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Intellectual property rights protection and the international transfer of low-carbon technologies through trade and foreign direct investments

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ABSTRACT :

We examine the effect of Intellectual property rights (IPR) protection on the two main channels of international transfer of low-carbon technologies i.e. trade in low-carbon capital goods, and foreign direct investments (FDI) by firms producing low-carbon technologies. Our data describes cross-country transfer through these channels between developing and developed countries in eight climate-related technology fields from 2006 to 2015. At the world level, we find that strengthening IPR protection increases transfer in six technology fields (solar PV, solar thermal, wind power, heating, lighting, and cleaner vehicles), while the effect is statistically insignificant in the others. However, when focusing on non-OECD countries, we find that a stricter IPR does not influence trade in low-carbon capital goods but is a significant determinant of inward FDI for most low-carbon technologies. These results have important implications for climate negotiations on North-South technology transfer.

KEYWORDS :

Climate change; Technology transfer; Intellectual property rights protection; International trade; Foreign direct investment.

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1. Introduction

Wide access to clean technologies is crucial to meet the Paris Agreement goal of limiting the increase in global temperatures to well below 2 degrees Celsius. With 90% of the increase in global carbon emissions until 2050 expected to occur in the developing world (Marchal, Dellink, Vuuren, & Clapp, 2012) while the vast majority of low-carbon technologies are still invented in developed countries, this likely requires considerable international technology transfer, in particular from North to South. As an illustration, Japan, USA, Germany, South Korea, and France together accounted for 75% of the low-carbon inventions patented from 2005 to 2015. [1] Although it is both possible and desirable that developing countries become major innovators in low-carbon technologies, international technology transfer seems a necessary option, at least in the short run, to mitigate carbon emissions using the most cost-effective technologies. [2]

The importance of technology transfer for global climate change mitigation efforts explains why the international diffusion of low-carbon technologies has been a cornerstone of climate negotiations since the adoption of the United Framework Convention on Climate Change (UNFCCC). Cross-country flows of technology have many determinants and are influenced by multiple policies related to scientific capabilities, innovation, trade, investment, environmental regulation, etc. Nonetheless, international negotiations have extensively revolved around the role of Intellectual property rights (IPR) protection. [3] The UNFCCC Technology Executive Committee, which is the policy body where these discussions take place, has so far not delivered any policy recommendations on the design of a climate-friendly IPR regime (de Coninck & Sagar, 2015) and the Paris Agreement does not make any mention of intellectual property rights protection,[4] indicating the lack of consensus on this subject.

International discussions over IPR are contentious (see (Ockwell, Haum, Mallett, Change, & 2010) for an analysis of early discussions and (Glachant & Dechezleprêtre, 2017) for an update). On the one hand, developed countries see a strong IPR regime as a necessary condition for technology transfer. In their view, technology owners would not transfer technologies if they could not appropriate the related benefits. On the other hand, some developing countries (e.g. India) consider that strong IPR protection may hinder technology transfer (Abdel-Latif, 2015); (Glachant & Dechezleprêtre, 2017). The argument is that strong IPR would prevent developing

[1] Authors' calculations based on the PATSTAT database. The concentration of climate mitigation R&D in a handful of countries is well established (see e.g. Dechezleprêtre et al., 2011). Figure 3 further illustrates the concentration of low-carbon inventions in OECD countries with more recent data.

[2] The vast majority of current technology transfers come from and are directed towards developed countries. OECD countries account for 75% of the imports and 62% of the exports in low-carbon capital goods. Similarly, 86% of the low-carbon FDI deals come from OECD countries and 75% are directed towards OECD countries. Authors' calculation based on the data described in Section 4.

[3] The other main subject has been the financing of technology transfer. To a lesser extent, other policy rules have also been discussed, such as tariffs and non-tariff barriers to trade and to FDI, climate regulation stringency and technological capacity buildings. Outside of the UNFCCC framework, since 2014, 17 WTO members have been negotiating an Environmental Goods Agreement (EGA) that aims to remove or drastically reduce tariff barriers applied to environmental goods and the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS).

[4] During preparations for the Paris COP-21, some countries made suggestions, such as making specific technologies available at concessional terms to developing countries. Other proposals were made in the July 2015 Ad hoc Working Group on the Durban Platform for Enhanced Action (ADP) draft negotiation text.

countries from accessing green technologies at an affordable price since monopoly rights associated with IPR provide innovators with important market power. This debate echoes the theoretical analysis by (Maskus K. E., 2000) who identifies two countervailing effects of strong IPR protection: a positive market expansion effect because stronger IPR create a market for foreign firms whose intellectual assets are secured; and a negative market power effect because stronger IPR leads to higher prices. Given these two opposing effects, the net impact of stronger IPR protection is an empirical question.

Against this background, the main objective of this paper is to inform the policy debate with empirical evidence on the effect of IPR on the international transfer of low-carbon technologies. Broadly speaking, technology transfer is a process involving the building of technological capabilities leading to sustainable forms of economic development (Ockwell et al., 2008; 2018).

In practice, low-carbon technology transfer takes place through various market and non-market channels which convey codified knowledge, technology-intensive goods, but also soft skills, know-how, and tacit knowledge. In this paper, we consider two of these channels: international trade in capital goods that are used to reduce emissions (e.g. wind turbines, energy efficient furnaces, electric vehicles), and foreign direct investment (FDI) by multinational enterprises that own low-carbon technologies (Glachant and Dechezleprêtre, 2017). These flows obviously do not provide a holistic picture of international technology transfer. However, it has been shown that they lead to significant productivity gains and innovation diffusion in the recipient economies (Xu, 2000; Branstetter et al., 2001, 2006; Görg and Strobl, 2005; Griffith et al., 2006; Haskel et al., 2007; Blalock and Gertler, 2008; Keller and Yeaple, 2013). Note also that both convey codified (i.e. patentable) knowledge, but also soft skills and know-how that are key ingredient for developing countries to access effective climate mitigation technologies.

We use a newly assembled dataset covering international trade in low-carbon capital goods and foreign direct investment in eight low-carbon technologies across up to 140 countries in the period 2006-2015 to analyze the impact of IPR protection in recipient countries on low-carbon technology transfer. The level of IPR protection is measured by an index developed by the Word Economic Forum that is available yearly and covers all kinds of IP instruments.

In addition, we examine how the impact of IPR varies between OECD and non-OECD countries and how the absorptive capacities of the recipient country influence the effect of IPR on technology transfer.[5] In the economic literature, these capacities are defined as the ability of the recipient country to successfully absorb foreign technologies and they include various factors such as the availability of skilled technical personnel and information on available technologies (Fagerberg, 1994; Keller, 1996; Worrell et al., 1997; Griffith et al., 2004; Kneller and Stevens, 2006). Weak capacities are predicted to decrease the market expansion effect of strong IPR, the intuition being that if domestic firms have weak technical capabilities, they will not be able to imitate the technologies, even if IPR protection is weak (Maskus and Penubarti, 1995). In our context, this theoretical assumption may have crucial policy implications. If valid, it implies that developing countries, which typically have weaker absorptive capacities, would benefit less from strengthening IPR. We use our data to directly test this prediction.

We adopt a fixed-effects panel data approach where we exploit annual variations in technology-specific trade or FDI flows within a given country pair to identify how the level of IPR protection in the recipient country affects technology transfer. Data on cross-country trade flows are

[5] As pointed out by Forero-Pineda (2006), some studies fail to account for the differences between developed and developing countries.

extracted from the CEPII's international trade BACI database. The database provides information on annual product-level shipments from exporters to importers at the 6-digit level of the harmonized system nomenclature. We exploit this high level of detail to precisely identify traded equipment corresponding to eight low-carbon technologies, i.e. hydroelectricity, solar PV, solar thermal, wind power, energy-efficient heating, insulation, energy-efficient lighting, and cleaner vehicles. We cover yearly trade flows from 2006 to 2015 between up to 140 countries accounting for 88% of global trade in low-carbon goods.[6] Importantly, the data set includes both industrialized countries and emerging economies such as India and China.

To measure FDI flows in low-carbon technologies, we rely on firm-level data on investment deals from Bureau Van Dijk's Zephyr database. The main challenge is that the data do not indicate whether a particular deal entails a transfer of low-carbon technologies. We only know the investing firm, the target firm, and their industry. We implement a two-stage procedure to identify deals that are likely to involve low-carbon technology transfers. In the first step, we match our FDI data with the World Patent Statistical Database (PATSTAT), a database which includes the vast majority of patents filed in the world over recent decades. A useful characteristic of PATSTAT is its very detailed patent classification system, which allows us to identify patents protecting low-carbon technologies. We then identify FDI deals in which the investing firm owns at least one low-carbon patent. In the second step, we exclude deals where the target firm belongs to an industry that is unambiguously unrelated to the low-carbon technology considered.[7] Ultimately, we obtain data on the 8 technologies covered by the trade data and up to 71 countries observed yearly between 2006 and 2015.[8]

We find that strengthening IPR protection has a statistically significant positive effect on the transfer of most of the low-carbon technologies covered in this study through either trade or FDI. The only exceptions are hydro power and insulation in which a higher level of IPR has no significant influence. Importantly, we find that the magnitude of the impact of IPR is larger for low-carbon technologies than for the average technology. A possible interpretation is a tougher cross-technology competition than in other fields (i.e. pharmaceuticals). These technologies are also probably more modular -- a new product is composed of numerous separately patentable elements -- than the average technology. Both tough competition and high modularity reduce the market power of individual patent owners, preventing them from raising prices, making it possible for the market expansion effect of stricter IPR to more than compensate the negative market power effect.

This general result does not distinguish between developed and developing countries. Yet, the key policy question is how to transfer more low-carbon technologies to developing countries. Therefore, we estimate additional models which yield specific results for this country group (which we identify by lower technological capabilities). We find a positive effect of IPR protection on FDI in 6 out of 8 technology fields: hydro power, solar PV, solar thermal, heating, lighting, and cleaner vehicles. In contrast, IPR protection has no significant effect on trade

[6] We measure the ratio between the sum of trade flows for the countries in our estimation sample and the sum of trade flows for all countries over the 2006-2015 period. This is possible because the BACI database cover the trade flows of all countries.

[7] For instance, if the investing firm owns a patent related to solar PV, we exclude target firms operating in industries such as "Manufacture of perfumes and toilet preparations" or "Manufacture of bodies for motor vehicles" but retain target firms operating in the energy production sector.

[8] More precisely, the estimation sample differs for each technology and contains up to 71 recipient countries. These pairs of countries account for 94% of the deals reported in the entire Zephyr database.

towards developing countries. This difference between the two channels can be considered positive as FDI conveys more knowledge than trade.

To get a sense of the magnitude of these effects, we perform simulations based on our model of FDI flows. They show that if large emitters like India, Brazil, and Indonesia were to converge to the global mean level of IPR protection (which roughly corresponds to the level of IPR protection in China in 2015), low-carbon FDI deals would grow by at least 4% in India, by 20% in Indonesia and by 28% in Brazil. In short, if those large emitters converged to the Chinese level of IPR protection, this could make a significant difference in terms of international transfer of climate change mitigation technology.

Our paper primarily contributes to the literature on the relationship between IPR protection and low-carbon technology transfer. Most of this literature provides anecdotal evidence and descriptive statistics (e.g. Barton, 2007; Kirkegaard et al., 2009; Ockwell et al., 2008; Glachant et al. 2013). The paper by Barton (2007) includes case studies on photovoltaics (PV), biomass and wind energy in Brazil, China, and India. It concludes that IP barriers are insignificant to developing nations' access to these technologies. Kirkegaard et al. (2009) give stylized facts which show that IP accounts for a very small part of the cost in the wind industry, and that wind technology is widely available for licensing. Ockwell et al (2008) stresses the fact that IPR alone may not be sufficient to facilitate transfers that require also absorptive capacities in recipient countries. Glachant et al. (2013) stress the one-size-fits-all approach of the patent system and discuss the potential of various solutions put forward to introduce flexibility in patent law for low-carbon technologies. We build on these qualitative pieces of evidence by conducting a quantitative analysis which allows us to control for confounding factors when evaluating the effect of IPR on the transfer of low-carbon technologies and to compare the different low-carbon technologies in a more systematic way.

To the best of our knowledge, Dechezleprêtre et al. (2013) have carried out the only econometric study estimating the impact of IPR (and of other policies) on the international diffusion of low-carbon technologies. They use the count of patents filed by non-residents as a measure of technology transfer. Unsurprisingly, they find that tightening IP regimes promotes foreign patenting. However, this result is difficult to interpret as it can simply reflect that a stronger IPR protection leads inventors to switch from secrecy to patent protection, leaving the total amount of technology transferred unchanged (Cohen et al., 2000). Our data on trade and investment flows do not suffer from this potential substitution between patented and unpatented technology as these two channels convey both patented and non-patented knowledge.

Our paper also relates more generally to the well-developed empirical literature on the role of IPR in international technology transfer. A first contribution is our focus on climate-related technologies. As argued by many authors, the trade-off between market expansion and market power put forward by Maskus (2000) is fundamentally determined by industry- , country-, and technology-specific variables such as the pre-existing nature and degree of competition, market size, technological maturity, imitability, technological capabilities, etc. We provide evidence in Section 2 that low-carbon sectors present some clear specificities. It is therefore risky to feed the climate policy debate with studies covering the entire manufacturing sector (Bosworth, 1980; Ferrantino, 1993; Maskus and Penubarti, 1995; Maskus, 1998b, Braga and Fink, 1998, 1999; Smith, 1999, 2001; Co, 2004; Nunnenkamp and Spatz, 2004; Delgado, Kyle, and McGahan, 2013, Maskus and Yang, 2018) or other technology fields (e.g. Ivus, 2010; Boring, 2015; and Campi and Dueñas, 2016). In addition, almost all of these studies do not yield specific results for developing countries.

A second contribution to the general literature on the relationship between IPR and technology transfer is to consider both trade and FDI as channels for technology transfer. This allows us to derive insights on the impact of IPR in countries with low technological capabilities. In particular, we show that tightening IPR protection increases FDI flows, but not trade flows. Our interpretation is that FDI bring to the recipient country the knowledge and soft skills that are necessary to produce the goods in which the technology is embedded. In this way, FDI increase local technological capabilities, reinforcing the need of strict IP rights to deter imitation. In contrast, trade does not increase technological capabilities, at least in the short run. This does not preclude imitation: imported goods may be imitated through reverse engineering, but imitation needs to rely on pre-existing imitation capacities. We are aware of only one study which also looks simultaneously at both channels: A cross-sectional study with gravity models of US firms relying on data from 1984 (Smith, 2001). This paper finds no impact on trade, a significant impact on FDI (like us), but the effect is stronger for high-capacity countries. However, cross-sectional gravity models suffer from serious omitted variable biases (in particular, for trade costs).

From a methodological point of view, our paper builds on recent advances in the gravity literature. We estimate technology-specific gravity models with country-pair fixed effects, which control for many unobserved determinants of trade and for technological specificities. On this methodological ground, the present study only compares to the most recent works by Boring (2015) and Campi and Dueñas (2016) which focus on specific sectors of the economy and Awokuse and Yin (2010) who provides estimates for several sectors.[9]

The paper is organized as follows. Section 2 presents the conceptual framework on property rights and the international transfer of technologies. In Section 3, we explain our empirical strategy. We provide the data sources and descriptive statistics in Section 4. Econometric results are described in Section 5. We conclude in Section 6.

2. Conceptual framework[10]

The channels of international technology transfer

The diversity of channels through which knowledge crosses borders makes technology transfer inherently difficult to measure. In some cases, transfer is mediated by markets. It may also occur outside the market through knowledge spillovers. In the present study, we focus on two market channels: trade in capital goods and FDI.

Importing capital goods, such as machines and equipment, entails technology transfer because they embody technologies. Purchasing and using these goods enable the buyer to reap the benefit provided by the technology (Keller, 2004). International trade induces limited cross-border transfer of knowledge as such, because the specific knowledge to reproduce these goods remains in the originating country (see Table 1). Nonetheless, there is evidence that trade subsequently generates knowledge spillovers within the recipient economy through reverse engineering and business relationships (Rivera-Batiz and Romer, 1991). Exporters also usually

[9] Awokuse and Yin (2010) estimate a gravity model using the instrumental variables estimator proposed by Hausman and Taylor (1981). The estimator relies on a strong identification assumption that the regressors used as instrumental variables are uncorrelated with unobserved heterogeneity.

[10] This section draws heavily on Glachant et al. (2013) and Ménière et al. (2017). See also Keller (2004) for a review on international technology diffusion.

offer a bundle which includes the capital good together with engineering services to install the device (Vandermerwe and Rada, 1988). Trade in pollution control equipment has long been used in the literature to analyze technology transfer of environmental technologies (see e.g. Lanjouw and Mody, 1996).

Foreign direct investments are another channel as multinational enterprises typically give their foreign affiliates or partners in joint ventures access to their technology. FDI convey more information than trade since the transfer covers not only the technology embedded in the goods or services that are locally produced by the subsidiary, but also the technology needed for this production. This means that, in contrast with the transfer of hard knowledge through trade, FDI improve the local capacities to imitate the technology, which is not without consequence for IPR. We will come back to this issue later on. Accordingly, FDI generates a larger amount of spillovers, especially via the domestic circulation of skilled labor. There is strong empirical evidence that FDI causes the diffusion of technology and productivity growth in recipient countries (Xu, 2000; Branstetter et al., 2001, 2006; Görg and Strobl, 2005; Griffith et al., 2006; Haskel et al., 2007; Blalock and Gertler, 2008; Keller and Yeaple, 2013).

Table 1: Characteristics of international technology transfer market channels

Transfer channel	Knowledge location	Spillover mechanisms in the recipient country	Knowledge intensity and imitation threat
Export of intermediate goods	Source country	Reverse engineering Business relationships	+
Foreign direct investment	Recipient country	Reverse engineering Business relationships Labor circulation	++

Source: Adapted from Glachant et al. (2013)

Although trade and FDI are viewed as the major market channels (Keller, 2004), technologies also cross borders via licensing, when corporations or public research bodies grant a patent license to a company abroad that uses it to upgrade its own production. The lack of disaggregated data prevents covering this aspect in the study. This is not so restrictive. In practice, licensing mostly concerns three sectors – chemicals, drugs, and electronics and electrical equipment (Anand and Khanna, 2000) – which do not contribute much to carbon emissions abatement.[11] Moreover, evidence shows that technology transfers via licensing are of a much smaller magnitude than trade and foreign direct investment. Flows (sum of revenue and expenditure) of "technology balance of payments" for the period 2010-2014 represented about 0.4% of global GDP, against 2.6% and 23.7% respectively for FDI and exports of goods and services (World Bank Indicators, 2016).[12]

We also do not consider international labor circulation between firms as data on international movement of skilled workers do not exist at the technology level. However, this movement frequently goes along with trade and FDI, bringing tacit knowledge which is necessary to exploit

[11] Chemicals and electronics are significant contributors to GHG emissions. However, they do not contribute significantly to GHG abatement using the technologies we cover in our study.

