standard-essential patents (SEPs) affect the way producers exchange knowledge and shape global production patterns. Therefore, standardisation can be regarded as an innovation network (Blind & Mangelsdorf, 2013). The effect of SEPs on the macroeconomic trade level has not yet been addressed despite its significant relevance. This article aims to provide a comprehensive analysis of the macroeconomic trade effects of SEPs on the ICT sector.

In this study, we use the definition of SEPs set by the European Telecommunications Standards Institute (ETSI), one of the major standard-setting organisations (SSO)s: 'When it is not possible on technical grounds to make or operate equipment or methods which comply with a standard without infringing an IPR, i.e. without using technologies that are covered by one or more IPR, we describe that IPR as "essential" (ETSI 2018). If this intellectual property right (IPR) is a patent, then we call it an SEP. Although the status of being standard essential increases the value of a patent, the commitment to license it under fair, reasonable and non-discriminatory (FRAND) conditions sets a general, even if not clearly defined, limit to the licensing fees that its owner can charge.

Previous studies conducted in this field did not analyse the relation between trade and SEPs that we present in this paper. On the one hand, the previous analyses of SEPs focus on the level of market structures (Bekkers, Duysters, & Verspagen, 2002), the selection of specific technologies using patent statistics (Rysman & Simcoe, 2008), companies' strategies within standardisation committees (Blind et al., 2011; Kang & Motohashi, 2015; Leiponen, 2008), questions on competition (Lerner & Tirole, 2015), or patent application processes (Berger, Blind, & Thumm, 2012). On the other hand, research on the trade effects of standards, as summarised for example by

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Swann (2010), generally neither control for patents with some exceptions such as Blind & Jungmittag (2005) nor for SEPs. Overall, only a few studies addressed the macroeconomic effects of standards, such as the study of Blind & Jungmittag (2008), who show their particularly important role in the ICT sectors of four European countries. Acemoglu, Gancia, & Zilibotti (2012) develop a theoretical model with standardisation as a growth engine. Some analyses found a positive effect of patents on exports (e.g. Frietsch, Neuhäusler, Jung, & van Looy, 2014; Greenhalgh, Taylor, & Wilson, 1994). The numerous studies summarised by Swann (2010) find an ambivalent effect of standards on trade: whereas international standards mostly foster trade, purely national standards can reduce trade flows. This article aims to close the research gap between microeconomic studies on SEPs and studies on standards and trade.

Studies including Blind et al. (2011), Pohlmann and Blind (2016) and Bekkers et al. (2014) reveal that referencing patents in standards is a specific phenomenon of the ICT sector but it is a rare exception in all other areas. If companies declare their patents to be essential for standards, they will agree to license these patents under the so-called FRAND conditions (Bekkers, Catalini, Martinelli, & Simcoe, 2012; Lerner & Tirole, 2014, Lerner & Tirole, 2015). Following the seminal contribution of Shapiro (2000), Rysman & Simcoe (2008) show that the inclusion of patents into standards pushes the number of their citations and value (Pohlmann, Neuhäusler, & Blind, 2016). Consequently, companies intend to declare their patents as essential because of the fast and wide effect of standards (Baron, Ménière, & Pohlmann, 2014).

SEPs combine the innovativeness of patents with the diffusion power of standards. We use trade in value-added flows in the ICT sector to analyse these effects. Production networks in the ICT sector are much more globally intermingled than those in the average industry in production (De Backer & Miroudot, 2014), and they are usually made possible by standards (Blind, Gauch, & Hawkins, 2010). Consequently, this high degree of interconnectedness, the problem of 'double counting' of trade flows, is especially prevalent in the ICT industry in which an above-average number of international production steps are executed (De Backer & Miroudot, 2014). Thus, whenever an intermediate product or a service crosses a national border to be processed in a different country, all of the production value and fees (e.g. tariffs), which are accumulated until then, get included in the trade statistics of the importing country. Therefore, identifying the real value that producers in a certain country added to a product is difficult. To circumvent these difficulties, we use newly available trade in value-added (TiVA) data provided by the Organisation for Economic Co-operation and Development and the World Trade Organisation (OECD & WTO, 2016) instead of gross trade flows in our model. This enables us to capture a realistic picture of the actual trade flows within global value chains (GVCs).

Although SEP ownership is concentrated among a few firms only, we assume a macro-perspective that attributes SEPs to countries rather than to companies to investigate their effects on international trade flows. We apply a gravity model of trade that we estimate using the Poisson pseudo-maximum likelihood regression method introduced by Silva & Tenreyro (2006). By estimating the effects of SEPs on trade flows, we find that when we omit China from the panel, SEPs (unlike 'conventional' patents, i.e., not standard essential) have a negative impact on imports and a positive effect on exports, protecting value creation at home. When we include China in the sample the effect of SEPs on exports becomes negative, underlining the overwhelming role of China in the global ICT trade and the low value of its SEP stock in the initial years of declaring patents to be standard essential.

The remainder of this paper is structured as follows: Section 2 describes the theoretical background i.e. the effects of patents, standards and SEPs on trade, the development of SEPs in the case of China and the concept of TiVa, and derives the hypotheses. Section 3 presents the empirical model and data sources. Section 4 gives and discusses the results. Section 5 derives important policy recommendations and concludes the study.

## 2. Conceptual background

As no theoretical concept on the trade effects of SEPs exists, we derive our assumptions from the available theoretical and empirical research on patents and standards. As SEPs combine the characteristics of patents and standards, we use previous findings on these two instruments to learn more about SEPs. Therefore, we present at first the trade impacts of patents and standards before we discuss the possible influence of SEPs on trade flows.

### 2.1. *General: patents, standards and SEPs*

#### 2.1.1. *Effects of patents on trade*

Patents can be seen as an output measure for R&D activities and consequently as an indicator of innovativeness (Griliches, 1998; Verhoeven, Bakker, & Veugelers, 2016). As patents convey innovations, the effects of patents on trade flows have regularly been subject to research. Blind & Jungmittag (2005) examine two different theoretical approaches: competitive advantage and intra-industry trade. Patents protect technologies against their use by other producers, creating a competitive advantage and strong incentives for innovation activities (e.g. Papageorgiadis & Sharma, 2016; Sweet & Maggio, 2015).

**Table 1**
Effects of patents on exports and imports.

| Theoretical approach | Economic effect | Effect on exports | Effect on imports |
|---|---|---|---|
| Competitive advantage | Create temporary monopoly in case of new products | ++ | – |
| | Improve quality and/or reduce costs of national products | ++ | – |
| Intra-industry trade | Increase product diversity | ++ | – |

Source (Blind, 2004).

Patents have a positive effect on exports and a negative effect on imports for two reasons. Firstly, a newly invented and protected technology can create a temporary monopoly for its owner, thus excluding potential competitors. Secondly, the new technology either increases the quality or reduces the price of the product, thus increasing the competitive advantage of its owner. From an intra-industry point of view, more patents representing a larger portfolio of products increase product diversity. When there are more products, the turnover of products of the country where the innovation was made increases. Therefore, again, exports increase and imports decrease. An overview of the different effects of patents on exports and imports is presented in Table 1.

A range of studies has empirically examined the relationship between innovative activity and the likelihood of companies to enter the export market. Studies on British (Ganotakis & Love, 2011; Wakelin, 1998a) and Spanish (Monreal-Pérez, Aragón-Sánchez, & Sánchez-Marín, 2012) firms show that innovations increase the likelihood to export.

Among the first studies examining the innovation and trade nexus is Greenhalgh (1990). The positive effects of patents as an innovation measure for trade are subsequently shown by Greenhalgh et al. (1994) and Greenhalgh, Mavrotas, & Wilson (2006). Swann, Temple, & Shurmer (1996) and Swann (2010) were the first to examine the macroeconomic effects of an innovation measure on trade while controlling for standards as a means of diffusion. Owing to data restrictions, the authors find only slightly significant, albeit positive, effects of innovation on exports and imports. Regarding bilateral trade flows between Germany and the United Kingdom, Blind & Jungmittag (2005) confirm their theoretical predictions in the panel estimations of export flows and trade balances. The coefficients for the patent measures show the expected signs. Only when the dependent variable is import flows are the predictions not confirmed because patents affect German imports positively. Another comparison between Germany and the United Kingdom by Anderton (1999) finds the expected overall negative effect of patents on imports. Wakelin (1998b) reveals the positive effects of patents on bilateral trade flows in the OECD. The strongly positive effect of patents on exports has been repeatedly proved by both older and more recent empirical research (Chen & Mattoo, 2008; Daniels, 1993; Frietsch, Neuhäusler, Jung, & van Looy, 2014; Madsen, 2007).

#### 2.1.2. *Effects of standards on trade*

A different way of codifying innovations other than patenting is developing standards.[1] In this way, the innovation is not protected, but made publicly available to facilitate its diffusion. All producers worldwide can use the standards to produce in accordance with them. By ensuring compatibility between products, standards increase a country's competitive advantage over those countries that choose not to produce according to standards. Moreover, they facilitate the exploitation of economies of scale. Similar to patents, standards increase the quality of domestically manufactured products (Swann, Temple, & Shurmer, 1996) but also enable a more cost effective production. As a result of the increased competitive advantage, the effects of standards on trade are expected to be positive but can also be negative if they pose too high compliance and adaptation costs for the domestic suppliers (Blind, 2004).

In the global intra-industry trade, standards are an important coordination mechanism. They ensure compatibility or minimum quality, enable exploitation of economies of scale and thus increase the openness of economies by making international collaboration easier and more attractive (WTO, 2005). The positive effects work both ways, so that a positive effect of international standards is expected on both exports and imports. By providing information to other market actors, standards increase additionally the openness of domestic markets (Blind, 2004; Swann, Temple, & Shurmer, 1996).

The validation of the various theoretical assumptions is the subject of numerous empirical studies (e.g. Blind, 2004; Blind & Jungmittag, 2005; Mangelsdorf, Portugal-Perez & Wilson, 2012; Moenius, 2004; Swann, Temple, & Shurmer, 1996). An overview and a comparison of most of the available studies are given by Swann (2010), who confirms the theoretical assumptions at large that standards facilitate the diffusion of innovations via international trade.

#### 2.1.3. *The special case of SEPs*

In this last section, we focus on the trade effects of SEPs as a specific subgroup of patents in general. Some patents are claimed by their owners to be standard essential, that is, the implementation of a standard requires the technology that is protected by these patents. The inclusion of the technology into the standard without the consent of the patent holder infringes on the patent holder's rights. SEPs are most common in the ICT sector. For example, telecommunication standards use several thousands of patents (Bekkers et al., 2012; Blind et al., 2011; Pohlmann, Blind, & Heß, 2020). To deal with this issue of standard essentiality, SSOs, which are organisations that coordinate the standardisation process and publish the standards, ask all the companies involved in the standard-setting process to disclose all patents that may be infringed by the implementation of the standard. Companies that choose not to be a member of the SSOs have little influence in this process. These disclosures should be made prior to the finalisation of the standard. Patent holders are then required to license their patents on FRAND terms to the standard users (Bekkers et al., 2012; Lerner & Tirole, 2015; Pohlmann, Neuhäusler, & Blind, 2016).

Consequently, ICT standards can have a strong effect on market structure (Bekkers, Duysters, & Verspagen, 2002). A number of them have become unique standards in the market and have reduced variety and competition that would have otherwise increased.[2]

[1] 'A standard is a technical document designed to be used as a rule, guideline or definition. It is a consensus-built, repeatable way of doing something. Standards are created by bringing together all interested parties such as manufacturers, consumers and regulators of a particular material, product, process or service. All parties benefit from standardization through increased product safety and quality as well as lower transaction costs and prices'. (definition by CEN (2018), the European Committee for Standardization).

[2] Examples of these standards are communication standards such as UMTS, GSM and LTE or audio, still picture and video codecs such as MPEG and JPEG (Blind et al., 2011).

One certain standard, namely, a specific technology, is then locked in and is globally used (Shapiro, 2000). Once included into a standard, SEPs receive an exposed position within the standard, promoting their relevance for follow-up innovations (Rysman & Simcoe, 2008). Therefore, they have the potential to penetrate the market intensively through the diffusion of the standard. Fig. 1 shows the development of SEP applications for a few selected countries.

SEPs combine the high innovativeness of patents with the power of diffusion that standards have. Therefore, we conclude that SEPs have a higher economic value than patents without a reference in standards because of these unique characteristics. Another indicator for the higher economic value is the fact that SEPs are cited more often than an average patent (Rysman & Simcoe, 2008). Patent citations are not only used as an indicator of patents' technological value, but despite their limitations they also commonly used to evaluate their economic value, which is our focus (see e.g. Blind, Cremers, & Mueller, 2009; Hall, Jaffe, & Trajtenberg, 2005). Moreover, the rate of citations increases significantly after a patent is declared to be standard essential (Rysman & Simcoe, 2008). Pohlmann, Neuhäusler, & Blind (2016) show that SEPs have a positive effect on a company's return on assets on the firm level. Hussinger & Schwiebacher (2015) find a positive effect on companies' market value.

Preliminary we conclude that SEPs have a higher technological and economic value before they are declared to be standard-essential by their owners. After this declaration, their technological and economic relevance is even further increasing, which might generate slightly different impacts on trade compared to patents in general. However, we will elaborate the differences between SEPs and conventional patents further in the derivation of the hypotheses.

### *2.2. The case and development of China*

As shown in Fig. 2, China has become not only the most important producer of ICT goods by far but also the most important exporter of the same within GVCs. This situation is hardly surprising for those following the development of world trade. What is more interesting is the development of the stock of patents and SEPs that originate from China. We will look at this issue in more detail in what follows.

Fig. 3 illustrates the contribution of China, Japan and South Korea to the SEP pool of selected standards in mobile data transmission. Focusing on their participation in the Internet Engineering Task Force, Contreras (2014) provides an in-depth analysis of their engagement that complements the observed picture. Although the Global System for Mobile (GSM) communications standard had been in place for some time, China still contributed some SEPs to GSM, whereas the other former main contributors such as Japan and Korea seemed to have lost interest in it. China entered the development of this standard as a laggard.

For the Universal Mobile Telecommunications System (UMTS) standard the picture has already changed to some extent. Although China contributed to the development of this standard far later into the standardisation process than the other main contributors, it was not a lone laggard when it did so. However, other countries such as Korea kept declaring their patents to be standard essential after their publication. As shown by the different scales of the graphs, the total number of SEPs for this standard also increased by a large factor.

For the Long-term Evolution (LTE) standard, the picture has again shifted. China declared a significant number of patents to be standard essential around the same time as other countries did, although still at a lower level as described by Kang, Huo, & Motohashi (2014).

Although this development is already remarkable, one other observation is worth mentioning: the Chinese stock of SEPs only started growing in 2005. These SEPs had low levels of citations per patent (Fig. 4). Naturally, a certain time lag always occurs until patents become cited, but this only started changing in 2008 in China's case. This situation is in accordance with the allegations that China, although increasing its output in patents, did so in a quantitative rather than qualitative dimension initially (Fisch, Sandner, & Regner, 2017). After a few years 'in the market', the quality of Chinese patents, as measured by citations, has been observed to increase and catch up with the citation ratios of other developed countries. In 2005, the average number of citations for Chinese patents was 3.7 citations per patent. It declined until 2008 (2.9) and then increased again to above 8 in 2011. Conversely, the average number of citations of the SEP stock of the United States went down from its peak in 2005 (18 citations per patent) to 14.5 in 2011. Although still being below most other big players in this regard, the positive trend of the quality of China's SEPs is obvious.

### *2.3. ICT production in GVCs*

In this section, we explain the trade patterns within GVCs, which are much more complex than in the traditional trade models based on the gross export or import of final products. Since the production of ICT products has been developed towards such complex GVCs, we cannot anymore use gross exports and imports as the dependent variables in our regression model, but the more adequate data on trade in value added.

GVCs emerged mainly because of the vanishing of barriers to trade (e.g. tariffs) and the advancements in ICT (Baldwin, 2012; OECD, WTO, & UNCTADT, 2013). These developments were taken on by researchers of a strand of literature that introduces new production patterns in economic theory. GVCs are defined as follows:

The value chain describes the full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use (Kaplinsky & Morris, 2001).

Melitz (2003) gives a first theoretical description of the basic mechanisms of GVCs in the realm of intra-industry trade. A basic finding of his model is that an increased number of internationally available trading partners enhance trade and welfare. Examining theoretically which firms engage in GVCs by sourcing their intermediates globally, Antràs & Helpman (2004) find that companies need

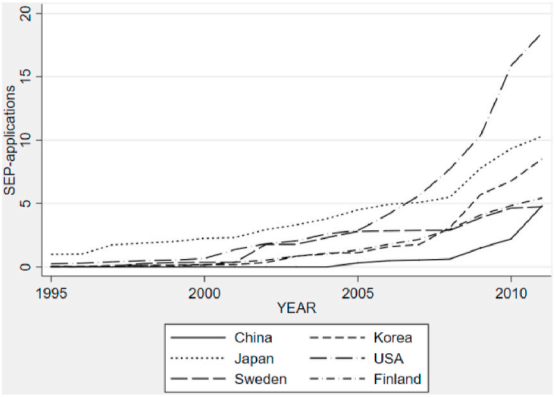


**Fig. 1.** Development of SEP applications in selected countries.

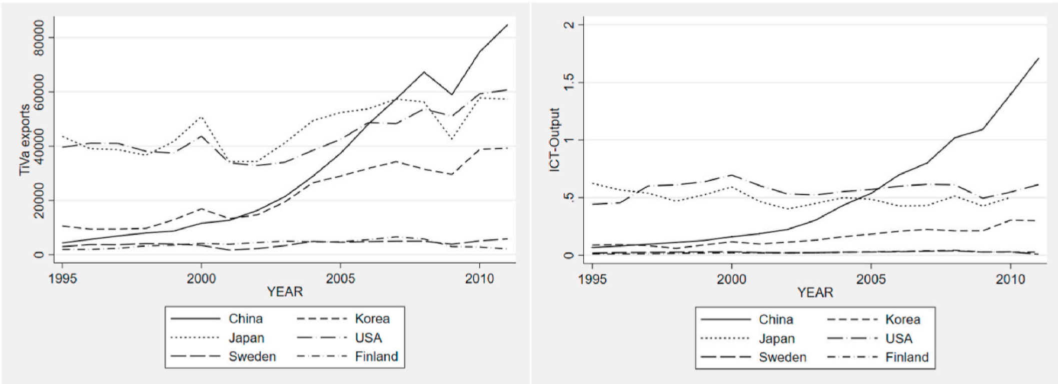


**Fig. 2.** Development of TiVa exports from selected countries (left); development of ICT output in selected countries (right).

to pass a certain threshold of productivity to be able to do so. Gereffi, Humphrey, & Sturgeon (2005) discuss the role of standards in GVCs and provide brief case studies to illustrate their framework. Grossman & Rossi-Hansberg (2008) introduce fragmentation into GVCs and modify the assumption that products are made of a discrete number of intermediates. Instead, production is described as a 'continuum of tasks' (Grossman & Rossi-Hansberg, 2008) comprising services and material intermediates in a continuous production function, thereby making the number of production stages infinitely small. Although studies do not observe such a fine fragmentation empirically, De Backer and Miroudot (2014) show that the number of production stages in GVCs increased between 1995 and 2008. They find that fragmentation did not increase in the domestic portions of a GVC, but only in the part that is produced internationally. This result gives strong evidence of a shift towards global production patterns. Baldwin & Robert-Nicoud (2014) present the first comprehensive theoretical framework that integrates goods trade and task trade. Their study combines the trade of final goods with the trade of intermediates and services in GVCs for production purposes.