[12] Source: http://data.worldbank.org/. However, this indicator should be considered as an upper bound of the magnitude of technology licensing. Indeed, it also includes items that are not related to technology, such as royalties on trademarks or copyrights. Moreover, part of the patent royalties reflects intra-group transfers between entities of the same corporations in different countries: they are likely to proceed from tax optimization strategies rather than actual technology transfers.

the imported technology. In this way, it can be argued that our two indicators partly capture skilled labor flows.

Lastly, we do not deal with transfers that take place outside the market. Cross-country knowledge spillovers could arise for example if a researcher examines a patent published in a foreign country or visits foreign research centers. We however indirectly account for such technology flows as non-market transfers tend to be positively correlated with market transfers. Cross-border spillovers are typically measured by patent citations, and Branstetter (2006) finds that the citation of US patents increases with the number of US affiliates in foreign countries. Madsen (2007) finds that foreign knowledge stocks weighted by import value have a positive effect on domestic patent applications.

The ambiguous impact of intellectual property rights protection on international technology diffusion

Before discussing the effect of IPR on technology transfer, it is worth recalling some basic properties of intellectual property. Its primary function is to provide greater innovation incentives as knowledge has public good features: other economic agents may imitate the new technology, or at least learn from it, thereby appropriating a share of the innovation benefits. Trade secrecy is the most natural strategy for innovators to prevent imitation, and the most widely used in practice (Cohen et al., 2000). It is however not perfect. As mentioned previously, imitators can rely on reverse engineering; skilled workers can circulate between firms, taking their knowledge with them, etc. The cost of maintaining trade secrets can also be high.

Granting intellectual property rights protection provides a policy solution to partly internalize these knowledge externalities. Patent is the most-well known instrument to do so. It ensures the exclusivity of the commercial use of the invention for a determined period of time (typically 20 years). Trademarks are also common IP instruments, including for protecting low-carbon technologies. For instance, Vestas, a global leader in wind power, commercializes V136-3.45 MW® wind turbine and many other trademark registered products. Canadian Solar has registered Canadian Solar as a trademark for the solar panels and cells it sells. Isofoton, a Spanish leader in PV and thermal solar energy technologies, holds six trademark registrations with the Spanish Patent and Trademark Office (SPTO) and one registration with the Trademarks and Designs Registration Office of the European Union (OHIM) for its name and logo according to the World Intellectual Property Organization. A trademark allows to exclusively identify the firm at the origin of a product or service. It protects the owner of the trademark from competitors selling products that are confusingly similar to the products registered under the trademark. In practice, patent and trademarks are complement. Patents protect product designs that are functional while trademarks protect ornamental designs.

Strengthening IPR protection has complex impacts on cross-country knowledge flows. On the one hand, the role of IPR – patents or trademarks – in easing the commercialization of new technologies can be especially strong in foreign markets, thereby promoting international technology diffusion. Appropriation is indeed more difficult abroad due to differences in legal systems and other factors. Foreign suppliers of technologies incur additional costs to monitor how partner firms and licensees use their technology (Keller and Yeaple, 2013). Contractual problems are also likely to be greater if the supplier and buyer of the technology operate in different countries. For instance, Antras and Rossi-Hansberg (2009) suggest that weak contract enforcement lowers the amount of technology transfer through outsourcing. Maskus and Penurbati (1995) refer to this positive role of IPR protection on technology transfer as the market-expansion effect. On the other hand, they also identify a market-power effect that goes in the opposite direction: IPR protection provide innovators with market power, giving the possibility to raise price barriers and reduce the market share of local imitators, thereby limiting technology diffusion.

To sum up, strong IPR protection increases the propensity to introduce a technology in a country but, if introduced, it gives latitude to technology owners to reduce market size by raising price barriers and reducing the market share of local imitators. This trade-off between market expansion and market power implies that, on theoretical grounds, the net impact on technology transfer of stronger IPR is ambiguous (Maskus, 2000). In addition, its size (and sign) is likely to vary across technologies, industries, and countries because it is determined by the degree and nature of competition, the market size, and domestic technological capabilities (Mansfield, 1986; Orsenigo and Sterzi, 2010).

Trade, FDI, and technological capabilities

The net impact of strong IPR on technology transfer is also likely to vary between trade and FDI. In this respect, the level of technological capabilities of recipient countries plays an important role.

This notion of technological capabilities deserves a thorough discussion as the climate negotiations on low-carbon technology transfer put a particular emphasis on developing countries which have capabilities to absorb and adopt knowledge and technology that tend to be lower than those of more advanced economies (Lall, 1992).

The ability to recognize, assimilate and apply new knowledge depends on factors such as the availability of researchers and engineers, a high number of past innovations, and high private and public R&D expenditures (Fagerberg, 1994; Keller, 1996; Worrell et al., 1997; Griffith et al., 2004; Kneller and Stevens, 2006). If a country has low absorptive capacities, domestic firms are less able to imitate an imported technology. In this context, IPR are less useful in securing innovation returns, and thus in providing technology owners with incentives to transfer. This weakens the market-expansion effect of IPR protection. This also reduces the market-power effect as technology owners have latitude to raise their price even when IPR protection is weak. In the end, how absorptive capacities influence the effectiveness of IPR protection deserves an empirical analysis. We will estimate below flexible models which account for this potential interaction between IPR and technological capabilities. Maskus and Penubarti (1995) arguably find some empirical evidence that the effect of IPR is lower in developing economies than in industrialized countries, but they do not deal with the specific case of low-carbon technologies.

Importantly for our analysis, there might be different results for trade and FDI. As previously explained, FDI bring to the recipient country the knowledge and soft skills that are necessary to produce the goods in which the technology is embedded. In this way, FDI increase local technological capabilities, reinforcing the need of strict IP rights to deter imitation. In contrast, trade does not increase technological capabilities, at least in the short run. This does not preclude imitation: imported goods may be imitated through reverse engineering, but imitation needs to rely on pre-existing imitation capacities. This argument indicates that, in low-capacity countries, the level of IPR protection may have less influence on the imports of capital goods than on inward FDI. We test this hypothesis in Section 0.

The specificities of low-carbon technologies regarding IPR

Although the empirical analysis is precisely aimed at providing results on low-carbon technologies, it is worth examining a few theoretical arguments that could suggest how IPR protection specifically influences the transfer of these technologies.

Several characteristics suggest that strengthening IPR is less likely to reduce technological diffusion of low-carbon technologies compared to the average technology. In his study on renewable energy technologies, Barton (2007) points out that the competition between alternative low-carbon innovations is probably tougher than in other sectors, thereby reducing the market power effect of IPR. He takes the example of the pharmaceutical industry where an individual patent may have a very substantial effect because a specific drug may not have any substitutes whereas renewable energy firms patent specific improvements or features. Therefore, there is competition not only between the sectors and alternate sources of fuel or electricity but also between firms producing different (patented or non-patented) products within a technology.

The solar photovoltaic industry provides an interesting illustration on the importance of competition. Chinese players now dominate solar PV cell and module markets (Wu & Mathews, 2012; Zhang et al., 2014) while, in the mid 2000's, the value chain for solar PV technologies was concentrated in the US, Germany and Japan with western companies holding the IPR. The necessary technology transfer was mostly achieved through the purchase by Chinese new entrants of turnkey fabrication lines; IPRs did not impede this transition because the global production equipment market was competitive (Zhang & Gallagher, 2016). Note that the exit of western players -- which were the major innovators -- led to a drastic fall of the level of patented innovation, which did not prevent an 85% price drop since 2009 (see Carvalho et al. 2017).

The distinction between discrete and complex technologies emphasized by Orsenigo and Sterzi (2010) -- whether a new product is composed of numerous separately patentable elements or few -- also provides support for a specific analysis of low-carbon technologies. For Orsenigo and Sterzi (2010), the market power effect of IPR is lower with complex technologies like electronics, software and semiconductors since protection usually requires the granting of many patents which makes it harder to appropriate the revenue. The present study deals with eight low-carbon technologies -- hydro power, solar PV, solar thermal, wind power, heating, insulation, lighting, and cleaner vehicles – which are arguably complex and described in Section 4.

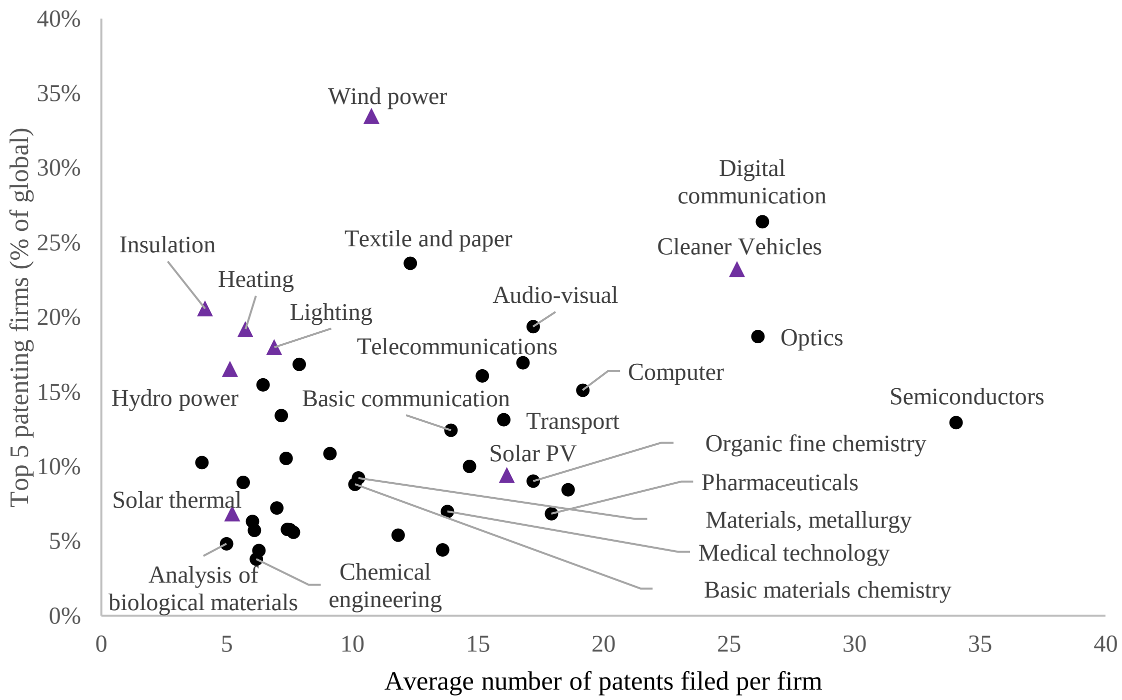
Not only is the role of patent likely to differ between low-carbon technologies and other technologies, but patent laws are likely applied differently across industries. Burk and Lemley (2003) argue that although patent law is technology-neutral in theory, it is technology-specific in application. This is because patent law gives the courts substantial freedom to adapt the patent statute to evolving technologies by the means of flexible legal standards called policy levers. Therefore, it is necessary to perform our analysis for each technology separately.

Figure 1 illustrates the difference between low-carbon and a variety of other technologies on two technology dimensions related to IPR. The first dimension on the x-axis is the intensity in patenting measured by the average number of patents filed by firms in the technology.[13] This intensity is increasing in the technology market size, complexity, and in codifiability. In theory, the role of IPR protection is more important for technologies that are patent intensive. The second dimension on the y-axis is the share of patents owned by the top 5 patenting firms worldwide. This indicator reflects the concentration of knowledge in each technology. The role of IPR protection may be more important for the diffusion of technologies that are invented by only few firms.

[13] The patent data described in detail in Section 0.

Figure 1 conveys three main messages. First, there is high heterogeneity between technologies in terms of patent intensity and concentration.[14] Second, low-carbon technologies are different from other technologies and are generally less patent intensive and more concentrated with the exception of solar PV and cleaner vehicles. Third, low-carbon technologies differ significantly from each other. These degrees of heterogeneity justify our methodological choice of estimating technology-specific equations.[15] More generally, it also justifies a specific study of low-carbon technologies, as the results obtained in different sectors are not transferable. For similar reasons, the net impact of IPR protection has no reason to be identical across different transfer channels.

Figure 1: Patent intensity and concentration by technology



Note: author calculation based on Patstat data of 2006-2015

3. Empirical Strategy

The conceptual framework has two main implications for the empirical analysis. First, because low-carbon technologies are highly heterogeneous, we have to perform regressions at the level of each technology. Second, we need to empirically investigate the interactions between the

[14] The high concentration in wind power is not surprising. According to Bloomberg New Energy Finance, 53% of the onshore wind turbines were deployed by 4 manufacturers in 2017: Denmark's Vestas, Spain's Siemens Gamesa, China's Goldwind and General Electric of the U.S. Our findings are consistent with previous classifications of technologies such as Delgado et al. (2013)'s categorization of patent intensity based on ESA-USPTO Report (U.S. Department of Commerce, 2012) as well as the categorization of IP intensity based on US Cluster Mapping Project (USCMP), the International Cluster Competitiveness Project (ICCP); and ESA-USPTO Report.

[15] Other factors can lead to heterogeneity in the effect of IPR such as the tradability of the technology.

level of IPR protection and the size of technological capabilities in order to derive insights on the specific impacts of IPR protection on developing countries.

To estimate the world-average effect of IPR protection on bilateral trade in low-carbon goods and FDI in a given low-carbon technology, we use the following gravity models:

$$TRADE_{ijkt} = \exp\left(\alpha_{0k} + \alpha_{1k} IPR_{jt-1} + \alpha_{2k} X_{ijt-1} + \delta_{ijk} + \gamma_{kt} + v_{ijkt}\right) \quad (1)$$

$$FDI_{ijkt} = \exp\left(\beta_{0k} + \beta_{1k} IPR_{jt-1} + \beta_{2k} X_{ijt-1} + \rho_{kt} + u_{ijkt}\right) \quad (2)$$

where $TRADE_{ijkt}$ denotes the shipment value of low-carbon goods embedding technology *k* exported from country *i* to country *j* during year *t* and FDI_{ijkt} the number of FDI deals in low-carbon technology *k* made between parent companies located in country *i* and target companies located in country *j* in year *t*. IPR_{jt} is the index of Intellectual property rights protection in the importing country *j*, which we describe in detail below.

Following Anderson and van Wincoop (2003), we exploit the panel structure of our dataset by using a fixed-effects estimator for our trade model. This allows us to control for any time-invariant characteristics denoted by δ_{ijk} that could be correlated with both IPR_{jt} and our dependent variables. δ_{ijk} includes all time-invariant country-pair characteristics typically used in gravity models, i.e. distance between the two countries, contiguity, common language, colonial ties, etc. as well as importer characteristics such as type of institutions, type of regulations, industrial structure of the economy, development level, etc. In addition, we include a comprehensive set of year dummies to account for shocks common across all countries. As a result, we rely on annual variations in technology-specific technology flows within a given country pair for identification.

In contrast to the trade data, the structure of the FDI data does not allow the use of country-pair fixed effects. The prevalence of zeros leads to the exclusion of more than 90% of the country-pairs when estimating the model with country-pair fixed effects.[16] As deals are mostly concentrated in OECD countries, we would exclude almost all non-OECD countries from the analysis. We do not want to do that as the primary goal of this paper is to test whether IPR influences investment in low-carbon technologies towards developing countries. Therefore, we replace the country-pair fixed effects by the traditional gravity control variables: logged distance between countries, contiguity, common language, and former colonial relationship.

To account for factors that vary over time and could be correlated with both IPR_{jt} and the dependent variable, we include a set of time-varying control variables in X. Some controls are common to the trade model and the FDI model. First, we control for the size and income of the exporting/investing country and the recipient country using GDP and GDP per capita, which is standard in gravity equations.

Second, we control for the recipient country's absorptive capacities, since this can influence the transfer of technologies and is likely correlated with IPR protection. These capacities are measured by enrolment in tertiary education as in Roper & Love (2006) and Castellacci & Natera (2013). Other proxies could be used such as the share of GDP allocated to R&D or the share of

[16] A country-pair is excluded in the estimation if it contains 0 for each year of observation.

researchers in the population. In contrast with these two indicators, enrollment in tertiary education is available for almost all countries, which limits sample selection bias.

Third, we include the level of IPR protection of the exporting/investing country because exporting/investing firms may react differently to recipient countries' IPR protection depending on the IPR protection in their country of origin. Fourth, we control for the stringency of environmental regulations in both exporting and importing countries because it is a determinant of country-level supply and demand in low-carbon technologies. Finally, we control for whether the two countries have a free trade agreement in place or whether they belong to the same custom union in year t.

We also use control variables that are specific to each model. In the trade model, we control for the importer's effectively applied tariff rate and the number of non-tariff measures for the low-carbon technology considered.[17] Controlling for non-tariff measures is particularly important since many countries apply Local Content Requirements (LCRs) in the renewable sector (Kuntze and Moerenhout, 2013).[18] LCRs are policy instruments that require foreign or domestic investors to source a certain share of intermediate goods from domestic manufacturers. Other things equal, LCRs have a negative impact on imports and might be correlated with IPR protection. In our FDI model, we include traditional determinants of inward FDI, which include the flexibility of business and labor regulations and the intensity of border regulations on the movement of capital and people. Table 16 in the Appendix provides the definition and the source of all variables.

We lag all regressors by one year for two reasons. First, we expect that changes in IPR protection do not affect technology transfer instantly but after a necessary time for foreign suppliers and investors to react. Second, lagging the regressors mitigates endogeneity since IPR_{jt-1} should be less correlated with v_{ijt} and u_{ijt} than IPR_{jt} and that some of the contemporary controls such as GDP contains the dependent variables.

In order to examine the specific impact of IPR protection on developing countries and the role of technological capabilities, we augment model (1) and (2) by introducing an interaction term between the recipient country's IPR protection and a dummy variable D_j as follows:

$$TRADE_{ijkt} = \exp\left(\alpha_{0k} + \alpha_{1k} IPR_{jt-1} + \alpha_{2\mathrm{k}}\left(IPR_{jt-1} \times D_j\right) + \alpha_{3k} X_{ijt-1} + \delta_{ijk} + \gamma_{kt} + u_{ijkt}\right) \qquad (3)$$

$$FDI_{ijkt} = \exp\left(\beta_{0k} + \beta_{1k} IPR_{jt-1} + \beta_{2\mathrm{k}}\left(IPR_{jt-1} \times D_j\right) + \beta_{2k} X_{ijt-1} + \rho_{kt} + u_{ijkt}\right) \qquad (4)$$

where D_{jk} denotes either strong absorptive capacities in country j, or OECD membership. As explained before, we expect the effectiveness of IPR to increase with recipient countries' imitation capacities.

Following Silva and Tenreyro (2006), models (1), (2), (3), and (4) are estimated by the Pseudo Poisson Maximum Likelihood (PPML) estimator for two reasons. First, the PPML estimator is less biased than the log-log OLS estimator under different assumptions regarding the data-generating process of the error term. Second, PPML, unlike OLS, accounts for outcomes equal

[17] We use effectively applied tariff rates, which consider the existence of bilateral trade agreements, as opposed to most favoured nation tariff rates, which are the maximum tariff rate applied by one WTO member to another WTO member.

[18] Developed and developing countries and regions have introduced LCRs: Ontario, Quebec, Italy, France, Greece, Croatia, USA, India, China, Brazil, South Africa, Turkey, etc. (see Kuntze and Moerenhout, 2013).

to zero, which is a natural result of the Poisson distribution. These observations are dropped when a log-log transformation of model (1)-(4) is applied.