Production in GVCs is especially prevalent in the ICT sector, as indicated by its regular use as anecdotal evidence, for example, the assembly of a smartphone. There is also empirical evidence that GVCs are particularly long and common in the ICT sector: ICT products can easily be sourced and produced globally because they are highly standardised, codified and interoperable (De Backer & Miroudot, 2014). Moreover, the ICT sector value chains consist of a wide range of company types. That is, companies can be part of these GVCs regardless of their size, location or specialisation. In addition, the 'length' of GVCs in the ICT sector is longer than that of average GVCs. The ICT sector has more production stages in a GVC. Moreover, the percentage of steps that is completed abroad before a product is sold in the domestic market is above average in the ICT sector (De Backer & Miroudot, 2014; OECD et al., 2013).

As GVCs consist of many stages that take place in different countries, measuring them accordingly is important. The problem of 'double counting' is prevalent here when the gross trade flows from one country to the other are used to model GVCs. De Backer and Miroudot (2014) find that, on average, only half of the export value of a country is made up of products that are part of a GVC. That is, we cannot attribute the other half of the export value to GVCs, and it is not of interest when considering the global production patterns. To determine the real structure of the GVC, we have to measure the trade in value-added terms. Value added is defined as the 'value that is added […] by a country in the production of any good or service' (Ahmad, 2013). By measuring trade in value added, we count only the actual value added in the last production stage, which gives a more realistic picture of the actual trade patterns (OECD & WTO, 2012). Fig. 5 illustrates the difference between trade in value added and gross exports. Note that in country C, we can only determine the value added contributed by country B if we use the trade in value-added statistics. The more different the countries are involved in

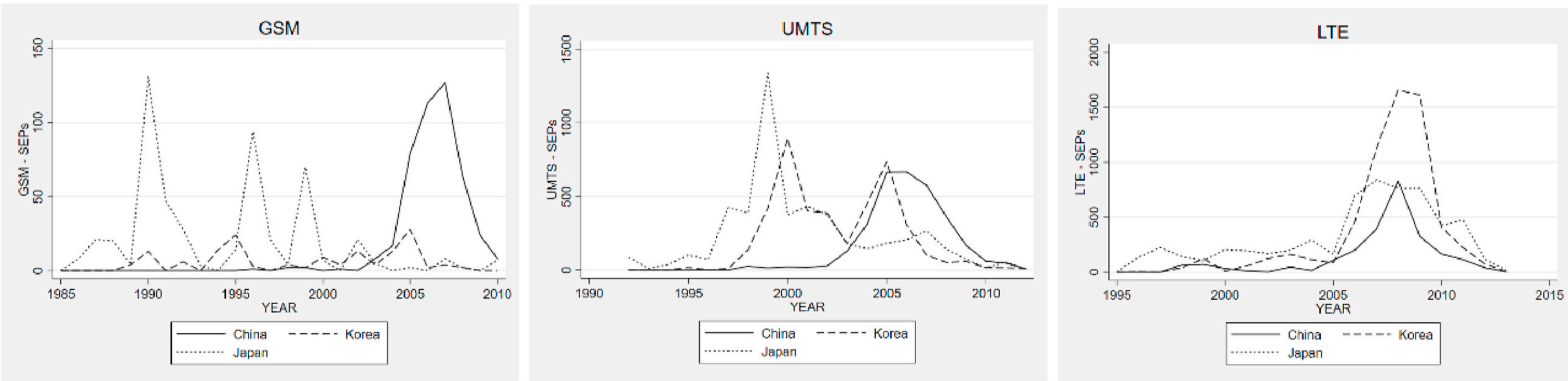


**Fig. 3.** SEPs for selected standards projects (source: (IPLytics 2016)).

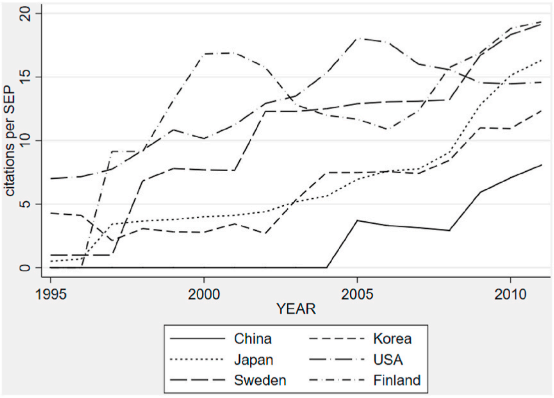


**Fig. 4.** Development of citations per SEP: China and other countries.

the GVC, the more important the value added becomes. Therefore, the value added should be used for determining the actual contributions of single countries in these GVCs.

Dedrick, Kraemer, & Linden (2010) give a graphic description of a GVC production process from the ICT sector. The authors describe the different components (e.g. microprocessors, memory) used in the production of an Apple iPod and a Hewlett–Packard notebook. The technologies implemented in these components come mostly from the United States and Japan, and the final assembly takes place in China. More than 10 different suppliers deliver the main parts for each product. When components are produced in the United States and Japan, value is added to them by the use of the factors of labour, intermediates and raw materials. These components are then exported to China, where again value is added through the process of assembly. Eventually, the final product travels to its ultimate destination. In case this destination is the United States or Japan, the statistical offices count the value of the original components into the gross trade statistics a second time even though they are now partly re-imports. To correctly capture production networks like this, using trade in value added is imperative in trade models. These numbers have the capacity to correctly allocate the productive activity to the respective country and to resemble the technological specialisations (Grossman, 2013). Blind, Mangelsdorf, Niebel, & Ramel (2018) use trade in value-added data to show empirically that standards are important instruments to reduce information asymmetries in GVCs.

### *2.4. Hypotheses*

From the above considerations, we derive our hypotheses, which are tested in the empirical part. As previously discussed in section 2.1.1, patents can be regarded as a measure of innovative capacity, which boosts output and exports based on the theory of competitive advantage. There is no reason to expect the ICT sector to be an exception in this regard. Therefore, our first hypothesis is as follows:

**H1.** The stock of conventional patents has a positive effect on exports in the ICT sector.

We deal with TiVa data in a market that is characterised by an exceptionally high number of production steps and a variety of different tasks within globalised value chains (De Backer & Miroudot, 2014). To become part of a GVC in the ICT sector, a certain level of technological sophistication is required (Felipe, Kumar, Usui, & Abdon, 2013). Therefore, the level of absorptive capacity (Cohen & Levinthal, 1990) of a country's firms is crucial for it to remain part of a GVC in the rapidly evolving ICT sector, and we regard patents as a sign of learning and upgrading. Hong, Chongyang Zhou, & Wang (2020) argue, that to benefit from GVC participation, absorptive capacity is essential and Filippetti, Frenz, & Ietto-Gillies (2017) find that in countries with low absorptive capacity, FDI and patenting are negatively correlated, while countries with high absorptive capacity gain more from the participation in GVCs. We hence expect absorptive capacity (Cohen & Levinthal, 1990) to be closely related to the number of conventional patent applications of a country.

Innovation benefit from GVC participation is contingent upon the abilities of the participants, namely, absorptive capacity and research and development collaboration experience. Consequently, we depart from the above-described theory of the effect of patents on imports and expect conventional patents to boost imports through their capacity building aspect within GVCs. Therefore, our second hypothesis is as follows:

**H2.** The stock of conventional patents has a positive effect on imports in the ICT sector.

The first empirical hint of the above-average effect of highly cited patents like SEPs is given by Frietsch et al. (2014). The authors show that these patents exert a positive effect on exports because the underlying technologies are superior and create additional demand for the products of the exporting country. In addition, if the patents have an above-average number of forward citations, this export-promoting effect will last longer and increase further. This effect relates to the findings of Rysman & Simcoe (2008) on SEPs. As patents with above-average forward citations affect exports positively, it can be concluded that SEPs, which are characterised by an above-average number of forward citations, affect exports more strongly than other patents. Notwithstanding these results, we claim that SEPs are categorically different from other patents and that this effect is not only driven by a higher value measured by citation

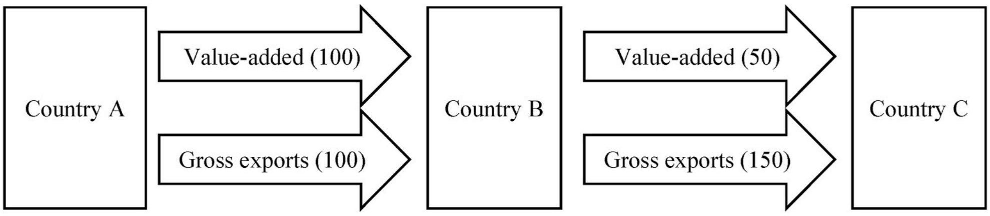


**Fig. 5.** Value added vs. gross export value, Source: Ahmad (2013).

counts.

SEPs combine the characteristics of patents and (international) standards. We expect their effects on trade to reflect this and enhance bidirectional trade through the standardisation effect while having an ambiguous effect through the patent protection effect. The more SEPs are held within a country, the more likely that the country produces and exports a larger fraction in terms of the value of a GVC. Frietsch, Neuhäusler, Jung, & van Looy (2014) show, that patent applications within a sector increase export value. As most SEPs are within the ICT sector, one can expect a positive effect of SEPs on exports.

In contrast to other patents, SEPs do not produce gains by granting a temporary monopoly or by providing the company with a technology that it can exploit financially on the market. FRAND licensing, at least in theory, limits such monopoly gains. Conversely, a competitive advantage is established, because SEPs grant the possibility for the company to have its technology implemented in a standard. This provides them with an early mover advantage and drastically increases the market size for their technology, eliminating competitive struggles that will occur if the technology has to compete with other technologies in the market. Moreover, holding SEPs may support the integration of companies in GVCs, for example, through cross-licensing (Grindley & Teece, 1997).

Standards that reference patents are upgraded and improved more often than other standards (Baron, Pohlmann, & Blind, 2016). Therefore, SEPs are found more in standards describing the latest technology than in older standards. Given that the technical merit of innovations of SEPs is higher than that of other patents (Caviggioli, Marco, Rogo, & Scellato, 2015), we assume that SEPs are more valuable assets than patents with no reference in standards. Therefore, we derive our third hypothesis as follows:

**H3.** As they combine the positive effects of patents and international standards on trade, SEPs have a trade-enhancing effect on exports.