4. Data

Bilateral trade in low-carbon goods

We use shipment value between countries as a measure of technology transfer. Trade data come from the BACI database developed by the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII), which reports bilateral trade between countries at a highly disaggregated product level. BACI is based on the United Nations COMTRADE database. BACI's major advantage over the original COMTRADE is its ability to provide harmonised and more reliable bilateral trade data by matching declarations between exporting and importing countries (Gaulier and Zignago, 2010). We use the description provided by the 6-digit level of the harmonised system classification of products in BACI to identify equipment goods that incorporate technologies mitigating greenhouse gas emissions.[19]

We cover eight low-carbon technology classes across different sectors of the economy.

Table 2 lists these technology classes. In the power generation sector, we cover hydro power, solar PV, solar thermal, and wind power. In the residential sector, the dataset includes various energy efficiency technologies, such as heating, insulation, and lighting. In the transportation sector, we cover electric and hybrid vehicles, hereafter referred to as cleaner vehicles. Appendix 8.1 includes a detailed description of these technologies (see Table 13) as well as their harmonized system codes and their description (see Table 14).

Although the dataset is representative of a variety of technologies and sectors, it is by no means comprehensive. For example, we cannot cover carbon mitigation technologies used in agriculture or forestry (e.g. soil restoration, reforestation, grassland management) because their transfer is not associated with trade in equipment goods. Process-integrated energy-saving technologies used in the manufacturing sector are also missing. These technologies are probably embedded in equipment goods, but the product classification is not detailed enough to identify them in BACI data. For instance, the code 841780 corresponds to "industrial/laboratory furnaces & ovens" but no difference is made between energy-efficient and inefficient ovens.

Lastly, due to missing data on some of our control variables, our final sample covers trade data for 140 countries between 2006 and 2015. This accounts for around 88% of global trade in the selected technologies. The list of countries is available in Table 11 of Appendix 8.1.

Figure 5 of Appendix 8.2 shows the evolution of global trade in low-carbon technologies. It is dominated by Solar PV that reached 60 billion USD in 2011 and stabilized at 40 billion USD in 2015.[20] The second most traded technology is energy-efficient heating equipment with 15 billion USD in 2015, followed by wind and insulation at around 7 billion USD in 2015. Figure 4 of Appendix 8.2 shows the top 20 importers of low-carbon capital goods. The ranking is consistent with expectations. Germany, which had one of the most ambitious feed-in tariff policies for

[19] We choose the 1996 version of the Harmonized System to maximize the number of years for which low-carbon goods are reported in the data.

[20] The domination of Solar PV is not surprising. It has a high value per weight ratio, is highly modular, and its cost has decreased significantly over time.

renewable energy, is the most important importer with 10 billion USD per year. The USA (with 9.3 billion USD per year) is the second importer followed by China at 4.9 billion USD per year.

Foreign direct investment deals in low-carbon goods

In contrast with trade data, accessing reliable FDI data at a disaggregated sectoral level is much more complicated, particularly in developing countries. The construction of this data set is thus an important contribution of our paper.

We extract foreign direct investment data from the financial database Zephyr, provided by Bureau Van Dijk under a commercial license. Zephyr provides information on investment deals between acquiring companies and target companies. We use the number of investment deals between companies in the source country and companies in the recipient country in year *t* as an indicator of the intensity of FDI between country pairs. We would prefer to use the volume of investments, but this information is often missing, particularly for non-OECD countries. We use only completed deals of any kind including acquisitions, capital increases, minority stakes and share buybacks.

The main difficulty lies in identifying deals that presumably entail the transfer of a low-carbon technology. We apply two filters to select these deals. The first consists in keeping deals where the investing firm has filed at least one low-carbon patent in the recipient country. This is based upon the presumption that a firm only files a patent in a foreign country if it plans to commercially exploit the technology there.

Low-carbon patents are extracted from PATSTAT, maintained by the European Patent Office. We select patents classified under the “Y02” category developed by the European Patent Office and applied to all patents in PATSTAT. The Y02 category provides the most accurate tagging method of climate change mitigation patents available today and is the international standard for innovation studies in green technologies. We select patents that are related to the eight technologies included in the trade data. These low-carbon patents are then matched with Zephyr to identify the relevant investing firms. We thus obtain an indicator of FDI at the technology level, which makes it possible to compare the impact of IPR on the two transfer channels.

The second filter applies to the target firms. We keep deals in which the target firm belongs to an industry related to the technology. We match industry codes and low-carbon technologies based on the industry’s label and the description of the patent category in Table 13.[21] For instance, the description of the Solar PV category is “Solar photovoltaic (conversion of light radiation into electrical energy), including solar panels”. Target firms operating in industries such as “2611 - Manufacture of electronic components” or “3511 - Production of electricity” are included in the computation of FDI deals related to Solar PV, while firms operating in “2751 - Manufacture of electric domestic appliances” are not. Table 15 provides the list of industry codes selected for each low-carbon technology.

In Zephyr, there exist several country pairs with no deal in a given year. It is, however, risky to infer that no single deal takes place in reality: although Zephyr is one of the most reliable data sources of its kind, it does not claim to cover every single deal. Our general strategy is therefore to assume that the value is missing. We do however introduce an exception: we assume a zero when we observe deals for the same country pair in the preceding and following years. For

[21] Zephyr provides the Statistical Classification of Economic Activities in the European Community (NACE) industry codes of the target firms.

instance, if we observe deals between Hungary and Poland in 2009 and 2011, but not in 2010, then we assume that the value for this country pair is 0 for 2010. The intuition is that observing deals before and after 2010 implies that Zephyr has the capacity to monitor deals in these countries. Our regressions results are, however, not sensitive to this choice. The final FDI sample contains 71 recipient countries listed in Table 11 of Appendix 8.1. and observed yearly between 2006 and 2015.

In our data, we include investment deals made by a local investor. In our model, this allows firms to invest at home if the conditions are more attractive than abroad. Excluding domestic investment deals would lead to a severe sample selection bias, but when using estimates to calculate marginal or average effects, we focus on cross-country investment.

Figure 6 of Appendix 8.2 shows the top 20 recipients of low-carbon investment. China received the highest number of deals (497) during the period of observation. It is followed by the United Kingdom with 363 deals and Italy with 170 deals. Interestingly, emerging economies such as India, Russia, and Brazil come respectively at the 4th, 8th, and 12th position. Figure 7 shows the top 20 flows of investment deals in low-carbon technologies. Unsurprisingly, countries with high GDP per capita such as Japan and the USA are the main investors of the top recipient countries.

Figure 8 shows the number of global FDI deals by technology over time. Overall FDI in low-carbon technologies is growing over time. The main technologies involved are cleaner vehicles, solar PV, solar thermal, and wind power. In contrast with international trade, solar PV is not the dominant technology for FDI. One reason is that the value to weight ratio, which determines the trade cost of a good, does not matter for FDI.

Finally, Figure 9 shows the evolution of FDI by country group over time. The growth in global low-carbon FDI deals is explained by the increase of FDI flows between OECD countries, which represent 77% of all deals in 2015. Low-carbon investment from OECD towards non-OECD countries represents 22% of deals and this proportion has remained fairly constant over the observation period. Investment flows originating from developing countries represent only 1% of the deals covered in our data.

We perform several checks to assess the quality of this new dataset. To start with, we compare the distribution of FDI across OECD and non-OECD countries in our data with numbers given in a report by UNCTAD (2010) based on data from the Financial Times's FDiIntelligence database and the UNCTAD FDI/TNC database.[22] In this report, 59% of the FDI deals in low-carbon business areas take place between OECD countries and that 29% take places from OECD to non-OECD countries. This is in line with our estimates, bearing in mind that the period of observation and technology coverage differ.

We are aware that holding a patent arguably signals that the investing firm may use the technology locally, but not that it will do it for sure. Besides, it is clear that the patented technology is not necessarily used in all investments made by the parent firm in the country. In order to further assess the quality of our FDI data, we compare our data with the Orbis Crossborder Investment database maintained by Bureau Van Dijk. This database provides headlines and comments for deals that were completed between 2013 and 2017. We consider these two string variables as well as the investor name and the target company name and search for keywords related to wind power

[22] Unfortunately, we do not have access to either database, so we can only compare aggregate numbers as provided by the UNCTAD report.

and solar photovoltaic technologies.[23] For instance, for solar PV, we search for “pv”, “photovoltaic”, “solar farm”, “photosensitive”. We obtain a first list of deals that we review manually. We then exclude deals when the investor is an investment fund that is not likely to hold knowledge in the technology.[24] We end up with a list of 3,643 low-carbon deals and with a list of 15 investors in wind power and solar PV. We then compute the number of deals at the country-pair level for the period 2013-2017 during which Zephyr and Orbis Crossborder Investment overlap and compute the correlation with the variables obtained with our main methodology using patent data. We find relatively high correlations: 0.64 for solar PV and 0.66 for wind power.

The final check consists in verifying that the number of FDI deals in our data is positively correlated with trade flows extracted from the well-established BACI database. Figure 2 plots the imports of low-carbon capital goods on the x-axis and the number of inward FDI deals in low-carbon technologies on the y-axis by recipient country. The correlation is very high. Unsurprisingly, larger countries receive more FDI and import more low-carbon equipment. However, the situation of emerging economies is heterogeneous: a significant amount of transfer takes place towards China, but much smaller transfers occur towards Mexico and India in spite of the size of their economies (but with a lower IPR protection than China).

Table 2: List of low-carbon technologies covered

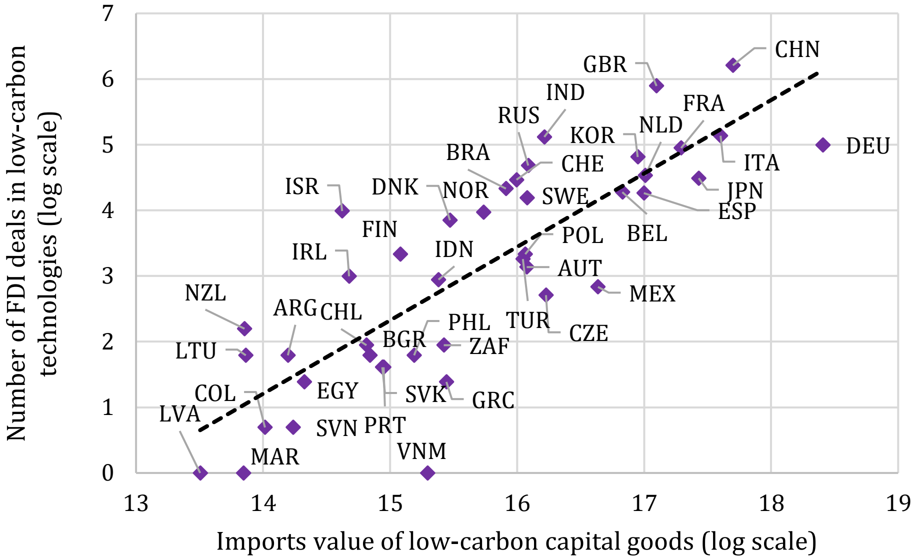
Sector	Technology class
Power generation	Hydro Solar photovoltaic Solar thermal Wind
Transport	Cleaner vehicles: hybrid and electric vehicles
Buildings	Heating Insulation Lighting

Note: Table 13 provides a detailed description of these technology fields in Patstat and Table 14 provides a harmonized system list of low-carbon capital goods for each technology.

[23] The procedure proved to be not feasible for other technologies, due to a lack of appropriate keywords in headlines and comments. Using patenting to identify low-carbon deals allow us to be more comprehensive, and to identify firms that does not exclusively operates in a specific low-carbon technology field. This explain why the correlation given below is not closer to 1.

[24] More specifically, we visit the website of the investing company to see if it is likely to hold knowledge in the technology. Also, we drop generic investment fund but keep investment fund specialized in renewables energies because they are susceptible to have knowledge in those technologies.

Figure 2: Technology transfer by recipient and by channel



Note: author calculation based on BACI, Zephyr, and Patstat. Values are summed over the technologies and over 2006-2015.

Intellectual property rights protection

We measure IPR protection using the indicator of Intellectual property protection of the Executive Opinion Survey (EOS) produced by the World Economic Forum (WEF). The EOS asks for each country a representative sample of leading business executives to quantify on a scale from 1 to 7 the extent of intellectual property protection.[25] The random sampling follows a dual stratification procedure based on the size of the company and the sector of activity.[26] The procedure ensures that both large and small firms representing the various economic sectors of the economy are captured in the final country-level score.[27] In 2011, the EOS covers 142 economies, accounting for 98 % of the World's GDP, with an average of 98 respondents per country.

We perform several checks to assess the quality of the indicator.
Figure 10

Figure 10of Appendix 8.2 shows the WEF IPR score as a function of real GDP per capita. As expected, IPR protection is strongly correlated with GDP per capita (73%). We also observe much greater variation between developing countries than between developed countries. Figure 11 shows the WEF IPR score as a function of the patent protection index of Park and Lippoldt (2008). Park and Lippoldt (2008)'s index is widely used in the literature. It ranges from zero (weakest) to

[25] 1 means that IP is not protected at all and 7 means that IP are protected to a great extent.
[26] The Executive Opinion Survey is administered by 150 Partner Institutes in their respective countries.
[27] In addition, surveys with a completion rate inferior to 50 percent are excluded from the sample because they demonstrate a lack of sufficient focus on the part of the respondent. Finally, a multivariate outlier analysis is applied to the data using the Mahalanobis distance technique.

five (strongest). This value is determined by the summation of five components: (i) extent of coverage, (ii) membership in international treaties, (iii) duration of protection, (iv) absence of restrictions on rights, and (v) statutory enforcement provision. We find a positive correlation of 0.64 between the two indicators, consistent with expectations.

Following Nunnenkamp & Spatz (2004), we choose the WEF index over the Park and Lippoldt (2008)'s index for several reasons. First, the Park and Lippoldt (2008)'s index focuses on patent protection whereas the WEF index covers all types of intellectual property rights. Second, the Park and Lippoldt (2008)'s index is available every 5 years whereas the WEF index is available on a yearly basis. Therefore, the WEF index provides many more degrees of freedom when estimating our model with country-pair and year fixed-effects. Third, the Park and Lippoldt (2008)'s index is more likely to fail to capture "enforced" IPR protection as opposed to IP laws "on the book". For example, the result of a court case suggesting that IPR protection is not enforced very strongly will be reflected in the WEF index of perceived stringency but not in the Park and Lippoldt index.

To measure the actual degree of Intellectual property rights protection, we follow Maskus and Yang (2013) by interacting the WEF IPR index with the Fraser Institute's legal system index. We do so because a weak legal system de facto implies weak IP rights, regardless of a country's IPR strictness. The legal systems index is extracted from the Fraser Institute's annual reports on the economic freedom of the world (Gwartney et al., 2014). It is a composite index between 0 and 10 built from other indices and including legal enforcement of contracts, judicial independence, impartial courts, and the integrity of the legal system. In practice, we multiply the IPR index by the legal systems – which are complements – and rescale the product from 0 to 10.

Our identification strategy requires that there is sufficient within-country variation in IPR. Our data meets this criterion. We show in Table 3 that the within-country coefficient of variation (standard deviation over mean) of our IPR protection index is 10% for all countries, 7% for OECD countries, and 13% for non-OECD countries.

Table 3: Within-country variation in IPR protection

	Mean	Within-country Std. Dev.	% of mean (C.V.)
All countries	3.84	0.40	10%
OECD countries	6.45	0.48	7%
Non-OECD countries	2.90	0.37	13%

Note: author calculation based on the estimation sample.

Absorptive capacities and control variables

We proxy a country's absorptive capacities with its gross rate of enrollment in tertiary education. Data come from the World Development Indicators database maintained by the World Bank. A country is considered to have high capacities if it has a tertiary enrolment rate higher than 20% which is the median of the distribution. Figure 12 plots the IPR protection against tertiary enrolment. The figure highlights the importance to control for absorptive capacities since it is correlated with IPR protection at 83% on the cross-sectional level. Figure 12 also shows that for a given level of IPR protection there exists significant variation between countries in terms of absorptive capacities. Table 12 in Appendix 8.1 provides the gross rate of enrolment in tertiary education, high capacity dummy, and OECD dummy for the countries of the dataset.

Data on GDP come from the World Development Indicators database maintained by the World Bank. Our proxy for stringency of environmental regulations is the Environmental Performance

Index (EPI) maintained by Yale University. The EPI ranks 180 countries on 24 performance indicators across ten issue categories covering environmental health and ecosystem vitality. Data on tariff and non-tariff measures come from the TRAINS database maintained by UNCTAD. Data on freedom of FDI and movement of people, labor regulations, and burden of business regulations come from the Fraser Institute's Economic Freedom of the World 2015 dataset. Finally, gravity controls data such as bilateral distance, contiguity, common language, and colonial relationship come from the geodis dataset maintained by the CEPII. Table 16 provides the definition and sources for all variables.

5. Results

In this section, we present the results of the estimation of the different models. We start with the baseline models, which provide the global average effect of IPR on trade and FDI deals. The results of the models, which account for cross-country heterogeneity, are subsequently discussed.

Average effect of IPR protection

Table 4 and Table 5 display the results of the estimation of model (1) for the trade of low-carbon goods and low-carbon FDI and by technology, respectively.[28] In all regressions, the coefficients of the control variables have their expected sign when statistically significant, suggesting reliable estimates. Increase in GDP is associated with larger imports of low-carbon equipment and greater inward foreign investments; increases in GDP per capita lead countries to invest more capital abroad; increases in tariff and non-tariff measures reduce imports of equipment goods; signing a trade agreement increases trade between partners. Interestingly, trade agreements also reduce FDI. A likely explanation is that trade and FDI are substitutes: when trade barriers are high, firms are more likely to resort to FDI to reach a foreign market.

The effect of IPR protection on trade and foreign direct investment is positive at conventional significance levels for many technologies. This is true for the international trade of equipment for solar PV, solar thermal, wind power, and heating. In terms of magnitude, an increase in the IPR protection index by 1 unit (corresponding to more than twice the within-country standard deviation of the variable over our sample) is predicted to increase imports of solar PV by 55%, solar thermal by 11%, wind power by 54%, and heating by 9%.[29] The effect on FDI is also statistically significant and positive for solar thermal, lighting, and cleaner vehicles. An increase in the IPR protection index by 1 unit is predicted to increase FDI in solar thermal by 26%, in lighting by 41% and in cleaner vehicles by 29%. These differences across technologies show the importance of industry-specific factors. For all these technologies, the market expansion effect of IPR protection thus more than compensates the negative impact through enhanced market power, leading to more transfer either through trade, FDI, or both channels.

Hydro power and insulation are the only exceptions for which IPR protection has neither a significant influence on trade nor on FDI. A possible interpretation is that they are more mature technologies with less necessity to protect advanced inventions. Another interpretation is that

[28] Summary statistics for the estimation are available in Table 17 and Table 19.

[29] In a Poisson regression model, the coefficients should be interpreted as semi-elasticities.

these technologies are the least patent intensive as shown in Figure 1. Therefore, changes in IPR protection should have a smaller effect on hydro power and insulation.

We find that, for a given technology, IPR protection increases have a differential effect across channels.[30] For instance, strengthening IPR protection promotes the transfer of cleaner vehicles technologies through FDI but not through trade. The complexity of this technology offers a possible interpretation. In comparison with FDI, importing cleaner vehicles brings a small share of the vast knowledge needed to master the technology. IPR protection is thus a minor issue for exporters. In comparison, this suggests that IPR protection matters for trade in wind power equipment or solar PV (Table 4) because they are simpler products, embedding more easily-imitable innovations. This is consistent with the ranking of the technologies in terms of patent intensity shown in Figure 1.

A potential concern for the comparison between trade and FDI is the difference between the composition of the trade and FDI samples, the former being significantly more comprehensive. In Table 22 of Appendix 8.3, we estimate the trade model using only the observations available in the FDI sample. The results are highly similar to our baseline estimation with the exception of hydro power for which IPR has a negative effect. This result could be explained by the high concentration in hydro power generation of the countries in the FDI sample. Nevertheless, the baseline estimates remain superior because the sample of countries twice as larger.

How do these results compare with technologies that do not aim to mitigate climate change? In Appendix, Table 27 and Table 28 display results of model (1) for trade in all capital goods and for FDI deals in all technologies. We find a positive and significant effect of IPR protection on trade, which is consistent with previous studies focusing on the manufacturing sector (Smith, 1999; Maskus and Penubarti, 1995, Braga and Fink, 1999; Co, 2004; Maskus and Yang, 2013). The estimated coefficient equals 0.07, which is much lower than the coefficient we estimated for solar PV and wind power and close to the coefficient estimated for heating. These differences further highlight the importance of estimating each technology separately. In Table 28, we also find a positive effect on FDI. Again, this is in line with the findings of the literature (Lee and Mansfield, 1996; Smith, 2001; Javorcik, 2004; Nunnenkamp and Spatz, 2004). The value of the coefficient is 0.23, which is close to what we observe for low-carbon technologies.

Finally, we perform a placebo test to check that IPR protection has no statistically significant impact on sectors that are known for being insensitive to patent protection. We focus on two sectors “CPC 0 - agriculture, forestry, and fishery products” and “CPC 1 - ores, minerals, electricity, gas and water”.[31] Table 27 shows the estimates for trade in CPC 0 in column 1 and in CPC 1 in column 2. As expected, we find that IPR does not affect trade in these two sectors. An equivalent test is not feasible for FDI as no FDI data are available for these two sectors.

Weak versus strong absorptive capacity countries

In Table 6 and Table 7, we present the results of models in which the IPR variable is interacted with the absorptive capacity dummy described in subsection 4.4. Climate policy debates indeed

[30] Note that the sample used to estimate FDI models includes less countries. One should thus be cautious when comparing the numbers for FDI and trade.

[31] These two sectors correspond to the Central Product Classification 0 and 1. Plant breeders' rights are an IP instrument used to appropriate technologies for seeds. However, seeds represent a small share of the goods classified under CPC 0.

commonly stress the low-absorptive vs high-capacity divide between developing and industrialized countries.

Considering developing countries, the most important result is probably that the impact of IPR protection is never negative at conventional significance levels. Results however appear quite different for trade and FDI. The impact on the import of low-carbon capital goods is only significantly positive for heating and insulation while it is positive at conventional levels for FDI for all technologies with the exception of hydro and insulation. This is in line with theoretical arguments developed in subsection 2.3. In contrast with trade, FDI bring more absorptive capacities in the recipient country, increasing the benefit of IPR protection in deterring imitation.

The comparison between low-capacity and high-capacity countries yield additional results. For all technologies, IPR protection exerts a higher positive influence on FDI in low-capacity countries than in high-capacity countries. That FDI bring imitation capacities in countries where they are missing might again offer an explanation.

In contrast, the ranking for trade between low- and high-capacity countries varies across technologies. IPR have a larger effect on the imports of heating and insulation technologies towards low-capacity countries while the opposite is true for solar PV, solar thermal, and wind power. The interpretation of these differences needs to rely on specificities of these technologies.

The market potential is a possible factor. For climatic reasons, developing countries tend to have lower heating and insulation need while large wind and solar resources promote the adoption of renewable energy technologies. As argued by Maskus and Penurbati (1995), strengthening IPR in large markets is more effective as filing and registering a patent or a trademark is a fixed cost. Also, competition between technologies increases with market size, implying a lower market-power effect of IPR protection.

Another explanation is that absorptive capacities do not only measure the capacity to imitate but are also a proxy for domestic production of low-carbon inventions. Therefore, higher effectiveness of IPR in weak-capacity countries may simply signal that these countries innovate less and are thus more dependent on technology imports. Moreover, low-capacity countries innovate much less in heating and insulation technologies than in renewable technologies. Table 18 of the appendix show the summary statistics for the discounted stock of patented inventions for low capacity countries. On average, the stock of patented inventions is at least twice as large for solar PV and wind power than for heating and insulation. Additionally, more than 30% of low-capacity countries have a positive stock of patented inventions for solar PV and wind power. This figure is only 18% for heating and 5% for insulation. Ultimately, these interpretations are hypotheses and going further would require further research.

Lastly, all these results are broadly in line with those of models in which IPR protection is interacted with a dummy variable equal to 1 when the importing country is an OECD country.

Simulating the effects of an increase in IPR in lax countries

Examining the marginal impact of a one-unit increase in the level of IPR protection, as presented above, is useful when comparing different channels, but it tells us little about how IPR protection impacts absolute levels of technology transfer. We thus conclude the discussion of our results with a simulation exercise in which we assume that countries below the median IPR protection level experience an increase in IPR protection to reach a global mean IPR level equal to 4.2. This average value roughly corresponds to the value of IPR protection in China in 2015 and involves a relatively small increase in IPR for large emitters such as India, Brazil and Indonesia. Table 10 shows the impact of this change on low-carbon FDI deals for each country.[32] We use the coefficients obtained from the estimation of the model with the interaction terms between IPR protection and the OECD dummy because they consider the specificity of the developing countries that we focus on in the simulation.

We find relatively large impacts. For instance, FDI deals into India are expected to grow by at least 4% in 6 technologies. This figure equals 20% for Indonesia and 28% for Brazil. In short, if big emitters like India, Brazil, and Indonesia were to converge to the Chinese level of IPR protection, this would make a significant difference in terms of international transfer of climate change mitigation technology.

6. Conclusion

In this paper, we have combined international trade and FDI data to analyze the impact of intellectual property rights protection on cross-border flows of climate change mitigation technologies. Our data cover up to 140 countries (both developed and developing) and include eight low-carbon technologies in the energy production, transportation, and building sectors. We exploit the fact that the level of IPR protection has evolved differentially over time across countries in our dataset to identify impact of greater IPR protection, and to analyze how this impact varies with the recipient country's absorptive capacities.

At the global level, stricter IPR regimes are found not to impede the transfer of climate change mitigation technology. Strengthening IPR is found to increase the transfer of several low-carbon technologies through the following channels: the imports of capital goods in solar PV, solar thermal, wind power, heating, and foreign direct investments in solar thermal, lighting, and cleaner vehicles. Hydro power is the only technological field in which a higher level of IPR has no significant influence. Importantly, we find that the magnitude of the impact of IPR is larger for low-carbon technologies than for the average technology, illustrating the role that IPR protection may play to accelerate the international diffusion of climate change-mitigation technologies. A reason might be that cross-technology competition is tougher than in other fields (i.e. pharmaceuticals). These technologies are also probably more complex and modular -- a new product is composed of numerous separately patentable elements -- than the average technology. Both characteristics are expected to reduce market power of technology owners.

The policy discussion on this issue primarily focuses on North-South technology transfer towards developing countries. Focusing on the country group with lower technological capabilities (using tertiary enrolment rates as a proxy), we find a positive effect IPR protection on FDI in 6 out of 8 technology fields: hydro power, solar PV, solar thermal, heating, lighting, and cleaner vehicles. In contrast, IPR protection has no significant effect on trade towards the same group of countries. Results are highly similar when considering the group of non-OECD countries.

Our interpretation is that FDI bring to the subsidiary the knowledge and soft skills that are necessary to produce the goods in which the technology is embedded. In this way, FDI increase local technological capabilities, reinforcing the role of IPR in deterring imitation. In contrast, trade does not increase technological capabilities, at least in the short run.

[32] We do not conduct the simulation on the trade channel as the effect of IPR is not significant for non-OECD countries.

The policy implications are substantial. In developing countries and for most of the low-carbon technologies considered, raising IPR protection would lead to increases in foreign investment, but not in more imports of innovation-intensive goods. That is not bad news as FDI convey knowledge and generate more spillovers in the recipient economy than trade in goods.

This delivers a clear-cut lesson for climate negotiations: relaxing IPR protection for low-carbon technologies appears in general as counterproductive for low-carbon technology transfer towards countries with lower technological capabilities. Instead, increasing IPR protection induces more FDI, which yields two specific benefits to developing countries: more technology transfer in the short term, and higher technological capabilities in the long term.

Helping developing countries to build absorptive technological capacities through various means, including cooperative research, training, development and demonstration programs, is commonly viewed as other major means to promote cross-border knowledge diffusion. Our study suggests subtle interactions between this approach and the reinforcement of IPR protection. With higher technological capabilities, strong IPR protection will continue to increase inward knowledge flows but would also shift these transfers from the FDI to the trade channel.

Moreover, we have estimated our trade and FDI models for all technologies (i.e. all products for trade and all sectors for FDI) in order to compare with the “average” technology (Table 27 and Table 28). Looking at the size of the coefficients, results are not so different for most of the technologies -- the two exceptions being solar PV and solar thermal. This indicates that the impact of IPR for low-carbon technologies does not deserve specific discussions under the UNFCCC. The World Trade Organization, which is the international body in charge of the global IPR policy, probably provides a better forum for addressing these issues. Climate negotiations should focus instead on other, and probably more important, issues such as the financing of technology transfer, mitigation policies (which create the demand for these technologies), and technological capacity building.

Although it is out of the scope of the present study, note that there is a potential role for other patent policy adjustments. As argued by Maskus (2010), while patents do not seem to represent today significant barriers to technology transfer, the establishment of antitrust safeguards against their potential abuse can certainly help. This would mainly imply investing in capacity building and training of competition authorities in targeted developing countries. Second, patent landscaping, i.e. the development of patent databases and recent patent landscaping software, represents a significant source of information on available technologies in a given field. This can help firms to find inspiration for R&D projects (spillovers), to identify potential blocking patents, or to license existing technology. Third, the development of voluntary patent pools could reduce both transaction costs and cumulative royalty rates. This option consists in inviting firms, universities and research institutions to put all their patents related to a particular technology in a single pool, so as to propose to users a single packaged license. However, patent pools make sense only for technologies that include a large number of patented elements such as cleaner vehicles.

Table 4: IPR protection and trade in low-carbon capital goods

	Hydro	Solar PV	Solar Thermal	Wind power	Heating	Insulation	Lighting	Cleaner vehicles
Importer IPR protection	-0.009	0.440**	0.101*	0.432**	0.086**	-0.01	-0.062	-0.146
	(0.117)	(0.215)	(0.052)	(0.173)	(0.035)	(0.038)	(0.087)	(0.141)
Importer Absorptive capacities	-0.79	-3.267	-0.645	-1.082	-0.760**	-0.542*	0.177	1.725
	(1.426)	(3.261)	(0.693)	(1.264)	(0.343)	(0.328)	(0.609)	(1.318)
Importer Log (GDP)	1.912**	1.688**	0.804	0.783	0.235	0.224	1.363***	0.058
	(0.820)	(0.741)	(0.593)	(1.095)	(0.203)	(0.357)	(0.391)	(0.988)
Importer Log (per capita GDP)	-5.654***	-0.101	-0.73	-0.949	0.18	0.934	-1.322	-0.903
	(1.512)	(1.358)	(1.028)	(3.258)	(0.376)	(0.583)	(1.044)	(1.889)
Importer Environmental Regulations	0.006	0.087	0.063	-0.119	0.02	-0.031	0.021	0.103
	(0.077)	(0.101)	(0.051)	(0.118)	(0.021)	(0.021)	(0.032)	(0.112)
Importer Effectively Applied Tariff	-0.093***	-0.043	0.007	-0.028	-0.020**	-0.026	-0.035*	-0.030***
	(0.020)	(0.050)	(0.018)	(0.025)	(0.010)	(0.018)	(0.018)	(0.004)
Importer Nr. of Non-Tariff Measures	0.004	-0.274***	-0.034*	-0.097	0.002	0.008	-0.023**	0.069
	(0.010)	(0.062)	(0.019)	(0.093)	(0.002)	(0.008)	(0.010)	(0.077)
Country pair in Trade Agreement (0/1)	-0.206	0.108	0.842***	0.135	0.337**	0.301**	-0.219**	-0.096
	(0.190)	(0.249)	(0.268)	(0.590)	(0.135)	(0.131)	(0.107)	(0.264)
Exporter Log (GDP)	0.01	0.009	0.206***	0.068	0.014	0.064*	0.05	-0.064
	(0.093)	(0.061)	(0.065)	(0.131)	(0.025)	(0.033)	(0.059)	(0.207)
Exporter Log (per capita GDP)	-0.514	-0.611***	-0.62	2.667	0.11	-0.205	0.458	3.762**
	(0.457)	(0.202)	(0.544)	(1.893)	(0.167)	(0.157)	(0.312)	(1.868)
Exporter IPR protection	2.276***	3.255***	1.451*	-3.316	0.495	1.321***	0.193	-9.099**
	(0.812)	(0.667)	(0.876)	(3.310)	(0.341)	(0.438)	(0.562)	(3.939)
Exporter Environmental Regulations	0.078	-0.059	-0.042	0.232*	0.083***	0.017	0.018	0.07
	(0.054)	(0.043)	(0.043)	(0.121)	(0.023)	(0.018)	(0.044)	(0.184)
Year fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-pair fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Nr. Observations	15,423	25,301	16,132	9,410	27,033	20,824	19,535	13,231
Nr. Country pairs	1,872	3,102	1,946	1,093	3,328	2,526	2,393	1,651

Notes: robust standard errors clustered at the recipient country level in parentheses. * Significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level. All columns are estimated with the Pseudo Poisson Maximum Likelihood Estimator with all regressors lagged one year. The dependent variable is the shipment value in low-carbon goods expressed in thousands of current USD and computed from BACI data. The Intellectual property rights protection (IPR) index is the intellectual property rights index from the World Economic Forum's Executive Opinion Survey multiplied by the legal systems and property rights from the 2014 Economic Freedom Dataset published by the Fraser Institute. Absorptive capacities are measured by enrollment in tertiary education. Index of tariff barriers and non-tariff barriers are built from the TRAINS database. The country-pair trade agreement equals 1 if both countries are in a free trade agreement or a custom union based on the WTO Regional Trade Agreements Information System. Environmental regulations are measured by the Environmental Performance Index from Yale University.

Table 5: IPR protection and FDI in low-carbon technologies

	Hydro	PV	Solar thermal	Wind	Heating	Insulation	Lighting	Cleaner vehicles
Importer IP protection	0.078	0.176	0.230*	0.132	0.289	-0.049	0.342**	0.257**
	(0.107)	(0.124)	(0.139)	(0.125)	(0.199)	(0.213)	(0.167)	(0.114)
Importer Absorptive capacities	1.212**	0.509	0.938	1.807**	-0.938	1.767*	-0.804	0.332
	(0.545)	(0.855)	(1.057)	(0.881)	(1.466)	(1.020)	(1.191)	(0.646)
Importer Log (GDP)	0.826***	0.820***	0.851***	1.038***	0.822***	1.032***	0.893***	0.880***
	(0.122)	(0.101)	(0.108)	(0.108)	(0.143)	(0.166)	(0.149)	(0.090)
Importer Log (per capita GDP)	-0.34	-0.025	-0.155	-0.723***	-0.175	0.13	0.374	-0.056
	(0.232)	(0.241)	(0.248)	(0.257)	(0.397)	(0.280)	(0.296)	(0.232)
Importer Environmental Regulations	0.002	-0.03	-0.017	0.028	0.016	-0.03	-0.079**	-0.045***
	(0.018)	(0.019)	(0.019)	(0.024)	(0.026)	(0.020)	(0.031)	(0.016)
Importer business regulations	-0.07	-0.098	-0.154	0.067	-0.076	-0.104	-0.432	-0.415**
	(0.246)	(0.232)	(0.269)	(0.223)	(0.429)	(0.383)	(0.295)	(0.179)
Importer labor market regulations	-0.096	-0.205***	-0.270***	-0.194***	-0.550***	-0.058	-0.348***	-0.127***
	(0.066)	(0.067)	(0.043)	(0.060)	(0.059)	(0.097)	(0.099)	(0.043)
Importer controls of capital and people movement	-0.118**	-0.096	-0.132	-0.184*	-0.187	-0.009	0.115	-0.025
	(0.058)	(0.094)	(0.114)	(0.096)	(0.163)	(0.125)	(0.098)	(0.080)
Country pair in Trade Agreement	-0.955***	-1.226***	-1.495***	-1.233***	-1.982***	-1.561***	-1.173***	-1.085***
	(0.240)	(0.298)	(0.329)	(0.290)	(0.417)	(0.463)	(0.414)	(0.277)
Exporter IP protection	0.243*	0.277**	0.261**	0.199*	0.369***	0.603**	0.292	0.261***
	(0.142)	(0.127)	(0.121)	(0.117)	(0.137)	(0.249)	(0.192)	(0.086)
Exporter Log (GDP)	1.478***	1.456***	1.267***	1.340***	1.225***	1.618***	1.719***	1.339***
	(0.109)	(0.131)	(0.110)	(0.122)	(0.115)	(0.135)	(0.144)	(0.073)
Exporter Log (per capita GDP)	0.694	0.816*	0.475	0.152	-0.143	1.961***	1.291***	0.754**
	(0.519)	(0.479)	(0.508)	(0.467)	(0.523)	(0.542)	(0.446)	(0.369)
Exporter Environmental Regulations	-0.113***	-0.141***	-0.074**	-0.046	-0.047	-0.225***	-0.220***	-0.121***
	(0.039)	(0.031)	(0.037)	(0.032)	(0.042)	(0.042)	(0.028)	(0.023)
Contiguity	-1.253***	-1.549***	-1.063***	-1.051***	-1.644***	-1.371**	-3.398***	-1.676***
	(0.355)	(0.368)	(0.388)	(0.312)	(0.477)	(0.583)	(0.578)	(0.379)
Common official language	0.759	1.046***	0.743**	0.935**	1.663***	0.881	1.666***	0.613
	(0.462)	(0.399)	(0.346)	(0.474)	(0.386)	(0.594)	(0.415)	(0.529)
Colonial relationship	-0.225	-0.200	-0.261	-0.226	0.015	-1.190***	-0.474	-0.113
	(0.366)	(0.312)	(0.292)	(0.389)	(0.484)	(0.372)	(0.344)	(0.258)
Log distance between most populated cities	-1.281***	-1.366***	-1.317***	-1.394***	-1.524***	-1.149***	-1.390***	-1.255***
	(0.154)	(0.118)	(0.117)	(0.145)	(0.131)	(0.166)	(0.170)	(0.096)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	23,055	24,037	23,583	25,666	22,469	17,839	18,679	23,791
Country-pairs	2,812	3,040	2,964	3,192	2,736	2,128	2,356	2,812

Notes: Robust standard errors in parentheses. * Significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level. All columns are estimated with the Pseudo Poisson Maximum Likelihood Estimator with all regressors lagged one year. The dependent variable is the number of inward FDI deals computed from Zephyr and Patstat data. The Intellectual property rights protection (IPR) index is the intellectual property rights index from the World Economic Forum's Executive Opinion Survey multiplied by the legal systems and property rights from the 2014 Economic Freedom Dataset published by the Fraser Institute. Absorptive capacities are measured by enrollment in tertiary education. Importer business regulations, labor market regulations, and controls of the movement of capital and people come from the 2014 Economic Freedom Dataset published by the Fraser Institute. The country-pair trade agreement equals 1 if both countries are in a free trade agreement or a custom union based on the WTO Regional Trade Agreements Information System. Environmental regulations are measured by the Environmental Performance Index from Yale University.