For imports, we assume a slightly different perspective. The high importance of SEPs in the ICT sector leads us to assume that they behave as claimed for patents in previous studies (e.g. Blind, 2004): a higher ownership of SEPs should lead to a higher value added produced in that country. This can be manifested in higher exports, lower imports, or, as we claim, both. Therefore, our fourth hypothesis is as follows:

**H4.** SEPs have a negative effect on imports because their outstanding importance shifts value adding towards the domestic market, outweighing the positive effect of their standardisation aspect.

## 3. Empirical model and data

### 3.1. Empirical model

To estimate the effect of SEPs on trade in value added, we use the gravity model equation introduced by Tinbergen (1962) and further developed by Anderson (1979) and Deardorff (1998), among others. The basic model has since been refined, and several issues have been addressed, which we take into account in this study. Until the seminal contribution of Silva & Tenreyro (2006), estimating the gravity model with ordinary least squares (OLS) while accounting for multilateral resistance terms (Anderson & van Wincoop, 2003) and various dummies (Baier & Bergstrand, 2007; Baldwin & Taglioni, 2006) was common. As shown by Silva & Tenreyro (2006), this approach bears several risks of potential biases of the coefficients in any direction. The proposed solution, applying a Poisson pseudo-maximum likelihood (ppml) regression to the gravity equations of trade, has several advantages. Firstly, it does not suffer from the potentially very strong biases that can be present in the OLS and other approaches. Secondly, it takes care of the zero trade flows in the sample. Thirdly, it does not need a linearisation of the model. Therefore, we analyse our data with the proposed ppml estimation approach. As our main variable of interest, the SEPs that a country holds in a specific year are specific to a country and year, we cannot use the country–time dummies as the control variables because they clearly absorb the SEP variable. Therefore, we follow Baldwin & Taglioni (2006) and use the country–pair and time dummies to account for multilateral resistance terms (Anderson & van Wincoop, 2003) and absorb any fixed effects that may be present.

### 3.2. Data sources

We compile our dataset, a panel comprising 22 countries and 17 years, from various sources, as no existing set includes our variable of interest, SEPs, and the controls that we need in our setup, such as patent and standard stocks.

Dependent variable: TiVa.

We retrieve our TiVA data from the trade in value-added database released by the OECD and WTO (2016). For the first time, trade data that report the actual value-added trade between countries are made available in this database. The final data are taken from the input–output tables for each country. TiVA measures the domestic valued added embodied in the foreign final domestic demand; that is, we regard it as 'exports of value-added'. Trade is reported as the bilateral value-added trade volumes between the trading partners. It includes the total of all value added that is traded between a country–pair whether the trade flow went through a third country or not. Therefore, the nature of the data enables us to utilise a traditional gravity trade model. The data are available for 18 selected industries following the International Standard Industrial Classification (ISIC) Revision 3 classification. To represent the ICT sector, we choose the sector aggregate 30–33 'electrical and optical equipment'. The database covers the years of 1995–2011. We restrict our sample to 22 countries and construct a panel with bilateral trade relations[3] because of the restrictions in data availability of our standards and patents data sources.

Independent variables.

Sector output.

As we only investigate trade in one sector, all our controls have to be on the same level, that is, that sector. Instead of using gross domestic product (GDP) as a control for the size of the economy, as is done in gravity models that analyse total trade, we use output in the ICT sector as our main control for size of the economy. These data can be found in the United Nations Industrial Development Organization database (UNIDO, 2018).

Stock of standards.

We retrieve the standard stocks from the Perinorm database. The standard stock in year t is defined as all standards published in a country until the end of that year minus all standards withdrawn until this period. Perinorm provides information on whether a given standard is purely national or if it has been harmonised on the European or international level. As a result of the integration of the common European market, new standards in the European Union are harmonised and automatically implemented as national standards by all member countries. Conversely, non-European countries mostly implement no European standards at all. To avoid having an additional category of European standards filled with zeros for non-EU countries, we combine the European and national standards into one variable. In the third case, that is, when an international reference for a standard exists, we classify it as international.

Out of all standards, we only include those that are relevant for the ICT sector in the panel. However, the standards are not classified by one of the established industry classifications, such as ISIC, but by the International Classification for Standards (ICS). As the ISIC classifies industries and the ICS classifies technologies, there exist no official concordance tables to match the two systems. Consequently, we construct a concordance table following the verbal descriptions of the classes as closely as possible.[4]

Stock of patents.

The patent variable pat encompasses the number of international [i.e. European Patent Office (EPO) and World Intellectual Property Organization (WIPO)] patent applications by country of applicant and application year, and it is retrieved from the PATSTAT database.[5] Time is counted using the date of the worldwide first filing. The data are cleaned for double applications through the Patent Cooperation Treaty and at the EPO, so that they are not counted twice (Frietsch & Schmoch, 2009). Patent applications can have different qualities and values (Harhoff, Scherer, & Vopel, 2003). To guarantee a minimum quality of patents, we only use patents that were cited at least once. As an additional check for value and following Hall, Jaffe, & Trajtenberg (2005), we add a weight of 3% per citation to the patent value (assumed to be '1' as the baseline value) for the valpat variable.

Stock of SEPs.

Data on the stock of SEPs were kindly made available to us by the IPLytics database. It is currently the most comprehensive database on SEPs, and it gathers information on SEPs from all relevant sources. As for regular patents, we control for the value of SEPs and add 3% per citation (at WIPO or EPO) to the value of each SEP. Citations are retrieved from PATSTAT using unique application numbers as identifiers. Unlike other trade studies, we do not lag the variables for patent and SEP stocks, as the ICT industry is characterised by a high speed of innovativeness, and technologies are assumed to be implemented in products at the time of patent application.

Controls: population and infrastructure.

We control for population and infrastructure, which we retrieve from The World Bank– World Development Indicators. The infrastructure index is developed as the average of air and rail traffic and fixed telephone lines, following Blind, Mangelsdorf and Pohlisch (2018). Table 2 provides an overview of the variables and their various source.

## 4. Results and discussion

The results of our model are shown in Table 3.[6] The first column shows the results of our baseline model. The stock of ICT-related

[3] The countries are Austria, Belgium, Brazil, Canada, China, Denmark, Finland, France, Germany, India, Italy, Japan, Republic of Korea, Netherlands, Poland, Russian Federation, South Africa, Spain, Sweden, Switzerland, the United Kingdom and the United States.

[4] We include standards with the ICS codes 29 'electrical engineering', 31 'electronics', 35 'information technology, office machines', and 37 'image technology'.

[5] We would like to thank Peter Neuhäusler for making these data available to us. Compare also Frietsch, Neuhäusler, Jung, & van Looy, 2014.

[6] Although our main interest is on studying the effects on trade in value added, we also show the results for total trade in the appendix (Appendix A). In the baseline model, the results are similar. Some coefficients, especially the coefficient for exporters' SEPs in the sample without China, are categorically different, highlighting the importance of accounting for trade only in value-added terms when investigating the global value chains.

**Table 2**
Descriptions and sources of variables.

| Variable | Description | Source |
|---|---|---|
| *TiVA/Exgr* | Domestic value added embodied in foreign final demand (ICT)/Total ICT–exports | OECD–WTO Trade in Value Added Database |
| *ICTout* | Output in the ICT sector | UNIDO database |
| *gdpcap* | GDP/capita | World Bank |
| *Inf* | Infrastructure index, own construction | World Bank |
| *pop* | Population | World Bank |
| **std* | Stock of (inter-)national standards | Perinorm |
| *pat(cited)* | Stock of patents, citations | Patstat |
| SEP | Stock of patents declared standard essential | IPlytics GmbH |

patents (patcited*) is not significant for the exporting country (i), whereas we hypothesise it to be positive in H1. For the importer (j), it has a positive and significant effect, consistent with H2. This result can be an indication that, to import intermediate ICT goods, a certain level of absorptive capacity (Cohen & Levinthal, 1990) must be present within domestic firms. The other results are as expected: the coefficient of the size of the ICT sector is positive. In accordance with the findings of previous research (e.g. Swann, 2010), the coefficient for the stock of national standards for an exporting country is negative.

In the next column, we add our variable for the SEP stock (appallSEPdec*) of both the exporter and the importer. Although doing so does not change the relevant coefficients of our baseline model in a categorical manner, the SEPs show a negative and significant coefficient for the importing countries, whereas the effect for exporters is not significant. This lack of significance of the coefficient for exporters is surprising as H3 predicts that a country will export high values of ICT goods if it has a large stock of SEPs. The larger the stock of SEPs in a country, the lesser (value) it will import and the larger the fraction of the value creation that it will keep at home. Therefore, it makes sense that the SEP coefficient for the importing country is negative, supporting H4. The coefficient for patent stock of the importing country (patcitedj) remains positive. These results confirm that SEPs should be regarded as categorically different from regular patents in the ICT sector.

In the third column, we control for the value of both regular patents and SEPs by weighing them with the number of citations they have received. For SEPs, we use the number of citations between application and declaration, as the declaration itself can boost the number of citations and introduce a potential bias (Rysman & Simcoe, 2008). Using different measures (e.g. all citations or citations within a four-year window after application) does not alter the results significantly. Although there is no broad consensus on the best way to measure patents' value and opinions range from using nonlinear approaches to citations to other measures such as family size (Bakker, 2017), for simplicity, we follow Hall, Jaffe, & Trajtenberg (2005) and assume that each citation increases the value of the patent by 3%. Although this is admittedly a rough approach, we also check for different valuations (1%–10%) to which our results are robust. Introducing the value-adjusted patent variables does not change our coefficients of interest by much. Running the regression that excludes the years after the financial crisis (i.e. 2009-2011, not shown) also does not change the results in a relevant way.