Table 6: Heterogeneous effect of IPR protection between OECD and non-OECD countries on trade in low-carbon capital goods and FDI in low-carbon technologies

		Hydro	Solar PV	Solar Thermal	Wind power	Heating	Insulation	Lighting	Cleaner vehicles
Trade	*Non-OECD*	0.196	-0.47	0.076	0.432	0.118	0.002	-0.082	-0.245
		(0.173)	(0.346)	(0.086)	(0.370)	(0.079)	(0.094)	(0.145)	(0.251)
	OECD	-0.211	0.827***	0.105*	0.432**	0.071**	-0.012	-0.054	-0.112
		(0.142)	(0.312)	(0.064)	(0.208)	(0.036)	(0.040)	(0.103)	(0.164)
FDI	*Non-OECD*	0.241*	0.359***	0.301**	0.207	0.593**	-0.077	0.759***	0.353***
		(0.146)	(0.126)	(0.140)	(0.147)	(0.236)	(0.275)	(0.197)	(0.121)
	OECD	0.051	0.148	0.219	0.124	0.27	-0.046	0.259	0.241**
		(0.116)	(0.130)	(0.149)	(0.129)	(0.211)	(0.236)	(0.166)	(0.121)

Notes: Robust standard errors clustered at the recipient country level in parentheses. * Significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level. The two panels correspond to separate regressions that include an interaction term between the recipient country IPR protection index and a dummy that indicates whether the country is a member of the OECD. All columns are estimated with the Pseudo Poisson Maximum Likelihood Estimator with all regressors lagged one year. For clarity, the control variables are not reported in this table. The complete results are available in Table 20 and Table 21 in Appendix 8.3.

Table 7: Heterogeneous effect of IPR protection between countries with weak and strong absorptive capacity on trade in low-carbon capital goods and FDI in low-carbon technologies

		Hydro	Solar PV	Solar Thermal	Wind power	Heating	Insulation	Lighting	Cleaner vehicles
Trade	*Weak absorptive capacity*	0.024	-0.45	0.142	-1.221	0.207***	0.253***	-0.071	0.106
		(0.200)	(0.286)	(0.111)	(0.924)	(0.077)	(0.074)	(0.288)	(0.260)
	Strong absorptive capacity	-0.029	0.693**	0.098*	0.505***	0.056*	-0.032	-0.06	-0.186
		(0.149)	(0.271)	(0.057)	(0.194)	(0.034)	(0.042)	(0.097)	(0.156)
FDI	*Weak absorptive capacity*	0.116	0.309**	0.268*	0.277*	0.587**	-0.16	0.571***	0.324**
		(0.129)	(0.132)	(0.151)	(0.149)	(0.283)	(0.243)	(0.198)	(0.131)
	Strong absorptive capacity	0.067	0.151	0.223	0.105	0.22	-0.025	0.300*	0.247**
		(0.114)	(0.130)	(0.141)	(0.127)	(0.215)	(0.227)	(0.167)	(0.117)

Notes: Robust standard errors clustered at the recipient country level in parentheses. * Significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level. The two panels correspond to separate regressions that include an interaction term between the recipient country IPR protection index and an absorptive capacity dummy that separates countries into two groups. The dummy, specific to each technology, is based on the median of the average stock of high-value inventions during the observation period. All columns are estimated with the Pseudo Poisson Maximum Likelihood Estimator with all regressors lagged one year. For clarity, the controls variables are not reported in this table. The complete results are available in Table 23 and Table 24in Appendix 8.3.

Table 8: IPR protection and trade in all capital goods

	BEC 47 – All capital goods	CPC 1 - ores, minerals, electricity, gas and water
Importer IPR protection	0.072***	0.048
	(0.026)	(0.046)
Importer Absorptive capacities	-0.250	-0.033
	(0.220)	(0.355)
Importer Log (GDP)	0.430***	0.215
	(0.106)	(0.192)
Importer Log (per capita GDP)	0.120	0.813**
	(0.216)	(0.374)
Importer Environmental Regulations	0.004	-0.013
	(0.014)	(0.021)
Importer Effectively Applied Tariff	-0.013	-0.008
	(0.010)	(0.013)
Importer Nr. of Non-Tariff Measures	-0.002	0.045
	(0.014)	(0.029)
Country pair in Trade Agreement (0/1)	0.038	0.002
	(0.040)	(0.095)
Exporter Log (GDP)	0.014	0.024
	(0.012)	(0.035)
Exporter Log (per capita GDP)	0.410***	0.412***
	(0.071)	(0.149)
Exporter IPR protection	0.509***	-1.288***
	(0.120)	(0.469)
Exporter Environmental Regulations	0.034***	-0.01
	(0.006)	(0.016)
Year fixed-effects	Yes	Yes
Country-pair fixed-effects	Yes	Yes
Nr. Observations	84,939	58,348
Nr. Country pairs	11,839	7,638

Notes: robust standard errors clustered at the recipient country level in parentheses. * Significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level. CPC is the Central Product Classification and BEC is the Broad Economic Categories nomenclature.

Table 9: IPR protection and FDI in all sectors

	Number of FDI deals in all sectors
Importer IP protection	0.226***
	(0.061)
Importer Absorptive capacities	1.666***
	(0.635)
Importer Log (GDP)	0.843***
	(0.067)
Importer Log (per capita GDP)	-1.105***
	(0.198)
Importer Environmental Regulations	0.056***
	(0.017)
Importer business regulations	-0.043
	(0.120)
Importer labor market regulations	-0.117
	(0.083)
Importer controls of capital and people movement	-0.09
	(0.084)
Country pair in Trade Agreement	-1.771***
	(0.193)
Exporter IP protection	0.126
	(0.112)
Exporter Log (GDP)	0.820***
	(0.079)
Exporter Log (per capita GDP)	-0.801***
	(0.216)
Exporter Environmental Regulations	0.073***
	(0.022)
Contiguity	-1.389***
	(0.236)
Common official language	1.418***
	(0.274)
Colonial relationship	0.126
	(0.280)
Log distance between most populated cities	-1.522***
	(0.055)
Year dummies	Yes
Observations	28,998
Country-pairs	5,232

Notes: Robust standard errors in parentheses. * Significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.

Table 10: Effect of a minimum level of IPR on inward FDI in low-carbon technologies

Country	CO2 emissions (Mt in 2014)	Change in IPR protection	% change in FDI deals					
			Hydro	Solar PV	Solar Thermal	Heating	Lighting	Cleaner vehicles
India	2,238	4%	4%	6%	5%	9%	12%	5%
Russian Federation	1,705	49%	39%	63%	51%	124%	181%	62%
Iran, Islamic Rep.	649	66%	49%	81%	64%	166%	250%	79%
Brazil	530	33%	28%	45%	36%	84%	118%	44%
Indonesia	464	22%	20%	31%	25%	56%	77%	30%
Thailand	316	52%	41%	67%	54%	134%	196%	66%
Kazakhstan	248	3%	3%	5%	4%	8%	11%	5%
Ukraine	227	72%	52%	87%	69%	180%	274%	85%
Argentina	204	76%	54%	90%	71%	189%	289%	88%
Egypt	202	113%	70%	121%	94%	269%	432%	118%

Notes: % change in FDI computed using the estimated coefficients in Table 7. Technologies for which there is no significant effect are not reported here. The CO2 emissions data come from UNEP (2016).

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8. Appendix

Definition of country groups, variables, and data sources

Table 11: List of recipient country by dataset

Country code	Country name	Trade dataset	FDI dataset	Country code	Country name	Trade dataset	FDI dataset
AGO	Angola	X		DZA	Algeria	X	X
ALB	Albania	X		ECU	Ecuador	X	X
ARE	United Arab Emirates	X	X	EGY	Egypt	X	X
ARG	Argentina	X	X	ESP	Spain	X	X
ARM	Armenia	X		EST	Estonia	X	X
AUS	Australia	X		ETH	Ethiopia	X	
AUT	Austria	X	X	FIN	Finland	X	X
AZE	Azerbaijan	X		FRA	France	X	X
BDI	Burundi	X		GAB	Gabon	X	
BEL	Belgium-Luxembourg	X	X	GBR	United Kingdom	X	X
BEN	Benin	X		GEO	Georgia	X	X
BFA	Burkina Faso	X		GHA	Ghana	X	
BGD	Bangladesh	X		GIN	Guinea	X	
BGR	Bulgaria	X	X	GMB	Gambia	X	
BHR	Bahrain	X		GRC	Greece	X	X
BIH	Bosnia Herzegovina	X		GTM	Guatemala	X	X
BLZ	Belize	X		GUY	Guyana	X	
BOL	Bolivia	X		HND	Honduras	X	X
BRA	Brazil	X	X	HRV	Croatia	X	X
BRN	Brunei Darussalam	X		HTI	Haiti	X	
BTN	Bhutan	X		HUN	Hungary	X	X
CAN	Canada	X		IDN	Indonesia	X	X
CHE	Switzerland	X	X	IND	India	X	X
CHL	Chile	X	X	IRL	Ireland	X	X
CHN	China	X	X	IRN	Iran	X	
CIV	Cote dIvoire	X		ISL	Iceland	X	X
CMR	Cameroon	X		ISR	Israel	X	X
COL	Colombia	X	X	ITA	Italy	X	X
CPV	Cabo Verde	X		JAM	Jamaica	X	
CRI	Costa Rica	X	X	JOR	Jordan	X	X
CYP	Cyprus	X	X	JPN	Japan	X	X
CZE	Czech Rep.	X	X	KAZ	Kazakhstan	X	X
DEU	Germany	X	X	KEN	Kenya	X	X
DNK	Denmark	X	X	KGZ	Kyrgyzstan	X	
DOM	Dominican Rep.	X	X	KHM	Cambodia	X	

Country code	Country name	Trade dataset	FDI dataset	Country code	Country name	Trade dataset	FDI dataset
KOR	Rep. of Korea	X	X	PRT	Portugal	X	X
KWT	Kuwait	X	X	PRY	Paraguay	X	
LAO	Lao	X		QAT	Qatar	X	X
LBN	Lebanon	X		ROU	Romania	X	
LBR	Liberia	X		RUS	Russian Federation	X	X
LKA	Sri Lanka	X		RWA	Rwanda	X	
LTU	Lithuania	X	X	SAU	Saudi Arabia	X	X
LVA	Latvia	X	X	SEN	Senegal	X	
MAR	Morocco	X	X	SGP	Singapore	X	
MDA	Rep. of Moldova	X	X	SLE	Sierra Leone	X	
MDG	Madagascar	X		SLV	El Salvador	X	X
MEX	Mexico	X	X	SRB	Serbia	X	
MKD	TFYR of Macedonia	X		SUR	Suriname	X	
MLI	Mali	X		SVK	Slovakia	X	X
MLT	Malta	X		SVN	Slovenia	X	X
MMR	Myanmar	X		SWE	Sweden	X	X
MNE	Montenegro	X		SYC	Seychelles	X	
MNG	Mongolia	X		TCD	Chad	X	
MOZ	Mozambique	X		THA	Thailand	X	X
MRT	Mauritania	X		TJK	Tajikistan	X	
MUS	Mauritius	X		TLS	Timor-Leste	X	
MWI	Malawi	X		TTO	Trinidad and Tobago	X	
MYS	Malaysia	X	X	TUN	Tunisia	X	X
NGA	Nigeria	X		TUR	Turkey	X	X
NIC	Nicaragua	X		TZA	United Rep. of Tanzania	X	
NLD	Netherlands	X	X	UGA	Uganda	X	
NOR	Norway	X	X	UKR	Ukraine	X	X
NPL	Nepal	X		URY	Uruguay	X	X
NZL	New Zealand	X	X	USA	USA	X	
OMN	Oman	X		VEN	Venezuela	X	
PAK	Pakistan	X		VNM	Viet Nam	X	X
PAN	Panama	X	X	YEM	Yemen	X	
PER	Peru	X	X	ZAF	South Africa	X	X
PHL	Philippines	X	X	ZMB	Zambia	X	
POL	Poland	X	X	ZWE	Zimbabwe	X	X

Table 12: List of recipient country by absorptive capacity group and OECD status

Country name	Country iso3	Tertiary enrollment	High capacity	OECD	Country name	Country iso3	Tertiary enrollment	High capacity	OECD
Afghanistan	AFG	3.7%	0	0	Congo	COG	6.1%	0	0
Albania	ALB	32.6%	1	0	Costa Rica	CRI	47.8%	1	0
Algeria	DZA	24.5%	1	0	Cote dIvoire	CIV	7.4%	0	0
Angola	AGO	3.5%	0	0	Croatia	HRV	45.7%	1	0
Antigua and Barbuda	ATG	15.9%	0	0	Cuba	CUB	51.1%	1	0
Argentina	ARG	67.4%	1	0	Curaçao	CUW	21.4%	1	0
Armenia	ARM	40.0%	1	0	Cyprus	CYP	35.6%	1	0
Aruba	ABW	29.1%	1	0	Czech Rep.	CZE	45.2%	1	1
Australia	AUS	93.6%	1	1	North Korea	PRK	29.8%	1	0
Austria	AUT	67.6%	1	1	Denmark	DNK	69.8%	1	1
Azerbaijan	AZE	20.6%	1	0	Djibouti	DJI	1.9%	0	0
Bahamas	BHS	15.1%	0	0	Dominican Rep.	DOM	42.2%	1	0
Bahrain	BHR	32.4%	1	0	Ecuador	ECU	33.6%	1	0
Bangladesh	BGD	8.8%	0	0	Egypt	EGY	29.6%	1	0
Barbados	BRB	55.2%	1	0	El Salvador	SLV	24.4%	1	0
Belarus	BLR	68.1%	1	0	Equatorial Guinea	GNQ	1.8%	0	0
Belgium	BEL	63.3%	1	1	Eritrea	ERI	1.7%	0	0
Belize	BLZ	19.7%	0	0	Estonia	EST	60.9%	1	1
Benin	BEN	8.3%	0	0	Ethiopia	ETH	3.3%	0	0
Bermuda	BMU	28.7%	1	0	Fiji	FJI	16.0%	0	0
Bhutan	BTN	6.5%	0	0	Finland	FIN	86.4%	1	1
Bosnia Herzegovina	BIH	22.3%	1	0	France	FRA	56.0%	1	1
Br. Virgin Isds	VGB	55.0%	1	0	FS Micronesia	FSM	14.1%	0	0
Brazil	BRA	33.4%	1	0	Gabon	GAB	7.9%	0	0
Brunei Darussalam	BRN	17.9%	0	0	Gambia	GMB	2.1%	0	0
Bulgaria	BGR	50.9%	1	0	Georgia	GEO	38.8%	1	0
Burkina Faso	BFA	2.9%	0	0	Germany	DEU	55.1%	1	1
Burundi	BDI	2.7%	0	0	Ghana	GHA	11.1%	0	0
Cabo Verde	CPV	12.3%	0	0	Greece	GRC	74.4%	1	0
Cambodia	KHM	6.1%	0	0	Grenada	GRD	78.4%	1	0
Cameroon	CMR	9.1%	0	0	Guatemala	GTM	15.3%	0	0
Canada	CAN	79.3%	1	1	Guinea	GIN	6.3%	0	0
Central African Rep.	CAF	2.2%	0	0	Guinea-Bissau	GNB	2.4%	0	0
Chad	TCD	1.4%	0	0	Guyana	GUY	10.9%	0	0
Chile	CHL	55.2%	1	1	Honduras	HND	15.6%	0	0
China	CHN	19.8%	0	0	Hungary	HUN	49.7%	1	1
China Hong Kong SAR	HKG	52.9%	1	0	Iceland	ISL	62.3%	1	1
China Macao SAR	MAC	54.2%	1	0	India	IND	15.2%	0	0
Colombia	COL	33.7%	1	0	Indonesia	IDN	19.2%	0	0

Comoros	COM	5.2%	0	0	Iran	IRN	35.6%	1	0

Country name	Country iso3	Tertiary enrollment	High capacity	OECD	Country name	Country iso3	Tertiary enrollment	High capacity	OECD
Iraq	IRQ	13.7%	0	0	Pakistan	PAK	7.2%	0	0
Ireland	IRL	54.9%	1	1	Palau	PLW	46.2%	1	0
Israel	ISR	57.1%	1	1	Panama	PAN	41.0%	1	0
Italy	ITA	58.0%	1	1	Papua New Guinea	PNG	2.5%	0	0
Jamaica	JAM	21.5%	1	0	Paraguay	PRY	23.4%	1	0
Japan	JPN	54.3%	1	1	Peru	PER	31.5%	1	0
Jordan	JOR	33.7%	1	0	Philippines	PHL	29.7%	1	0
Kazakhstan	KAZ	42.9%	1	0	Poland	POL	59.5%	1	1
Kenya	KEN	3.1%	0	0	Portugal	PRT	55.8%	1	1
Kuwait	KWT	23.1%	1	0	Qatar	QAT	16.5%	0	0
Kyrgyzstan	KGZ	39.3%	1	0	Rep. of Korea	KOR	85.7%	1	1
Lao	LAO	9.7%	0	0	Rep. of Moldova	MDA	35.8%	1	0
Latvia	LVA	60.7%	1	0	Romania	ROU	41.4%	1	0
Lebanon	LBN	43.2%	1	0	Russian Federation	RUS	66.7%	1	0
Liberia	LBR	12.2%	0	0	Rwanda	RWA	4.5%	0	0
Libya	LBY	54.7%	1	0	Saint Lucia	LCA	14.6%	0	0
Lithuania	LTU	64.6%	1	0	Samoa	WSM	9.5%	0	0
Madagascar	MDG	3.0%	0	0	San Marino	SMR	63.0%	1	0
Malawi	MWI	0.5%	0	0	Sao Tome and Principe	STP	7.8%	0	0
Malaysia	MYS	33.6%	1	0	Saudi Arabia	SAU	33.0%	1	0
Maldives	MDV	8.9%	0	0	Senegal	SEN	7.5%	0	0
Mali	MLI	3.8%	0	0	Serbia	SRB	48.8%	1	0
Malta	MLT	32.2%	1	0	Seychelles	SYC	8.5%	0	0
Marshall Isds	MHL	29.6%	1	0	Sierra Leone	SLE	1.8%	0	0
Mauritania	MRT	4.0%	0	0	Slovakia	SVK	39.6%	1	1
Mauritius	MUS	23.0%	1	0	Slovenia	SVN	69.0%	1	1
Mexico	MEX	23.4%	1	1	South Africa	ZAF	19.8%	0	0
Mongolia	MNG	42.9%	1	0	Spain	ESP	68.8%	1	1
Montenegro	MNE	32.0%	1	0	Sri Lanka	LKA	17.9%	0	0
Morocco	MAR	15.1%	0	0	State of Palestine	PSE	36.9%	1	0
Mozambique	MOZ	3.5%	0	0	Sudan	SDN	12.7%	0	0
Myanmar	MMR	10.4%	0	0	Suriname	SUR	12.7%	0	0
Nepal	NPL	9.5%	0	0	Sweden	SWE	67.2%	1	1
Netherlands	NLD	59.6%	1	1	Switzerland	CHE	46.3%	1	1
New Zealand	NZL	73.8%	1	1	Syria	SYR	25.6%	1	0
Nicaragua	NIC	13.1%	0	0	Tajikistan	TJK	21.6%	1	0
Niger	NER	1.2%	0	0	TFYR of Macedonia	MKD	29.7%	1	0
Nigeria	NGA	9.3%	0	0	Thailand	THA	40.7%	1	0
Norway	NOR	72.0%	1	1	Timor-Leste	TLS	14.9%	0	0
Oman	OMN	21.2%	1	0	Togo	TGO	7.8%	0	0

Country name	Country iso3	Tertiary enrollment	High capacity	OECD	Country name	Country iso3	Tertiary enrollment	High capacity	OECD
Tonga	TON	4.9%	0	0	Uruguay	URY	44.7%	1	0
Trinidad and Tobago	TTO	8.0%	0	0	USA	USA	76.4%	1	1
Tunisia	TUN	27.3%	1	0	Uzbekistan	UZB	10.6%	0	0
Turkey	TUR	44.7%	1	1	Vanuatu	VUT	4.3%	0	0
Turkmenistan	TKM	8.0%	0	0	Venezuela	VEN	50.4%	1	0
Uganda	UGA	3.3%	0	0	Viet Nam	VNM	16.5%	0	0
Ukraine	UKR	66.2%	1	0	Yemen	YEM	9.7%	0	0
United Arab Emirates	ARE	23.1%	1	0	Zambia	ZMB	3.2%	0	0
United Kingdom	GBR	57.7%	1	1	Zimbabwe	ZWE	6.5%	0	0
United Rep. of Tanzania	TZA	1.5%	0	0					

Note: the figures on tertiary enrolment are averages over the observation period. Countries with high capacities have tertiary enrolment rate higher than 20% which is the median of the distribution.