Although robust to other shocks such as leaving out other countries or the years after the financial crisis, our model reacts strongly to the omission of China. Hence, we rerun the aforementioned regressions without China. In the baseline model (column 4), the results are consistent with the full sample results except for the loss of significance for exporters' population. However, models 2 and 3 (columns 5 and 6, respectively) show important differences: The previously insignificant coefficient for exporters' SEPs (appallSEPdeci) becomes positive and highly significant in the second model, in line with H3. In the third model, which again controls for the patent value, the sign switches from negative to positive and the significance increases from a 10% level to a 1% level in comparison with the model without China. In both specifications, the coefficient of importers' regular patents remains positive supporting H2 and that of importers' SEPs remains negative, supporting H4.

How this China effect can be so strong is clarified when looking into the development of China's SEP landscape in more detail. The first year when China had a relevant amount of SEPs was in 2005. It was not until 2008 that these SEPs were quoted in a frequency comparable with that of the SEPs of other countries. Therefore, the relatively late start of the surge in Chinese SEPs from 2005 until the last year of our panel in 2011 can be assumed to bias our results. As shown above, the ICT exports of China have been high and quickly increasing even before the large-scale participation in SEP declaration, when the main competitive advantage of China lay in low labour and production cost. Therefore, we assume that the initial SEPs of China did not have a strong impact on its already large ICT exports because they were of comparatively low value. The variable for exporters' SEPs (valfappallSEPdeci) adds some evidence to this view because of its low level of significance. In column 2, the coefficient of SEPs on a country's ICT exports has a negative sign but is not significantly different from zero. When adding a control for the value of patents in the form of citations (column 3), the negative sign remains and the significance level increases, albeit only to a 10% level. Although we do not claim this result to have strong explanatory power, it is still remarkable. Without China, this variable is positive and strongly significant. With China it is (negative but) insignificant, but when we introduce a value control, its negativity becomes more credible. Adding a country with large exports and only a few SEPs towards the end of the period of the study dispels the positive SEP effect for exporters. Controlling for the value of SEPs, thus further shrinking the relative size of China's SEP stock, changes their effect to negative. We conclude that in the period of the study, Chinas was still in the catch-up phase with respect to its ICT capacities, resulting in China having low-value patents. We expect this situation to have changed by now.

To summarise, we examined the effects of SEPs on trade in value added in the ICT sector using a panel of 17 years and 22 countries and a gravity model approach. As shown in Table 4, we found that unlike conventional patents, SEPs have the effect that was described for patents by Blind (2004): a positive effect on exports and a negative effect on imports. Conversely, conventional patents have no

**Table 3**
Regression results.

| TiVa | With China | | | Without China | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| VARIABLES | Y=TiVa | Y=TiVa | Y=TiVa | Y=TiVa | Y=TiVa | Y=TiVa |
| ICTouti | 0.8938*** | 0.8945*** | 0.8744*** | 1.4982*** | 1.4913*** | 1.4840*** |
| | (0.15) | (0.12) | (0.12) | (0.22) | (0.20) | (0.21) |
| ICToutj | 0.3936*** | 0.2247* | 0.2238* | 0.3493** | 0.1558 | 0.1508 |
| | (0.14) | (0.12) | (0.12) | (0.14) | (0.12) | (0.12) |
| Gdpcapi | 5.7885 | 4.2667 | 4.4052 | 8.0729 | 13.8946** | 13.5263** |
| | (7.14) | (5.78) | (5.68) | (6.64) | (5.48) | (5.58) |
| Gdpcapj | −7.7025 | −8.1448 | −7.7379 | −11.2537** | −12.1671*** | −11.5231*** |
| | (6.62) | (5.19) | (4.94) | (5.44) | (4.21) | (4.04) |
| Nstdi | −0.4707*** | −0.4376*** | −0.4370*** | −0.2772*** | −0.2659*** | −0.2674*** |
| | (0.06) | (0.05) | (0.05) | (0.04) | (0.03) | (0.03) |
| Nstdj | −0.0936* | −0.0327 | −0.0294 | −0.0878 | −0.0317 | −0.0287 |
| | (0.06) | (0.05) | (0.05) | (0.06) | (0.05) | (0.05) |
| istdi | −0.0313 | −0.0228 | −0.0230 | −0.0294 | −0.0365* | −0.0353* |
| | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) |
| istdj | −0.0217 | −0.0100 | −0.0105 | −0.0157 | −0.0057 | −0.0062 |
| | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) |
| infi | −0.1756*** | −0.1656*** | −0.1645*** | −0.1272** | −0.0692 | −0.0766 |
| | (0.06) | (0.06) | (0.06) | (0.06) | (0.06) | (0.06) |
| infj | 0.1690* | 0.1493* | 0.1511* | 0.1715** | 0.1557** | 0.1575** |
| | (0.09) | (0.09) | (0.09) | (0.08) | (0.07) | (0.07) |
| popi | 0.0122*** | 0.0125*** | 0.0127*** | 0.0001 | −0.0076** | −0.0070** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| popj | 0.0121*** | 0.0150*** | 0.0151*** | 0.0121*** | 0.0148*** | 0.0149*** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| patcitedi | 0.0055 | 0.0011 | | −0.0144 | −0.0051 | |
| | (0.01) | (0.01) | | (0.01) | (0.01) | |
| patcitedj | 0.0576*** | 0.0386** | | 0.0575*** | 0.0392*** | |
| | (0.02) | (0.02) | | (0.02) | (0.01) | |
| appallSEPdeci | | −0.0087 | | | 0.0211*** | |
| | | (0.01) | | | (0.01) | |
| appallSEPdecj | | −0.0257*** | | | −0.0262*** | |
| | | (0.01) | | | (0.01) | |
| valpati | | | 0.0025 | | | −0.0023 |
| | | | (0.01) | | | (0.01) |
| valpatj | | | 0.0276** | | | 0.0286** |
| | | | (0.01) | | | (0.01) |
| valfappallSEPdeci | | | −0.0068* | | | 0.0133*** |
| | | | (0.00) | | | (0.00) |
| valfappallSEPdecj | | | −0.0183*** | | | −0.0187*** |
| | | | (0.00) | | | (0.00) |
| Observations | 6900 | 6900 | 6900 | 6566 | 6566 | 6566 |
| Number of pair_id | 420 | 420 | 420 | 400 | 400 | 400 |

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

observable effect on exports and a positive effect on imports, which we attribute to the absorptive capacity needed to become part of a GVC. This situation changes when China is included in the sample. The relatively late start of SEP accumulation and their initially low value in China, paired with its high ICT exports, are strong enough to make the coefficient of SEPs on exports to become negative. This result is the outcome of investigating a special stage in the catching-up process of an emerging big player like China.

## 5. Policy implications

Several policy implications can be derived from our findings. Firstly, we show for the first time that SEPs have relevant macroeconomic effects and can be regarded as tools for maintaining value creation within a country. Therefore, SEPs should not be neglected by policymakers. Our findings also highlight the importance of active participation in standardisation with respect to SEPs, as experienced standardisation experts are more likely to successfully declare their patents as standard essential (Kang & Motohashi, 2015). Secondly, the example of China as an emerging market, which started early to strategically focus on standardisation as a driver of innovation (Wang, Wang, & Hill, 2010), holds important lessons for other emerging markets. Standardisation and participating in it, especially on an international level, requires expertise (Kang & Motohashi, 2015). Therefore, countries should enter standardisation early to accumulate knowledge and experience. The remarkable increase in the number of secretariats held at ISO over the last decade (EFI , 2018) and the observed initially low but increasing value of its SEPs are just two examples of the dynamism of China's standardisation strategy. According to Blind (2005), standards may hold less relevance for developing countries. When trying to

**Table 4**
Overview of results.

| | Hypothesis | Sample with China | Sample without China |
|---|---|---|---|
| H1 | The stock of conventional patents has a positive effect on exports in the ICT sector. | Not significant | Not significant |
| H2 | The stock of conventional patents has a positive effect on imports in the ICT sector. | ✓ | ✓ |
| H3 | As they combine the positive effects of patents and international standards on trade, SEPs have a trade-enhancing effect on exports. | Not significant | ✓ |
| H4 | SEPs have a negative effect on imports because their outstanding importance shifts value adding towards the domestic market, outweighing the positive effect of their standardisation aspect. | ✓ | ✓ |

‘emerge’ to become a developed country, developing a long-term strategy for standardisation is even more important.

Finally, our analysis has the following limitations. The availability of data is a major issue. The initiative to track trade in value added is an impressive effort to reflect the real net trade flows. As it is a relatively new way of trade accounting, it has to be treated with caution. Regrettably, the panel ends in 2011 for our research due to be able to use the lagging patent citation data and restrictions of the trade data. However, the time series is sufficient in particular for analysing the catch-up process of China. Especially, with regard to the developments in China, we would have liked to expand the time series of our econometric analyses. Fortunately, Pohlmann, Blind, and Heß (2020) provide the most recent data on SEPs related to 5G, the most recent mobile communication standard following LTE. Their result reveals that the 5G standard is highly patented with almost 100,000 declarations mainly from 2017 to 2019 breaking down to more than 20,000 unique patent families. As of January 1st, 2020, Huawei from China has declared most 5G patents followed by Samsung (Korea), ZTE (China), LG (Korea), Nokia (Finland), Ericsson (Sweden) and Qualcomm (US). All of those top 5G patent owners have already been active in the LTE standard development, but several new market players from China are now in the top patent owner list. In summary, this new data on SEPs related to 5G confirm the role of China as game changer in mobile communication technologies already started before 2010 related to LTE as revealed above (Fig. 3).

For the lack of elaborate concordance tables, we had to match data from different sources. While we did this carefully and to the best of our knowledge, matching can always be a source of loss of accuracy. The same ‘roughness critique’ applies for our measures of patent and standard stocks. Although we used the best data available at this point, a sketchy picture remains of the real world, as some datasets might not be complete or be biased towards certain regions.

Although SEP ownership is concentrated among a few firms only, we assume a macro-perspective attributing SEPs to countries rather than to companies to investigate international trade flows. Therefore, transfer pricing and other means to shift value at will when production stages are happening within the same firm but in different countries cannot be accounted for.

In spite of these data-related shortcomings, our explorative study provides some initial insights into the macroeconomic effects of SEPs and the effects of emerging markets entering into GVCs.

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## Appendix

**Appendix A**

| Total Exports | | | | 10-12 w/o China | | |
|---|---|---|---|---|---|---|
| VARIABLES | (7)<br>Y = Exgr | (8)<br>Y = Exgr | (9)<br>Y = Exgr | (10)<br>Y = Exgr | (11)<br>Y = Exgr | (12)<br>Y = Exgr |
| ICTouti | 0.9873*** | 0.8430*** | 0.8080*** | 1.6925*** | 1.7650*** | 1.7620*** |
| | (0.19) | (0.13) | (0.13) | (0.39) | (0.35) | (0.36) |
| ICToutj | 0.5216*** | 0.4219*** | 0.4169*** | 0.3919** | 0.2521* | 0.2399* |
| | (0.18) | (0.15) | (0.14) | (0.17) | (0.15) | (0.15) |
| Gdpcapi | 5.2715 | 1.3349 | 1.3782 | 13.4699 | 10.5094 | 9.7982 |
| | (10.66) | (8.46) | (8.14) | (9.10) | (7.64) | (7.58) |
| Gdpcapj | −15.7405 | −16.2196** | −15.6949** | −24.9267*** | −23.4715*** | −22.6236*** |
| | (10.26) | (7.43) | (7.25) | (9.03) | (6.85) | (6.59) |
| Infi | −0.5873*** | −0.4566*** | −0.4564*** | −0.2348*** | −0.2210*** | −0.2213*** |
| | (0.10) | (0.07) | (0.07) | (0.05) | (0.05) | (0.05) |
| Infj | −0.2456*** | −0.1679** | −0.1638** | −0.2403*** | −0.1655** | −0.1629** |
| | (0.08) | (0.07) | (0.07) | (0.08) | (0.07) | (0.07) |
| Nstdi | −0.0628* | −0.0396 | −0.0405 | −0.0534* | −0.0475* | −0.0467* |
| | (0.03) | (0.03) | (0.03) | (0.03) | (0.03) | (0.03) |
| Nstdj | −0.0238 | −0.0034 | −0.0038 | −0.0127 | −0.0007 | −0.0013 |
| | (0.03) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) |

(continued on next page)

**Appendix A** (*continued*)

| Total Exports | | | | 10-12 w/o China | | |
|---|---|---|---|---|---|---|
| Istdi | −0.2728*** | −0.2737*** | −0.2647*** | −0.1467** | −0.1300** | −0.1308** |
| | (0.08) | (0.08) | (0.08) | (0.06) | (0.05) | (0.05) |
| Istdj | 0.1003 | 0.0844 | 0.0868 | 0.0983* | 0.0770 | 0.0788 |
| | (0.09) | (0.09) | (0.08) | (0.06) | (0.06) | (0.06) |
| Popi | 0.0158*** | 0.0177*** | 0.0180*** | −0.0113*** | −0.0090*** | −0.0084** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| Popj | 0.0138*** | 0.0164*** | 0.0165*** | 0.0145*** | 0.0168*** | 0.0171*** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| Patcitedi | 0.0226 | 0.0012 | | −0.0133 | −0.0125 | |
| | (0.02) | (0.02) | | (0.02) | (0.02) | |
| Patcitedj | 0.0624*** | 0.0435** | | 0.0571*** | 0.0349** | |
| | (0.02) | (0.02) | | (0.02) | (0.02) | |
| appallSEPdeci | | −0.0478*** | | | −0.0080 | |
| | | (0.01) | | | (0.01) | |
| appallSEPdecj | | −0.0282*** | | | −0.0334*** | |
| | | (0.01) | | | (0.01) | |
| Valpati | | | 0.0012 | | | −0.0100 |
| | | | (0.02) | | | (0.02) |
| Valpatj | | | 0.0323* | | | 0.0263* |
| | | | (0.02) | | | (0.01) |
| valfappallSEPdeci | | | −0.0341*** | | | −0.0070 |
| | | | (0.00) | | | (0.01) |
| valfappallSEPdecj | | | −0.0203*** | | | −0.0238*** |
| | | | (0.00) | | | (0.01) |
| Observations | 6900 | 6900 | 6900 | 6566 | 6566 | 6566 |
| Number of pair_id | 420 | 420 | 420 | 400 | 400 | 400 |

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

**Appendix B**
Summary statistics of the regression variables

| year | fddva | ICTouti | gdpcapi | nstdi | istdi | infi | popi | patci~di | appal~ci | valpati | valfap.. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1995 | 390.630 | 0.083 | 0.021 | 0.770 | 0.820 | 0.707 | 153.564 | 0.682 | 0.078 | 0.807 | 0.082 |
| 1996 | 389.392 | 0.082 | 0.022 | 0.784 | 0.963 | 0.702 | 155.360 | 0.703 | 0.083 | 0.851 | 0.087 |
| 1997 | 389.282 | 0.091 | 0.023 | 0.788 | 1.076 | 0.718 | 157.149 | 0.851 | 0.136 | 1.053 | 0.152 |
| 1998 | 390.135 | 0.088 | 0.024 | 0.799 | 1.160 | 0.706 | 158.897 | 0.979 | 0.162 | 1.215 | 0.184 |
| 1999 | 416.286 | 0.091 | 0.025 | 0.811 | 1.255 | 0.733 | 160.584 | 1.192 | 0.176 | 1.460 | 0.202 |
| 2000 | 473.332 | 0.100 | 0.026 | 0.824 | 1.355 | 0.802 | 162.211 | 1.364 | 0.202 | 1.656 | 0.234 |
| 2001 | 386.785 | 0.089 | 0.027 | 0.820 | 1.465 | 0.793 | 163.816 | 1.358 | 0.255 | 1.673 | 0.305 |
| 2002 | 400.572 | 0.084 | 0.028 | 0.815 | 1.661 | 0.800 | 165.387 | 1.347 | 0.400 | 1.676 | 0.498 |
| 2003 | 471.083 | 0.093 | 0.028 | 0.811 | 1.789 | 0.824 | 166.925 | 1.410 | 0.486 | 1.787 | 0.609 |
| 2004 | 562.592 | 0.108 | 0.030 | 0.814 | 1.891 | 0.858 | 168.445 | 1.424 | 0.582 | 1.780 | 0.746 |
| 2005 | 606.705 | 0.116 | 0.031 | 0.824 | 2.005 | 0.908 | 169.949 | 1.321 | 0.695 | 1.643 | 0.910 |
| 2006 | 673.164 | 0.127 | 0.032 | 0.841 | 2.110 | 0.939 | 171.438 | 1.231 | 0.838 | 1.518 | 1.107 |
| 2007 | 742.738 | 0.139 | 0.034 | 0.855 | 2.173 | 0.955 | 172.920 | 1.195 | 0.960 | 1.487 | 1.271 |
| 2008 | 775.361 | 0.155 | 0.035 | 0.875 | 2.299 | 0.978 | 174.397 | 1.177 | 1.187 | 1.473 | 1.606 |
| 2009 | 649.161 | 0.135 | 0.034 | 0.898 | 2.397 | 0.835 | 175.819 | 1.199 | 1.704 | 1.497 | 2.372 |
| 2010 | 783.568 | 0.163 | 0.035 | 0.911 | 2.488 | 0.879 | 177.198 | 1.267 | 2.193 | 1.550 | 3.122 |
| 2011 | 848.041 | 0.168 | 0.036 | 0.924 | 2.570 | 0.848 | 178.480 | 1.258 | 2.601 | 1.503 | 3.731 |
| Total | 549.931 | 0.112 | 0.029 | 0.833 | 1.734 | 0.823 | 166.620 | 1.176 | 0.749 | 1.452 | 1.013 |

| country | fddva | ICTouti | gdpcapi | nstdi | istdi | infi | popi | patci~di | appal~ci | valpati | valfap.. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AUT | 154.549 | 0.015 | 0.039 | 0.254 | 2.651 | 0.858 | 8.146 | 0.079 | 0.001 | 0.092 | 0.001 |
| BEL | 89.968 | 0.012 | 0.037 | 0.179 | 1.090 | 0.413 | 10.451 | 0.152 | 0.005 | 0.179 | 0.005 |
| BRA | 40.016 | 0.035 | 0.006 | 0.595 | 0.092 | 0.415 | 181.671 | 0.006 | 0.000 | 0.007 | 0.000 |
| CAN | 252.511 | 0.029 | 0.039 | 0.264 | 0.740 | 2.752 | 31.743 | 0.529 | 0.214 | 0.662 | 0.294 |
| CHE | 367.970 | 0.042 | 0.065 | 0.147 | 1.610 | 0.697 | 7.381 | 0.383 | 0.025 | 0.458 | 0.033 |
| CHN | 1548.315 | 0.532 | 0.002 | 0.740 | 1.125 | 0.517 | 1283.347 | 0.576 | 0.618 | 0.698 | 0.741 |
| DEU | 1730.405 | 0.194 | 0.036 | 2.783 | 3.625 | 0.542 | 82.062 | 2.262 | 0.545 | 2.679 | 0.635 |
| DNK | 87.848 | 0.010 | 0.048 | 0.252 | 2.712 | 0.322 | 5.396 | 0.097 | 0.001 | 0.122 | 0.001 |
| ESP | 146.329 | 0.028 | 0.025 | 0.239 | 2.649 | 0.228 | 42.774 | 0.064 | 0.001 | 0.077 | 0.001 |
| FIN | 182.773 | 0.024 | 0.038 | 0.155 | 0.219 | 0.775 | 5.230 | 0.785 | 1.519 | 1.044 | 2.255 |
| FRA | 549.530 | 0.091 | 0.035 | 2.616 | 0.357 | 0.424 | 62.308 | 1.436 | 0.727 | 1.706 | 0.803 |
| GBR | 661.444 | 0.072 | 0.032 | 0.999 | 3.974 | 0.285 | 60.081 | 0.791 | 0.054 | 1.012 | 0.077 |
| IND | 63.407 | 0.028 | 0.001 | . | . | 0.127 | 1106.541 | 0.016 | 0.000 | 0.020 | 0.001 |
| ITA | 420.537 | 0.074 | 0.031 | 0.153 | 0.383 | 0.264 | 57.737 | 0.253 | 0.011 | 0.299 | 0.019 |
| JPN | 2204.987 | 0.495 | 0.046 | 1.565 | 0.883 | 0.218 | 127.226 | 6.910 | 4.100 | 8.729 | 5.263 |
| KOR | 1054.593 | 0.157 | 0.015 | 0.552 | 1.229 | 0.246 | 47.684 | 1.261 | 1.863 | 1.574 | 2.424 |