Table 13: List of the technologies in the patent classification

Energy generation from renewable and non-fossil sources	
Hydro power	Hydro power stations; hydraulic turbines; submerged units incorporating electric generators; devices for controlling hydraulic turbines
Solar PV	Solar photovoltaic (conversion of light radiation into electrical energy), incl. solar panels
Solar thermal	Use of solar heat for heating & cooling
Wind power	Wind motors (mechanisms for converting the energy of natural wind into mechanical power, and transmission of such power to its point of use); blades; devices aimed at controlling wind motors
Emissions abatement and fuel efficiency in transportation	
Electric vehicles	Electric propulsion of vehicles; arrangement of batteries
Hybrid vehicles	Hybrid propulsion systems comprising electric motors and internal combustion engines
Energy Efficiency in Buildings and Lighting	
Heating	Hot-water and hot-air central heating systems using heat pumps; energy recovery systems in air conditioning, ventilation or screening; heat pumps
Insulation	Elements or materials used for heat insulation; double-glazed windows
Lighting	Compact fluorescent lamps; electroluminescent light sources (LED)

Table 14: List of low-carbon equipment goods

Technology	Code in the harmonized system	Description
Renewable power generation		
Hydro power	841011	Hydraulic turbines & water wheels, of a power not > 1000kW
	841012	Hydraulic turbines & water wheels, of a power > 1000kW but not >10000kW
	841013	Hydraulic turbines & water wheels, of a power > 10000kW
	841090	Parts (incl. regulators) of the hydraulic turbines & water wheels of 8410.11-8410.13
Solar PV	854140	Photosensitive semiconductor devices, incl. photovoltaic cells whether/not assembled in modules/made up into panels; light emitting diodes
Solar thermal	841919	Instantaneous/storage water heaters, non-electric (excl. of 8419.11)
Wind power	850231	Wind-powered electric generating sets
Energy efficiency in building		
Heating	903210	Thermostats
	841861	Compression-type refrigerating/freezing equip. whose condensers are heat exchangers, heat pumps other than air conditioning machines of heading 84.15
	841950	Heat exchange units, whether/not electrically heated
Insulation	680610	Slag wool, rock wool & similar mineral wools (incl. intermixtures thereof), in bulk/sheets/rolls
	680690	Mixtures & articles of heat-insulating/sound-insulating/sound-absorbing mineral materials (excl. of 68.11/68.12/Ch.69)
	700800	Multiple-walled insulating units of glass
	701939	Webs, mattresses, boards & similar non-woven products of glass fibres
Lighting	853931	Electric discharge lamps (excl. ultra-violet lamps), fluorescent, hot cathode
Other sectors		
Cleaner vehicles	870390	Vehicles principally designed for the transport of persons (excl. of 87.02 & 8703.10-8703.24), with C-I internal combustion piston engine (diesel/semi-diesel), n.e.s. in 87.03

Table 15: List of NACE codes of the target industries by technology

Hydro	Solar PV	Solar thermal	Wind	Heating	Insulation	Lighting	Cleaner vehicles
2351	0729	2013	2013	2521	1712	2611	2611
2361	2013	2221	2060	2651	1729	2660	2651
2651	2221	2311	2410	2751	2013	2670	2711
2711	2311	2319	2420	2790	2014	2712	2720
2712	2319	2521	2511	2813	2016	2720	2790
2790	2611	2611	2599	2814	2060	2731	2812
2811	2612	2651	2611	2825	2229	2740	2815
2813	2651	2670	2651	3530	2311	2790	2899
2815	2670	2711	2711	4120	2319	4120	2910
2899	2711	2712	2712	4299	2361	4321	2931
3315	2712	2720	2720	4321	2399	7112	2932
3511	2720	2731	2790	4322	2512	7120	3091
3513	2731	2790	2811	7112	2521	7219	4511
4222	2790	2811	2815	7120	2651		4519
4299	2899	2813	2899	7219	2712		5229
7112	3511	2899	3030		4120		7112
7120	3513	3511	3312		7112		7120
7219	4222	3513	3315		7120		7219
	4321	4222	3511		7219		7711
	7112	4299	3513				
	7120	7112	4222				
	7219	7120	4299				
		7219	7112				
			7120				
			7219				

The labels of these industry codes are available at http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

Table 16: Variable definition and data sources

Variable	Definition	Source
Dependent variable		
Shipment of low-carbon equipment	Volume of trade flows in low-carbon equipment between two countries.	Cepii's BACI database
Number of FDI deals	Number of deals between two countries where the investor owns a low-carbon patent in any country.	Bureau Van Dijk's Zephyr database and PATSTAT database
Regressors		
IPR protection index	This index is the multiplication of the WEF intellectual property right index and the Fraser Institute's legal system and property rights index. It is rescaled from 0 to 10.	World Economic Forum's Global Competitiveness Report and Fraser Institute's Economic Freedom of the World 2015
WEF IPR index	Score from 1 to 7 quantifying the extent of protection of intellectual property. The country-level score is obtained through aggregation of the surveys completed by executives randomly sampled.	World Economic Forum's Executives Opinion Survey
Park index	Park and Lippoldt (2008) is an index of patent protection rights determined by the summation of 5 components: (i) extent of coverage, (ii) membership in international treaties, (iii) duration of protection, (iv) absence of restrictions on rights, and (v) statutory enforcement provision.	Park and Lippoldt (2008)
Legal system and property rights	This index is built from the aggregation of 4 components: (i) legal enforcement of contracts, (ii) judicial independence, (iii) impartial courts, and (iv) the integrity of the legal system.	Fraser Institute's Economic Freedom of the World 2015
Log (parent/exporter GDP)	Parent/exporter country's Gross Domestic Product in current USD.	World Bank's World Development Indicators
Log (host/importer GDP)	Recipient/importer country's Gross Domestic Product in current USD.	World Bank's World Development Indicators
Environmental regulations	Environmental Performance Index ranks 180 countries on 24 performance indicators across ten issue categories covering environmental health and ecosystem vitality.	Yale University
Effectively Applied Tariff	Simple Average of Effectively Applied Ad Valorem tariff computed at the technology level.	TRAINS
Number of Non-Tariff Measures	Number of imports and non-IPR related non-tariff measures computed at the technology level.	TRAINS
Freedom of FDI and movement of people (0 - 10 best)	The index is constructed through the calculation and aggregation of 3 indicators: (i) foreign ownership/investment restrictions, (ii) capital controls, and (iii) freedom of foreigners to visit.	Fraser Institute's Economic Freedom of the World 2015
Labor regulations (0 - 10 flexible)	The index is constructed through the calculation and aggregation of 6 indicators: (i) difficulty of hiring, (ii) flexibility of hiring and firing regulations, (iii) centralization of wage bargaining, (iv) rigidity of working hours, (v) mandated cost of worker dismissal, and (vi) military conscription.	Fraser Institute's Economic Freedom of the World 2015
Burden of business regulations (0 - 10 flexible)	The index is constructed through the calculation and aggregation of 6 indicators: (i) administrative requirements, (ii) bureaucracy costs, (iii) time and money required to start a business, (iv) extra payments frequency, (v) licensing restrictions, and (vi) cost of tax compliance.	Fraser Institute's Economic Freedom of the World 2015
Absorptive capacities	Enrollment in tertiary education	World Bank's World Development Indicators

Descriptive statistics and stylized facts

Table 17: Summary statistics for the trade model estimation

Variable	Obs	Mean	Std. Dev.	Min	Max
Shipment value in thousand USD					
Hydro	25,301	284	2,098	0	102,441
Solar PV	25,301	8,139	91,995	0	5,201,144
Solar thermal	25,301	283	2,130	0	108,550
Wind power	25,301	1,185	12,802	0	581,000
Heating	25,301	2,832	12,295	0	310,800
Insulation	25,301	1,297	6,859	0	189,535
Lighting	25,301	937	7,876	0	328,474
Cleaner vehicles	25,301	635	7,279	0	478,743
Regressors					
Importer IP protection	25,301	4.67	2.25	0.82	10.00
Importer Absorptive capacities	25,301	0.52	0.24	0.01	1.17
Importer Log (GDP)	25,301	26.19	1.79	20.62	29.98
Importer Log (per capita GDP)	25,301	9.37	1.31	5.68	11.02
Importer Environmental regulations	25,301	76.34	12.24	38.35	90.89
Country pair in Trade Agreement	25,301	0.41	0.49	0	1
Exporter Log (GDP)	25,301	5.10	2.38	0	10
Exporter Log (per capita GDP)	25,301	26.38	1.76	20.54	30.49
Exporter IP protection	25,301	9.56	1.26	5.45	11.43
Exporter Environmental regulations	25,301	77.00	10.88	29.75	91.05
Year	25,301	2011	3	2006	2015

Table 18: Discounted stock of low-carbon technologies

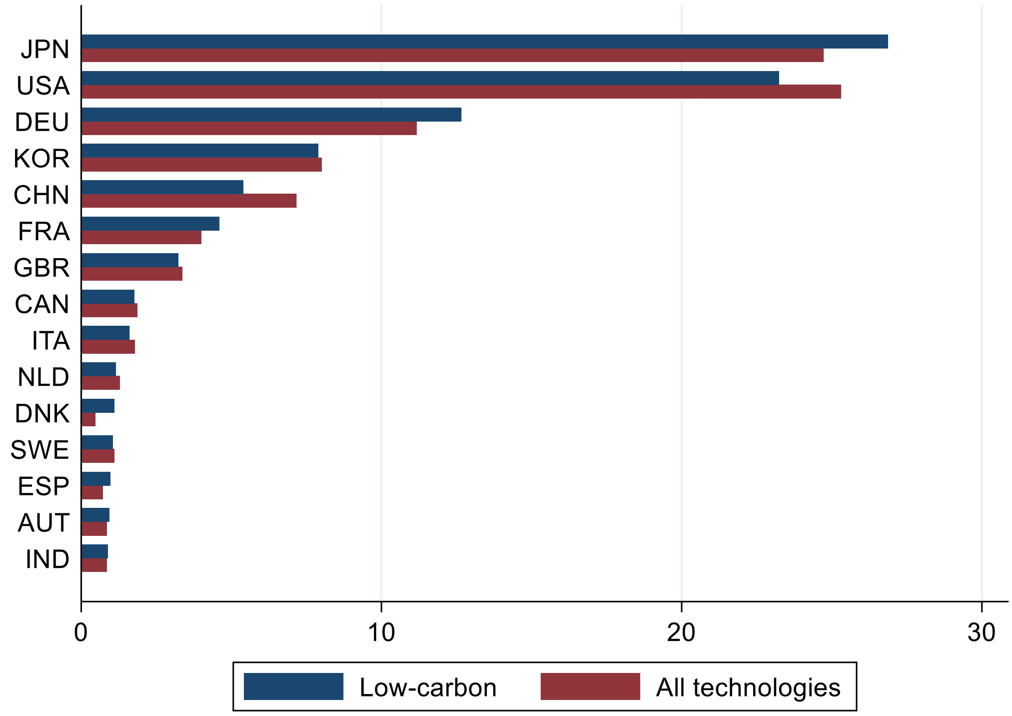
Technology	Number of countries	Countries with positive stock (%)	Mean	Std. Dev.	Min	Max
Heating	79	18	24	211	0	1,877
Insulation	79	5	3	22	0	197
Solar PV	79	37	58	497	0	4,414
Wind power	79	32	71	617	0	5,481

Notes: Authors' calculation from PATSTAT data for the sample of low absorptive capacity countries. Values of 2016 are used.

Table 19: Summary statistics for the FDI model estimation

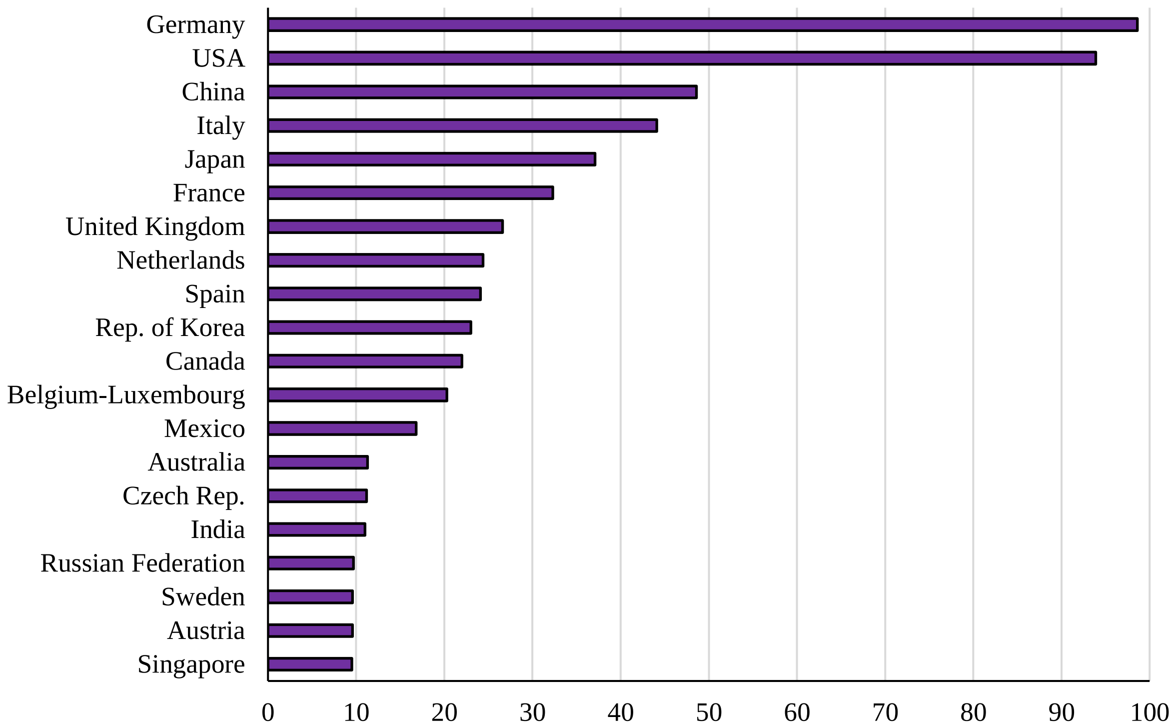
Variable	Obs	Mean	Std. Dev.	Min	Max
Number of FDI deals					
Hydro	22,312	0.03	0.52	0	31
Solar PV	23,369	0.07	1.53	0	93
Solar thermal	22,180	0.06	1.12	0	93
Wind power	25,666	0.06	1.04	0	50
Heating	19,864	0.04	1.02	0	95
Insulation	16,655	0.01	0.32	0	19
Lighting	18,679	0.05	1.09	0	93
Cleaner vehicles	22,388	0.07	1.38	0	93
Regressors					
Importer IP protection	25,666	5.47	2.41	1.52	10.00
Importer Absorptive capacities	25,666	0.60	0.21	0.10	1.17
Importer Log (GDP)	25,666	26.92	1.28	23.28	29.98
Importer Log (per capita GDP)	25,666	9.85	1.09	6.88	11.60
Importer Environmental regulations	25,666	79.35	9.05	52.06	90.89
Importer lbusiness regulations	25,666	6.69	1.14	3.38	8.89
Importer labor market regulations	25,666	6.25	1.24	3.83	8.69
Importer controls capital and people movements	25,666	5.55	1.58	1.60	8.80
Country pair in Trade Agreement	25,666	0.40	0.49	0	1
Exporter IP protection	25,666	4.76	2.31	1.10	10.00
Exporter Log (GDP)	25,666	26.06	1.66	22.21	30.49
Exporter Log (per capita GDP)	25,666	9.46	1.21	6.39	11.63
Exporter Environmental regulations	25,666	76.75	9.18	52.06	91.05
Contiguity	25,666	0.04	0.19	0	1
Common language	25,666	0.07	0.25	0	1
Former colonial relationship	25,666	0.03	0.18	0	1
Log distance between most populated cities	25,666	8.41	1.07	2.95	9.89
Year	25,666	2011	3	2006	2015

Figure 3: Top 15 inventors of technologies



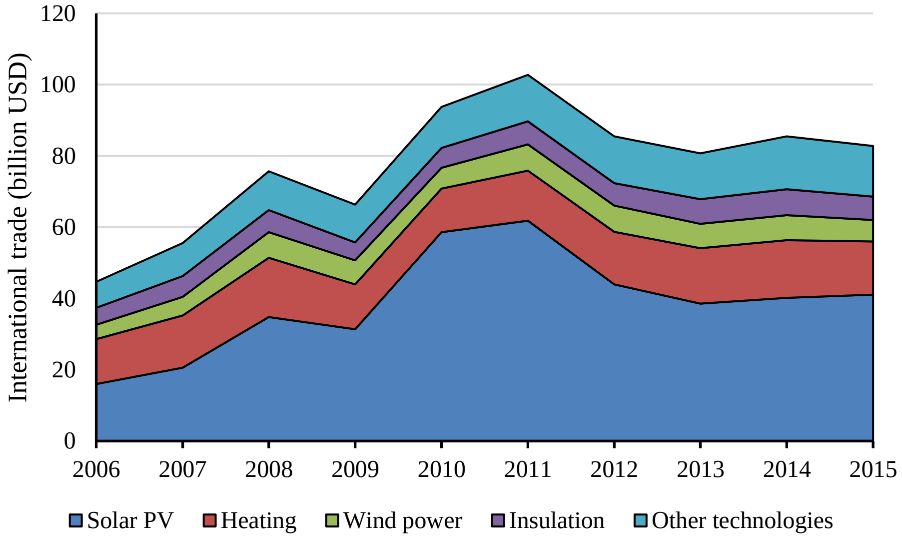
Note: Share of world's discounted stock of high value inventions in 2016. Authors' calculation from Patstat data.

Figure 4: Top 20 importers of low-carbon capital goods



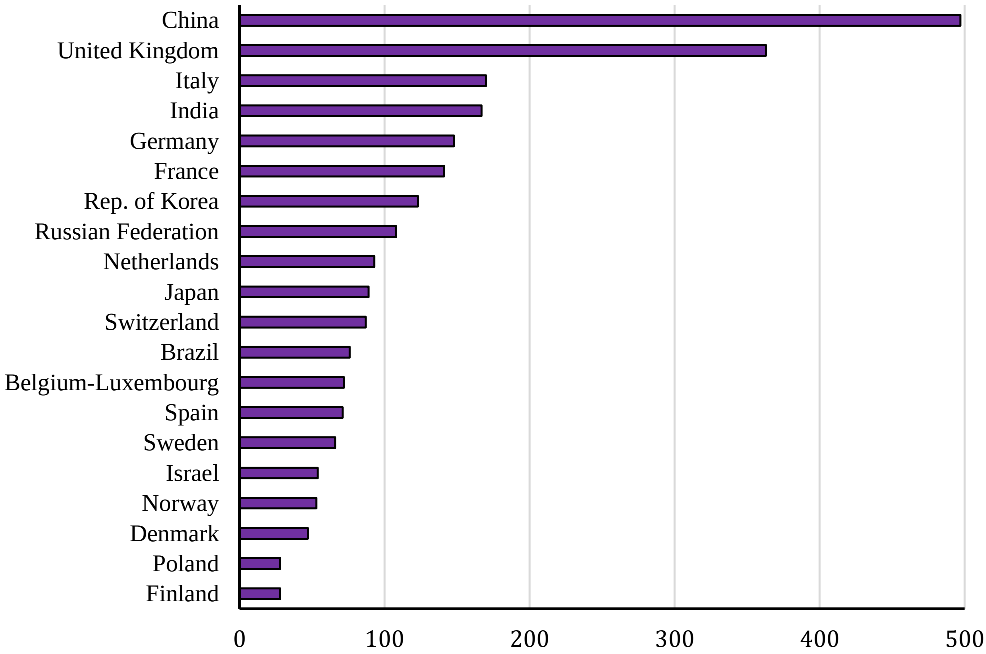
Note: Total imports in billion USD during the 2006-2015 period. Authors' calculation based on the estimation sample.

Figure 5: Evolution of global trade in low-carbon capital goods



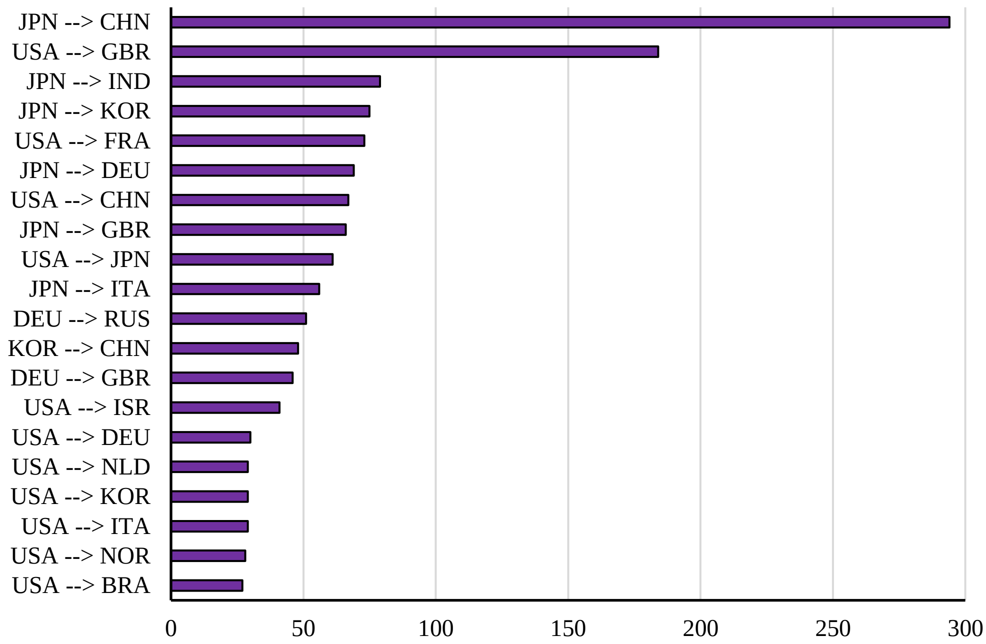
Note: Total imports in billion USD. Authors' calculation based on the estimation sample. Other technologies include solar thermal, hydro power, lighting, and cleaner vehicles.

Figure 6: Top 20 recipients of low-carbon FDI deals



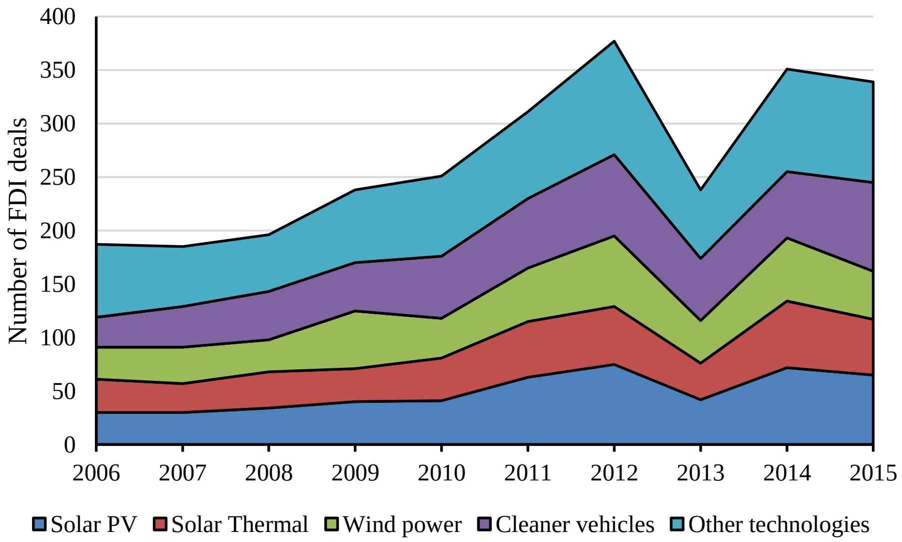
Note: Sum of deals during the 2006-2015 period. Authors' calculation based on the estimation sample.

Figure 7: Top 20 country-pairs of low-carbon FDI deals



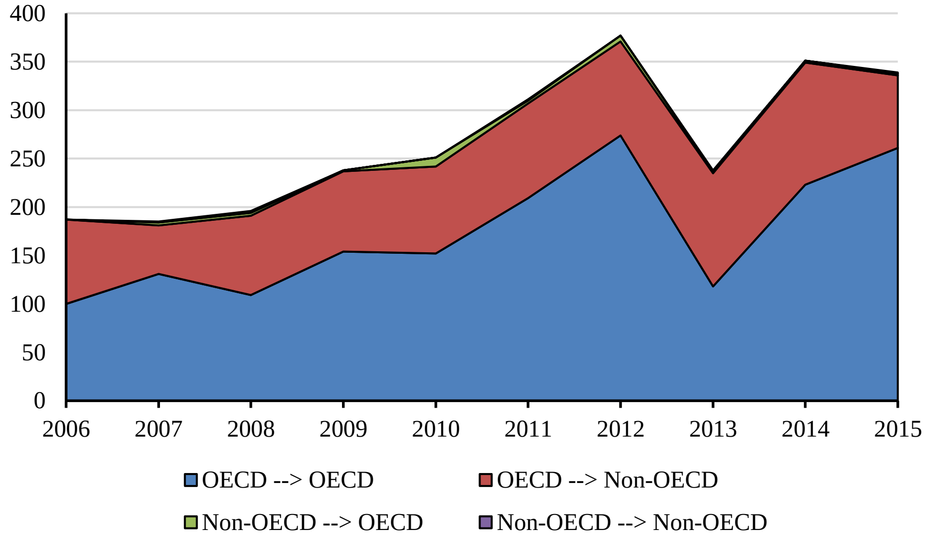
Note: Sum of deals during the 2006-2015 period. Authors' calculation based on the estimation sample.

Figure 8: Evolution of foreign direct investment in low-carbon technologies



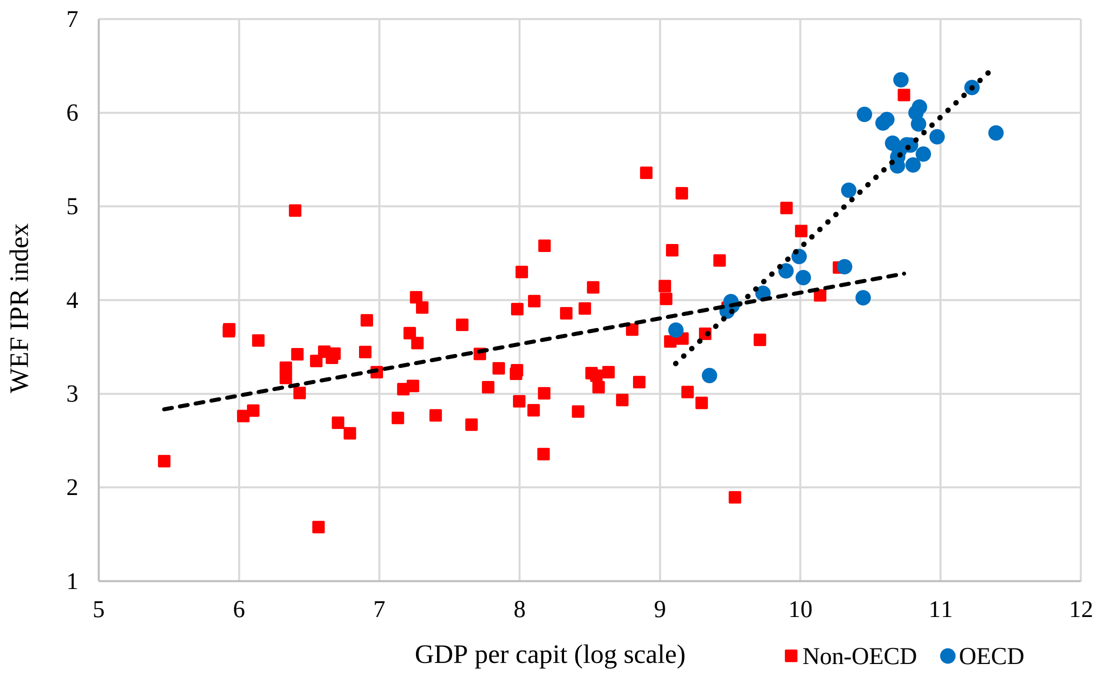
Note: Authors' calculation based on the estimation sample. Other technologies include hydro power, heating, insulation, and lighting.

Figure 9: Evolution of pattern of foreign direct investment in low-carbon technologies



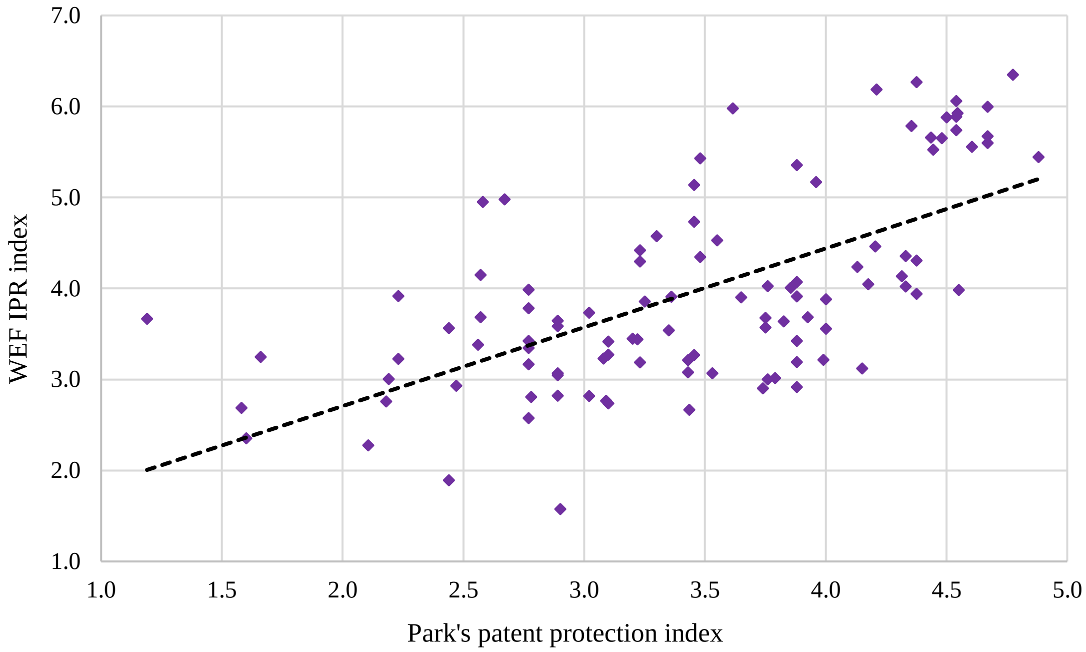
Note: Authors' calculation based on the estimation sample.

Figure 10: Correlation between WEF IPR index and GDP per capita



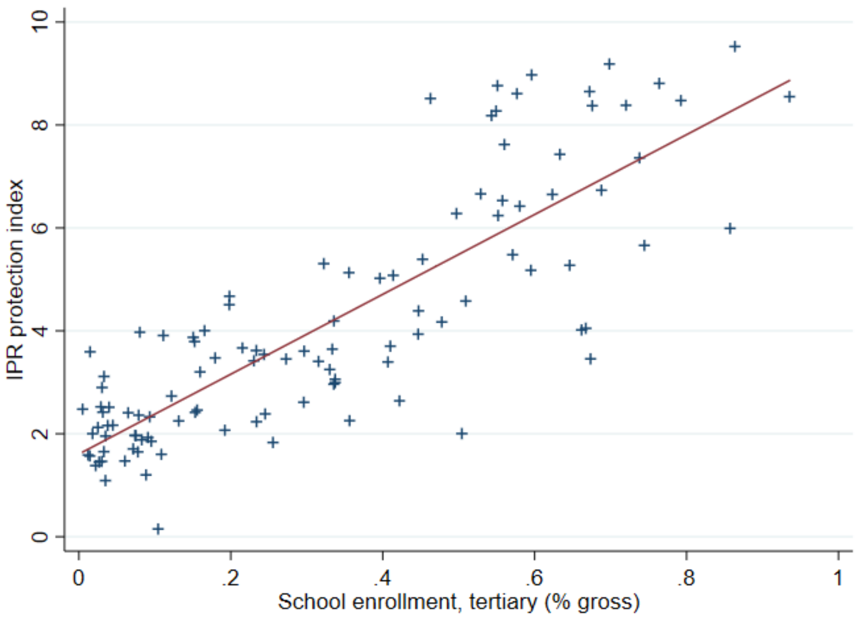
Note: Values average over 2010 and 2015.

Figure 11: Correlation between WEF IPR index and Park's patent protection index



Note: Values average over 2010 and 2015.

Figure 12: Correlation between IPR protection and absorptive capacities



Note: Averages over the sample period. Each cross is a country.

Additional regression results

Table 20: Effect of IPR protection on imports in non-OECD and OECD countries

	Hydro	Solar PV	Solar Thermal	Wind power	Heating	Insulation	Lighting	Cleaner vehicles
Importer IP protection	0.196	-0.470	0.076	0.432	0.118	0.002	-0.082	-0.245
	(0.173)	(0.346)	(0.086)	(0.370)	(0.079)	(0.094)	(0.145)	(0.251)
Importer IP protection x OECD	-0.407*	1.297**	0.029	0.000	-0.047	-0.014	0.028	0.133
	(0.226)	(0.573)	(0.123)	(0.462)	(0.090)	(0.098)	(0.170)	(0.299)
Importer Absorptive capacities	-0.773	-3.909	-0.646	-1.082	-0.748**	-0.536	0.168	1.644
	(1.410)	(3.043)	(0.689)	(1.420)	(0.359)	(0.336)	(0.614)	(1.320)
Importer Log (GDP)	1.978**	1.744**	0.808	0.783	0.226	0.221	1.374***	0.103
	(0.822)	(0.749)	(0.601)	(1.101)	(0.197)	(0.353)	(0.394)	(1.017)
Importer Log (per capita GDP)	-5.710***	-0.105	-0.733	-0.949	0.188	0.937	-1.335	-1.01
	(1.573)	(1.287)	(1.033)	(3.225)	(0.373)	(0.578)	(1.070)	(1.971)
Importer Environmental Regulations	0.007	0.109	0.065	-0.119	0.017	-0.031	0.022	0.107
	(0.076)	(0.102)	(0.055)	(0.118)	(0.021)	(0.020)	(0.033)	(0.116)
Importer Effectively Applied Tariff	-0.104***	-0.04	0.007	-0.028	-0.022**	-0.026	-0.035*	-0.029***
	(0.022)	(0.046)	(0.018)	(0.026)	(0.011)	(0.018)	(0.018)	(0.004)
Importer Nr. of Non-Tariff Measures	0.002	-0.224***	-0.033	-0.097	0.002	0.008	-0.022**	0.073
	(0.011)	(0.063)	(0.021)	(0.093)	(0.002)	(0.008)	(0.009)	(0.077)
Country pair in Trade Agreement (0/1)	-0.212	-0.004	0.834***	0.135	0.343**	0.304**	-0.219**	-0.1
	(0.187)	(0.233)	(0.280)	(0.591)	(0.139)	(0.129)	(0.105)	(0.257)
Exporter Log (GDP)	0.003	0.007	0.205***	0.068	0.014	0.064*	0.049	-0.056
	(0.091)	(0.060)	(0.066)	(0.130)	(0.025)	(0.033)	(0.059)	(0.205)
Exporter Log (per capita GDP)	-0.537	-0.736***	-0.622	2.667	0.111	-0.204	0.459	3.779**
	(0.463)	(0.186)	(0.541)	(1.900)	(0.168)	(0.158)	(0.314)	(1.871)
Exporter IP protection	2.407***	3.547***	1.455*	-3.316	0.497	1.321***	0.189	-9.150**
	(0.831)	(0.618)	(0.870)	(3.322)	(0.342)	(0.438)	(0.565)	(3.931)
Exporter Environmental Regulations	0.071	-0.042	-0.042	0.232*	0.083***	0.017	0.018	0.069
	(0.055)	(0.035)	(0.043)	(0.122)	(0.022)	(0.018)	(0.044)	(0.183)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-pair fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Nr. Observations	15,423	25,301	16,132	9,410	27,033	20,824	19,535	13,231
Nr. Country pairs	1,872	3,102	1,946	1,093	3,328	2,526	2,393	1,651

Notes: robust standard errors clustered at the recipient country level in parentheses. * Significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level. All columns are estimated with the Pseudo Poisson Maximum Likelihood Estimator with all regressors lagged one year.