(*continued on next page*)

**Appendix B** (*continued*)

| country | fddva | ICTouti | gdpcapi | nstdi | istdi | infi | popi | patci~di | appal~ci | valpati | valfap.. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NLD | 113.349 | 0.019 | 0.041 | 0.114 | 5.950 | 0.249 | 16.122 | 1.387 | 0.451 | 1.712 | 0.566 |
| POL | 96.176 | 0.013 | 0.008 | 0.630 | 1.716 | 0.514 | 38.302 | 0.007 | 0.000 | 0.010 | 0.000 |
| RUS | 50.861 | 0.013 | 0.005 | 1.597 | 0.737 | 3.840 | 145.097 | 0.014 | 0.018 | 0.017 | 0.022 |
| SWE | 189.266 | 0.025 | 0.042 | 0.108 | 0.710 | 0.747 | 9.028 | 0.929 | 1.880 | 1.211 | 2.714 |
| USA | 2084.450 | 0.571 | 0.040 | 3.275 | 3.435 | 2.882 | 289.876 | 7.652 | 4.444 | 9.277 | 6.415 |
| ZAF | 9.199 | 0.005 | 0.004 | 0.279 | 0.524 | 0.783 | 47.436 | 0.012 | 0.008 | 0.015 | 0.008 |
| Total | 549.931 | 0.112 | 0.029 | 0.833 | 1.734 | 0.823 | 166.620 | 1.176 | 0.749 | 1.452 | 1.013 |

## References


Acemoglu, D., Gancia, G., & Zilibotti, F. (2012). Competing engines of growth: Innovation and standardization. *Journal of Economic Theory, 147*(2), 570–601. https://doi.org/10.1016/j.jet.2010.09.001

Ahmad, N. (2013). Estimating trade in value-added: Why and how? In D. Elms, & P. Low (Eds.), *Global Value Chains in a Changing World*. Geneva/TFCTN: WTO.

Anderson, J. E. (1979). A theoretical foundation for the gravity equation. *The American Economic Review, 69*(1), 106–116. RePEc:aea:aecrev:v:69:y:1979:i:1:p:106-16.

Anderson, J. E., & van Wincoop, E. (2003). Gravity with gravitas: A solution to the border puzzle. *The American Economic Review, 93*(1), 170–192. https://doi.org/10.1257/000282803321455214

Anderton, B. (1999). Innovation, product quality, variety, and trade performance: An empirical analysis of Germany and the UK. *Oxford Economic Papers, 51*(1), 152–167. https://doi.org/10.1093/oep/51.1.152

Antràs, P., & Helpman, E. (2004). Global sourcing. *Journal of Political Economy, 112*(3), 552–580. https://doi.org/10.1086/383099

De Backer, K., & Miroudot, S. (2014). *Mapping global value chains* (ECB Working Paper No. 1677). Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2436411. https://doi.org/10.1787/5k3v1trgnbr4-en.

Baier, S. L., & Bergstrand, J. H. (2007). Do free trade agreements actually increase members' international trade? *Journal of International Economics, 71*(1), 72–95. RePEc:eee:inecon:v:71:y:2007:i:1:p:72-95.

Bakker, J. (2017). The log-linear relation between patent citations and patent value. *Scientometrics, 110*(2), 879–892. https://doi.org/10.1007/s11192-016-2208-7

Baldwin, Richard (2012). *Global supply chains: Why they emerged, why they matter, and where they are going," CEPR Discussion Papers 9103, C.E.P.R. Discussion Papers. RePEc:cpr:ceprdp:91*.

Baldwin, R., & Robert-Nicoud, F. (2014). Trade-in-goods and trade-in-tasks: An integrating framework. *Journal of International Economics, 92*(1), 51–62. https://doi.org/10.1016/j.jinteco.2013.10.002

Baldwin, R., & Taglioni, D. (2006). *Gravity for dummies and dummies for gravity equations*. Cambridge, MA: National Bureau of Economic Research. https://doi.org/10.3386/w12516

Baron, J., Ménière, Y., & Pohlmann, T. (2014). Standards, consortia, and innovation. *International Journal of Industrial Organization, 36*, 22–35. https://doi.org/10.1016/j.ijindorg.2014.05.004

Baron, J., Pohlmann, T., & Blind, K. (2016). Essential patents and standard dynamics. *Research Policy, 45*(9), 1762–1773. https://doi.org/10.1016/j.respol.2016.05.004

Bekkers, R. N. A., Birkman, L., Canoy, M. S., Bas, P.de, Lemstra, W., Ménière, Y., Gorp, Sainz I., van, N., Voogt, B., Zeldenrust, R., Nomaler, Z. O., Baron, J., Pohlmann, T., Martinelli, A., Smits, J. M., & Verbeek, A. (2014). *Patents and standards : a modern framework for IPR-based standardisation. European Commission*. https://doi.org/10.2769/90861

Bekkers, R. N. A., Catalini, C., Martinelli, A., & Simcoe, T. (2012). Intellectual property disclosure in standards development. In *Paper presented at conference; NBER Conference on Standards, Patents & Innovation; 2012-01- 20; 2012-01-21*.

Bekkers, R., Duysters, G., & Verspagen, B. (2002). Intellectual property rights, strategic technology agreements and market structure: The case of GSM. *Research Policy, 31*(7), 1141–1161. RePEc:eee:respol:v:31:y:2002:i:7:p:1141-1161.

Berger, F., Blind, K., & Thumm, N. (2012). Filing behaviour regarding essential patents in industry standards. *Research Policy, 41*(1), 216–225. https://doi.org/10.1016/j.respol.2011.07.004

Blind, K. (2004). *The Economics Of Standards: Theory, Evidence, Policy, Edward Elgar*.

Blind, K. (2005). *Standards, technical change and IPRs: Lessons from industrialized countries for developing countries*. Retrieved from. United Nations Industrial Development Organization (UNIDO), Industrial Development Report 2005 https://open.unido.org/assets/data/publications/2005.html.

Blind, K., Bekkers, R. N. A., Dietrich, Y., Iversen, E. J., Köhler, F., Müller, B., Pohlmann, T., Smeets, S. J. J., & Verweijen, G. J. H. (2011). *Study on the interplay between standards and intellectual property rights (IPRs)*. Publications Office of the European Union.

Blind, K., Cremers, K., & Mueller, E. (2009). The influence of strategic patenting on companies' patent portfolios. *Research Policy, 38*(2), 428–436. RePEc:eee:respol:v:38:y:2009:i:2:p:428-436.

Blind, K., Gauch, S., & Hawkins, R. (2010). How stakeholders view the impacts of international ICT standards. *Telecommunications Policy, 34*(3), 162–174. RePEc:eee:telpol:v:34:y:2010:i:3:p:162-174.

Blind, K., & Jungmittag, A. (2005). Trade and the impact of innovations and standards: The case of Germany and the UK. *Applied Economics, 37*(12), 1385–1398. https://doi.org/10.1080/13504850500143294

Blind, K., & Jungmittag, A. (2008). The impact of patents and standards on macroeconomic growth: A panel approach covering four countries and 12 sectors. *Journal of Productivity Analysis, 29*(1), 51–60. https://doi.org/10.1007/s11123-007-0060-8

Blind, K., & Mangelsdorf, A. (2013). Alliance formation of SMEs: Empirical evidence from standardization committees. *IEEE Transactions on Engineering Management, 60*(1), 148–156. https://doi.org/10.1109/TEM.2012.2192935

Blind, K., Mangelsdorf, A., Niebel, C., & Ramel, F. (2018). Standards in the global value chains of the European Single Market. *Review of International Political Economy, 25*(1), 28–48. https://doi.org/10.1080/09692290.2017.1402804

Blind, K., Mangelsdorf, A., & Pohlisch, J. (2018). The effects of cooperation in accreditation on international trade: Empirical evidence on ISO 9000 certifications. *International Journal of Production Economics, 198*, 50–59. https://doi.org/10.1016/j.ijpe.2018.01.033

Caviggioli, F., Marco, A. de, Rogo, F., & Scellato, G. (2015). Patenting strategies and characteristics of declared inventions in the long term evolution standard. *R & D Management, 46 S2*, 664–676. https://doi.org/10.1111/radm.12194

CEN (the European Committee for Standardization). (2018). What is a Standard?. Retrieved from https://www.cen.eu/work/ENdev/whatisEN/Pages/default.aspx.

Chen, M. X., & Mattoo, A. (2008). Regionalism in standards: Good or bad for trade? *Canadian Journal of Economics/Revue Canadienne D'économique, 41*(3), 838–863. https://doi.org/10.1111/j.1540-5982.2008.00488.x

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly, 35*(1), 128–152. http://links.jstor.org/sici?sici=0001-8392%28199003%2935%3A1%3C128%3AACANPO%3E2.0.CO%3B2-5.

Contreras, J. L. (2014). Divergent patterns of engagement in Internet standardization: Japan, Korea and China. *Telecommunications Policy, 38*(10), 914–932. https://doi.org/10.1016/j.telpol.2014.09.005

Daniels, P. (1993). Research and development, human capital and trade performance in technology-intensive manufactures: A cross-country analysis. *Research Policy, 22*(3), 207–241. RePEc:eee:respol:v:22:y:1993:i:3:p:207-241.

Dedrick, J., Kraemer, K. L., & Linden, G. (2010). Who profits from innovation in global value chains? A study of the iPod and notebook PCs. *Industrial and Corporate Change, 19*(1), 81–116. RePEc:oup:indcch:v:19:y:2010:i:1:p:81-116.

Deardorff, A. (1998). Determinants of Bilateral Trade: Does Gravity Work in a Neoclassical World?. In *NBER Chapters, in: The Regionalization of the World Economy, pages 7-32, National Bureau of Economic Research, Inc.*. NBER.

EFI. (2018). *Expertenkommission Forschung und Innovation: Gutachten zu Forschung*. Retrieved from. Berlin: Innovation und technologischer Leistungsfähigkeit Deutschlands https://www.e-fi.de/fileadmin/Gutachten_2018/EFI_Gutachten_2018.pdf.

ETSI (European Telecommunications Standards Institute). (2018). Intellectual property rights (IPRs): Essential IPRs in ETSI. Retrieved from http://www.etsi.org/about/how-we-work/intellectual-property-rights-iprs.

Felipe, J., Kumar, U., Usui, N., & Abdon, A. (2013). Why has China succeeded? And why it will continue to do so. *Cambridge Journal of Economics, 37*(4), 791–818. https://doi.org/10.1093/cje/bes058

Filippetti, A., Frenz, M., & Ietto-Gillies, G. (2017). The impact of internationalization on innovation at countries' level: The role of absorptive capacity. *Cambridge Journal of Economics, 41*(2), 413–439. RePEc:oup:cambje:v:41:y:2017:i:2:p:413-439.

Fisch, C., Sandner, P., & Regner, L. (2017). The value of Chinese patents: An empirical investigation of citation lags. *China Economic Review, 45*, 22–34. https://doi.org/10.1016/j.chieco.2017.05.011

Frietsch, R., Neuhäusler, P., Jung, T., & van Looy, B. (2014). Patent indicators for macroeconomic growth—the value of patents estimated by export volume. *Technovation, 34*(9), 546–558. https://doi.org/10.1016/j.technovation.2014.05.007

Frietsch, R., & Schmoch, U. (2009). Transnational patents and international markets. *Scientometrics, 82*(1), 185–200. https://doi.org/10.1007/s11192-009-0082-2

Ganotakis, P., & Love, J. H. (2011). R&D, product innovation, and exporting: Evidence from UK new technology based firms. *Oxford Economic Papers, 63*(2), 279–306. RePEc:oup:oxecpp:v:63:y:2011:i:2:p:279-306.

Gereffi, G., Humphrey, J., & Sturgeon, T. (2005). The governance of global value chains. *Review of International Political Economy, 12*(1), 78–104. https://doi.org/10.1080/09692290500049805

Greenhalgh, C. (1990). Innovation and trade performance in the United Kingdom. *The Economic Journal, 100*(400), 105–118. RePEc:ecj:econjl:v:100:y:1990:i:400:p:105-18.

Greenhalgh, C., Mavrotas, G., & Wilson, R. (2006). Intellectual property, technological advantage and trade performance of UK manufacturing industries. *Applied Economics, 28*(5), 509–519. https://doi.org/10.1080/00036849600000029

Greenhalgh, C., Taylor, P., & Wilson, R. (1994). Innovation and export volumes and prices-a disaggregated study. *Oxford Economic Papers*, 102–135.

Griliches, Z. (1998). Patent statistics as economic Indicators: A survey. *R&D and Productivity: The Econometric Evidence* (pp. 287–343). University of Chicago Press.

Grindley, P. C., & Teece, D. J. (1997). Managing intellectual capital: Licensing and cross-licensing in semiconductors and electronics. *California Management Review, 39*(2), 8–41. https://doi.org/10.2307/41165885

Grossman, G. M., & Rossi-Hansberg, E. (2008). Trading tasks: A simple theory of offshoring. *The American Economic Review, 98*(5), 1978–1997. https://doi.org/10.1257/aer.98.5.1978

Hall, B. H., Jaffe, A., & Trajtenberg, M. (2005). Market value and patent citations. *The RAND Journal of Economics, 36*(1), 16–38. RePEc:rje:randje:v:36:y:2005:1:p:16-38.

Harhoff, D., Scherer, F. M., & Vopel, K. (2003). Citations, family size, opposition and the value of patent rights. *Research Policy, 32*(8), 1343–1363. RePEc:eee:respol:v:32:y:2003:i:8:p:1343-1363.

Hong, J., Zhou, C., & Wang, R. (2020). Influence of local institutional profile on global value chain participation: An emerging market perspective. *Chinese Management Studies, 14*(3), 715–735.

Hussinger, K., & Schwiebacher, F. (2015). The market value of technology disclosures to standard setting organizations. *Industry & Innovation, 22*(4), 321–344. https://doi.org/10.1080/13662716.2015.1049866

Kang, B., Huo, D., & Motohashi, K. (2014). Comparison of Chinese and Korean companies in ICT global standardization: Essential patent analysis. *Telecommunications Policy, 38*(10), 902–913. https://doi.org/10.1016/j.telpol.2014.09.004

Kang, B., & Motohashi, K. (2015). Essential intellectual property rights and inventors' involvement in standardization. *Research Policy, 44*(2), 483–492. https://doi.org/10.1016/j.respol.2014.10.012

Kaplinsky, R., & Morris, M. (2001)*, Vol. 4. A Handbook for Value Chain Research*. IDRC.

Leiponen, A. E. (2008). Competing through cooperation: The organization of standard setting in wireless telecommunications. *Management Science, 54*(11), 1904–1919. https://doi.org/10.1287/mnsc.1080.0912

Lerner, J., & Tirole, J. (2014). A better route to tech standards. *Science, 343*(6174), 972–973. https://doi.org/10.1126/science.1246439

Lerner, J., & Tirole, J. (2015). Standard-essential patents. *Journal of Political Economy, 123*(3), 547–586. https://doi.org/10.1086/680995

Madsen, J. B. (2007). Innovations and manufacturing export performance in the OECD countries. *Oxford Economic Papers, 60*(1), 143–167. RePEc:oup:oxecpp:v:60:y:2008:i:1:p:143-167.

Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica, 71*(6), 1695–1725. https://doi.org/10.1111/1468-0262.00467

Moenius, J. (2004). Information versus product adaptation: The role of standards in trade. *SSRN Electronic Journal* (Advance online publication).

Monreal-Pérez, J., Aragón-Sánchez, A., & Sánchez-Marín, G. (2012). A longitudinal study of the relationship between export activity and innovation in the Spanish firm: The moderating role of productivity. *International Business Review, 21*(5), 862–877.

OECD, & WTO. (2012). *Trade in value-added: Concepts, methodologies and challenges*. Retrieved from. Joint OECD-WTO Note http://www.oecd.org/sti/ind/49894138.pdf.

OECD, & WTO. (2016). Trade in Value added database. Retrieved from http://www.oecd.org/sti/ind/global-value-chains.htm.

OECD, WTO, & UNCTADT. (2013). *Implications of global value chains for trade, investment, development and jobs*. Retrieved from. Prepared for the G-20 Leaders Summit Saint Petersburg (Russian Federation) http://www.oecd.org/trade/G20-Global-Value-Chains-2013.pdf.

Papageorgiadis, N., & Sharma, A. (2016). Intellectual property rights and innovation: A panel analysis. *Economics Letters, 141*, 70–72. https://doi.org/10.1016/j.econlet.2016.01.003

Perinorm. database. Retrieved from https://perinorm.com/search.aspx.

Pohlmann, T., & Blind, K. (2016). Landscaping study on standard essential patents (SEPs). Retrieved from https://www.iplytics.com/wp-content/uploads/2017/04/Pohlmann_IPlytics_2017_EU-report_landscaping-SEPs.pdf.

Pohlmann, T., Neuhäusler, P., & Blind, K. (2016). Standard essential patents to boost financial returns. *R & D Management, 46*(S2), 612–630. https://doi.org/10.1111/radm.12137

Pohlmann, T., Blind, K., & Heß, P. (2020). *Fact finding study on patents declared to the 5G standard*. Report on Behalf of the German Federal Ministry of Economic Affairs and Energy.

Rysman, M., & Simcoe, T. (2008). Patents and the performance of voluntary standard-setting organizations. *Management Science, 54*(11), 1920–1934. https://doi.org/10.1287/mnsc.1080.0919

Shapiro, C. (2000). Navigating the patent thicket: Cross licenses, patent pools, and standard setting. *Innovation Policy and the Economy, 1*, 119–150.

Silva, J. M. C. S., & Tenreyro, S. (2006). The log of gravity. *The Review of Economics and Statistics, 88*(4), 641–658. https://doi.org/10.1162/rest.88.4.641

Swann, G. M. P. (2010). *International Standards and Trade: A Review of the Empirical Literature, OECD Trade Policy Papers 97*. OECD Publishing.

Swann, P., Temple, P., & Shurmer, M. (1996). Standards and trade performance: The UK experience. *The Economic Journal, 106*(438), 1297–1313. RePEc:ecj:econjl:v:106:y:1996:i:438:p:1297-1313.

Sweet, C. M., & Maggio, D. S. E. (2015). Do stronger intellectual property rights increase innovation? *World Development, 66*, 665–677. https://doi.org/10.1016/j.worlddev.2014.08.025

Tinbergen, J. (1962). *Shaping the world economy; Suggestions for an international economic policy*: Twentieth century fund. New York. Retrieved from http://hdl.handle.net/1765/16826.

UNIDO. (2018). Retrieved from. United Nations Industrial Development Organization http://stat.unido.org/.

Verhoeven, D., Bakker, J., & Veugelers, R. (2016). Measuring technological novelty with patent-based indicators. *Research Policy, 45*(3), 707–723. https://doi.org/10.1016/j.respol.2015.11.010

Wakelin, K. (1998a). Innovation and export behaviour at the firm level. *Research Policy, 26*(7–8), 829–841.

Wakelin, K. (1998b). The role of innovation in bilateral OECD trade performance. *Applied Economics, 30*(10), 1335–1346.

Wang, P., Wang, Y., & Hill, J. (2010). *Standardization strategy of China – achievements and challenges. East-West Center Working Papers, Economics Series, No. 107*.

WTO. (2005). *World Trade Report 2005: Exploring the Links Between Trade, Standards and the WTO*. Geneva: WTO. https://www.wto.org/english/res_e/booksp_e/anrep_e/world_trade_report05_e.pdf.