Table 21: Effect of IPR protection on FDI in non-OECD and OECD countries

	Hydro	PV	Solar thermal	Wind	Heating	Insulation	Lighting	Cleaner vehicles
Importer IP protection	0.241*	0.359***	0.301**	0.207	0.593**	-0.077	0.759***	0.353***
	(0.146)	(0.126)	(0.140)	(0.147)	(0.236)	(0.275)	(0.197)	(0.121)
Importer IP protection x OECD	-0.19	-0.211*	-0.082	-0.083	-0.323*	0.032	-0.501***	-0.111
	(0.148)	(0.122)	(0.135)	(0.122)	(0.193)	(0.359)	(0.189)	(0.128)
Importer Absorptive capacities	1.399***	0.811	1.035	1.885**	-0.35	1.731*	0.167	0.496
	(0.499)	(0.826)	(0.982)	(0.880)	(1.407)	(0.993)	(1.148)	(0.605)
Importer Log (GDP)	0.787***	0.795***	0.841***	1.019***	0.821***	1.038***	0.848***	0.858***
	(0.127)	(0.104)	(0.115)	(0.116)	(0.136)	(0.163)	(0.150)	(0.097)
Importer Log (per capita GDP)	-0.118	0.209	-0.066	-0.624**	0.156	0.086	0.959***	0.063
	(0.257)	(0.261)	(0.312)	(0.275)	(0.466)	(0.588)	(0.343)	(0.223)
Importer Environmental regulations	-0.004	-0.035*	-0.018	0.026	0.013	-0.028	-0.095***	-0.048***
	(0.019)	(0.020)	(0.020)	(0.024)	(0.026)	(0.024)	(0.029)	(0.015)
Exporter Log (per capita GDP)	-0.041	-0.071	-0.141	0.070	-0.082	-0.107	-0.362	-0.401**
	(0.265)	(0.236)	(0.275)	(0.226)	(0.421)	(0.401)	(0.292)	(0.189)
Importer labor market regulations	-0.058	-0.166**	-0.260***	-0.182***	-0.528***	-0.063	-0.233***	-0.101*
	(0.075)	(0.067)	(0.045)	(0.063)	(0.073)	(0.103)	(0.086)	(0.058)
Importer controls of capital and people movement	-0.079	-0.054	-0.115	-0.166*	-0.126	-0.014	0.199*	-0.003
	(0.072)	(0.100)	(0.122)	(0.099)	(0.157)	(0.153)	(0.104)	(0.094)
Country pair in Trade agreement	-0.928***	-1.204***	-1.485***	-1.222***	-1.951***	-1.570***	-1.138***	-1.072***
	(0.245)	(0.299)	(0.326)	(0.284)	(0.414)	(0.495)	(0.422)	(0.277)
Exporter IP protection	0.232	0.264**	0.256**	0.194	0.348**	0.606**	0.272	0.255***
	(0.146)	(0.130)	(0.125)	(0.120)	(0.139)	(0.264)	(0.189)	(0.089)
Exporter Log (GDP)	1.479***	1.454***	1.269***	1.341***	1.231***	1.617***	1.694***	1.339***
	(0.108)	(0.128)	(0.109)	(0.121)	(0.111)	(0.136)	(0.139)	(0.073)
Exporter Log (per capita GDP)	0.697	0.816*	0.475	0.152	-0.153	1.959***	1.287***	0.753**
	(0.524)	(0.487)	(0.509)	(0.466)	(0.521)	(0.556)	(0.472)	(0.370)
Exporter Environmental regulations	-0.110***	-0.138***	-0.073**	-0.044	-0.04	-0.225***	-0.212***	-0.119***
	(0.039)	(0.031)	(0.037)	(0.031)	(0.043)	(0.040)	(0.028)	(0.023)
Contiguity	-1.257***	-1.550***	-1.064***	-1.058***	-1.655***	-1.364**	-3.363***	-1.675***
	(0.361)	(0.376)	(0.389)	(0.315)	(0.468)	(0.601)	(0.570)	(0.386)
Common official language	0.727	1.025***	0.740**	0.932**	1.689***	0.88	1.560***	0.601
	(0.459)	(0.396)	(0.344)	(0.470)	(0.371)	(0.598)	(0.413)	(0.526)
Colonial relationship	-0.168	-0.161	-0.246	-0.202	0.087	-1.195***	-0.385	-0.087
	(0.377)	(0.324)	(0.295)	(0.384)	(0.496)	(0.345)	(0.392)	(0.261)
Log distance between most populated cities	-1.286***	-1.369***	-1.320***	-1.398***	-1.544***	-1.149***	-1.382***	-1.257***
	(0.155)	(0.119)	(0.119)	(0.146)	(0.141)	(0.166)	(0.168)	(0.097)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	23,055	24,037	23,583	25,666	22,469	17,839	18,679	23,791
Country-pairs	2,812	3,040	2,964	3,192	2,736	2,128	2,356	2,812

Notes: Robust standard errors in parentheses. * Significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level. All columns are estimated with the Pseudo Poisson Maximum Likelihood Estimator with all regressors lagged one year. The dependent variable is the number of inward FDI deals computed from Zephyr and Patstat data. The Intellectual property rights protection (IPR) index is the intellectual property rights index from the World Economic Forum's Executive Opinion Survey multiplied by the legal systems and property rights from the 2014 Economic Freedom Dataset published by the Fraser Institute. Absorptive capacities are measured by enrollment in tertiary education. Importer business regulations, labor market regulations, and controls of the movement of capital and people come from the 2014 Economic Freedom Dataset published by the Fraser Institute. The country-pair trade agreement equals 1 if both countries are in a free trade agreement or a custom union based on the WTO Regional Trade Agreements Information System. Environmental regulations are measured by the Environmental Performance Index from Yale University.

Table 22: IPR protection and trade in low-carbon capital goods for countries in the FDI sample

	Hydro	Solar PV	Solar Thermal	Wind power	Heating	Insulation	Lighting	Cleaner vehicles
Importer IPR protection	-0.254**	0.441*	0.148***	0.408**	0.074**	-0.004	-0.095	0.002
	(0.110)	(0.248)	(0.055)	(0.193)	(0.033)	(0.043)	(0.083)	(0.180)
Importer Absorptive capacities	-0.696	-4.711	-0.332	-1.626	-0.728*	-0.770*	0.636	2.854***
	(1.106)	(3.748)	(0.800)	(2.028)	(0.442)	(0.396)	(0.863)	(1.010)
Importer Log (GDP)	2.725***	1.325	1.343**	-0.167	0.031	0.155	1.582***	1.02
	(0.922)	(0.826)	(0.587)	(1.083)	(0.149)	(0.368)	(0.613)	(1.688)
Importer Log (per capita GDP)	-7.110***	0.898	-1.477	-0.184	0.429	1.225*	-2.621*	-3.163
	(1.564)	(1.435)	(1.041)	(4.057)	(0.283)	(0.688)	(1.482)	(2.786)
Importer Environmental Regulations	0.000	-0.017	0.112*	-0.051	0.025	-0.022	-0.041	-0.071
	(0.088)	(0.130)	(0.059)	(0.170)	(0.022)	(0.032)	(0.028)	(0.142)
Importer Effectively Applied Tariff	-0.080*	-0.210***	0.009	-0.037	-0.033**	0.158	0.077	-0.025***
	(0.043)	(0.072)	(0.029)	(0.025)	(0.016)	(0.106)	(0.097)	(0.007)
Importer Nr. of Non-Tariff Measures	0.019**	-0.285***	-0.008	0.004	0.005***	0.003	-0.019**	0.076
	(0.007)	(0.072)	(0.011)	(0.088)	(0.002)	(0.008)	(0.008)	(0.097)
Country pair in Trade Agreement (0/1)	-0.133	0.058	0.478	1.046	0.081	0.566**	-0.429***	1.068
	(0.278)	(0.284)	(0.521)	(0.786)	(0.187)	(0.242)	(0.155)	(0.839)
Exporter Log (GDP)	0.125	0.019	0.177***	0.100	0.014	0.065*	0.059	-0.028
	(0.077)	(0.064)	(0.063)	(0.132)	(0.028)	(0.035)	(0.070)	(0.259)
Exporter Log (per capita GDP)	-0.495	-0.785***	-0.055	3.757*	0.05	-0.267	0.522	5.794***
	(0.579)	(0.210)	(0.360)	(2.057)	(0.181)	(0.168)	(0.334)	(2.081)
Exporter IPR protection	2.477**	3.498***	0.533	-5.486	0.564	1.304***	-0.099	-12.340***
	(1.210)	(0.619)	(0.610)	(3.509)	(0.378)	(0.484)	(0.632)	(4.454)
Exporter Environmental Regulations	0.040	-0.075	-0.023	0.274**	0.080***	0.03	0.021	0.079
	(0.059)	(0.048)	(0.045)	(0.139)	(0.026)	(0.021)	(0.049)	(0.205)
Year fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-pair fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Nr. Observations	8,701	13,219	9,144	6,236	13,539	9,238	8,513	7,272
Nr. Country pairs	1,872	3,102	1,946	1,093	3,328	2,526	2,393	1,651

Notes: robust standard errors clustered at the recipient country level in parentheses. * Significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level. All columns are estimated with the Pseudo Poisson Maximum Likelihood Estimator with all regressors lagged one year. The dependent variable is the shipment value in low-carbon goods expressed in thousands of current USD and computed from BACI data. The Intellectual property rights protection (IPR) index is the intellectual property rights index from the World Economic Forum's Executive Opinion Survey multiplied by the legal systems and property rights from the 2014 Economic Freedom Dataset published by the Fraser Institute. Absorptive capacities are measured by enrolment in tertiary education. Index of tariff barriers and non-tariff barriers are built from the TRAINS database. The country-pair trade agreement equals 1 if both countries are in a free trade agreement or a custom union based on the WTO Regional Trade Agreements Information System. Environmental regulations are measured by the Environmental Performance Index from Yale University.

Table 23: Effect of IPR protection on imports as a function of absorptive capacities

	Hydro	Solar PV	Solar Thermal	Wind power	Heating	Insulation	Lighting	Cleaner vehicles
Importer IP protection	0.024	-0.45	0.142	-1.221	0.207***	0.253***	-0.071	0.106
	(0.200)	(0.286)	(0.111)	(0.924)	(0.077)	(0.074)	(0.288)	(0.260)
Importer IP protection x high capacities	-0.053	1.143**	-0.044	1.726*	-0.150*	-0.285***	0.01	-0.292
	(0.257)	(0.497)	(0.140)	(0.981)	(0.087)	(0.085)	(0.317)	(0.298)
Importer Absorptive capacities	-0.807	-3.611	-0.647	-1.197	-0.729**	-0.506	0.176	1.815
	(1.422)	(3.247)	(0.695)	(1.292)	(0.365)	(0.331)	(0.607)	(1.339)
Importer Log (GDP)	1.921**	1.762**	0.795	0.797	0.215	0.173	1.366***	-0.026
	(0.806)	(0.770)	(0.614)	(1.048)	(0.195)	(0.346)	(0.417)	(1.004)
Importer Log (per capita GDP)	-5.658***	-0.268	-0.716	-0.857	0.195	1.026*	-1.325	-0.613
	(1.520)	(1.381)	(1.054)	(2.702)	(0.396)	(0.549)	(1.087)	(1.973)
Importer Environmental Regulations	0.007	0.067	0.063	-0.122	0.022	-0.031	0.022	0.102
	(0.077)	(0.100)	(0.051)	(0.118)	(0.020)	(0.020)	(0.035)	(0.113)
Importer Effectively Applied Tariff	-0.094***	-0.041	0.007	-0.033	-0.026*	-0.031**	-0.035*	-0.031***
	(0.021)	(0.048)	(0.018)	(0.024)	(0.013)	(0.016)	(0.018)	(0.004)
Importer Nr. of Non-Tariff Measures	0.004	-0.239***	-0.034*	-0.073	0.002	0.009	-0.023**	0.058
	(0.010)	(0.059)	(0.020)	(0.081)	(0.002)	(0.007)	(0.010)	(0.077)
Country pair in Trade Agreement (0/1)	-0.205	0.099	0.839***	-0.056	0.327**	0.301**	-0.220*	-0.111
	(0.191)	(0.227)	(0.266)	(0.576)	(0.134)	(0.127)	(0.113)	(0.270)
Exporter Log (GDP)	0.01	0.003	0.206***	0.072	0.014	0.065**	0.05	-0.077
	(0.092)	(0.061)	(0.066)	(0.132)	(0.025)	(0.033)	(0.059)	(0.208)
Exporter Log (per capita GDP)	-0.515	-0.710***	-0.619	2.641	0.127	-0.188	0.458	3.739**
	(0.461)	(0.193)	(0.542)	(1.888)	(0.166)	(0.161)	(0.312)	(1.873)
Exporter IP protection	2.286***	3.436***	1.448*	-3.299	0.475	1.306***	0.193	-8.999**
	(0.831)	(0.663)	(0.873)	(3.285)	(0.338)	(0.442)	(0.561)	(3.957)
Exporter Environmental Regulations	0.077	-0.042	-0.042	0.238**	0.083***	0.018	0.018	0.072
	(0.055)	(0.034)	(0.043)	(0.119)	(0.022)	(0.018)	(0.044)	(0.185)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-pair fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Nr. Observations	15,423	25,301	16,132	9,410	27,033	20,824	19,535	13,231
Nr. Country pairs	1,872	3,102	1,946	1,093	3,328	2,526	2,393	1,651

Notes: robust standard errors clustered at the recipient country level in parentheses. * Significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level. All columns are estimated with the Pseudo Poisson Maximum Likelihood Estimator with all regressors lagged one year.

Table 24: Effect of IPR protection on FDI as a function of absorptive capacities

	Hydro	PV	Solar thermal	Wind	Heating	Insulation	Lighting	Cleaner vehicles
Importer IP protection	0.116	0.309**	0.268*	0.277*	0.587**	-0.16	0.571***	0.324**
	(0.129)	(0.132)	(0.151)	(0.149)	(0.283)	(0.243)	(0.198)	(0.131)
Importer IP protection	-0.048	-0.158	-0.045	-0.172*	-0.367	0.135	-0.271**	-0.077
x high capacities	(0.114)	(0.098)	(0.090)	(0.095)	(0.227)	(0.236)	(0.126)	(0.107)
Importer Absorptive capacities	1.317**	1.042	1.07	2.336**	-0.056	1.441	0.14	0.586
	(0.609)	(0.928)	(1.060)	(0.983)	(1.535)	(1.107)	(1.322)	(0.683)
Importer Log (GDP)	0.814***	0.807***	0.847***	1.007***	0.794***	1.059***	0.898***	0.871***
	(0.127)	(0.099)	(0.108)	(0.106)	(0.143)	(0.176)	(0.139)	(0.090)
Importer Log (per capita GDP)	-0.302	0.06	-0.125	-0.626***	0.172	0.002	0.561**	-0.008
	(0.211)	(0.221)	(0.251)	(0.239)	(0.464)	(0.333)	(0.274)	(0.206)
Importer Environmental	0.004	-0.025	-0.015	0.035	0.027	-0.033	-0.076***	-0.043***
regulations	(0.019)	(0.019)	(0.019)	(0.024)	(0.027)	(0.023)	(0.029)	(0.016)
Importer business	-0.078	-0.133	-0.166	0.023	-0.188	-0.064	-0.529*	-0.444**
regulations	(0.249)	(0.243)	(0.273)	(0.243)	(0.474)	(0.345)	(0.309)	(0.183)
Importer labor market	-0.084	-0.158**	-0.260***	-0.148**	-0.501***	-0.083	-0.268***	-0.104*
regulations	(0.080)	(0.073)	(0.048)	(0.068)	(0.084)	(0.100)	(0.099)	(0.060)
Importer controls of capital	-0.109*	-0.066	-0.123	-0.154*	-0.115	-0.03	0.185*	-0.008
and people movement	(0.064)	(0.097)	(0.117)	(0.091)	(0.175)	(0.134)	(0.104)	(0.092)
Country pair in Trade	-0.961***	-1.208***	-1.493***	-1.229***	-2.013***	-1.541***	-1.139***	-1.084***
agreement	(0.242)	(0.298)	(0.327)	(0.286)	(0.419)	(0.447)	(0.415)	(0.274)
Exporter IP protection	0.245*	0.279**	0.262**	0.203*	0.386***	0.604**	0.292	0.262***
	(0.141)	(0.127)	(0.121)	(0.118)	(0.141)	(0.253)	(0.189)	(0.086)
Exporter Log (GDP)	1.478***	1.454***	1.267***	1.341***	1.229***	1.612***	1.710***	1.339***
	(0.109)	(0.130)	(0.110)	(0.122)	(0.111)	(0.137)	(0.138)	(0.072)
Exporter Log (per capita GDP)	0.697	0.829*	0.477	0.165	-0.156	1.946***	1.319***	0.756**
	(0.524)	(0.491)	(0.510)	(0.473)	(0.530)	(0.549)	(0.467)	(0.373)
Exporter Environmental	-0.113***	-0.141***	-0.074**	-0.046	-0.046	-0.225***	-0.220***	-0.120***
regulations	(0.039)	(0.032)	(0.037)	(0.033)	(0.043)	(0.041)	(0.027)	(0.023)
Contiguity	-1.248***	-1.562***	-1.064***	-1.057***	-1.635***	-1.367**	-3.478***	-1.678***
	(0.359)	(0.379)	(0.391)	(0.325)	(0.476)	(0.580)	(0.581)	(0.385)
Common official language	0.756	1.014**	0.737**	0.917*	1.689***	0.865	1.582***	0.602
	(0.462)	(0.409)	(0.348)	(0.473)	(0.371)	(0.604)	(0.431)	(0.528)
Colonial relationship	-0.222	-0.205	-0.262	-0.219	0.031	-1.174***	-0.499	-0.115
	(0.369)	(0.324)	(0.295)	(0.399)	(0.503)	(0.374)	(0.359)	(0.264)
Log distance between most	-1.282***	-1.365***	-1.317***	-1.396***	-1.532***	-1.144***	-1.376***	-1.254***
populated cities	(0.154)	(0.118)	(0.117)	(0.146)	(0.134)	(0.170)	(0.165)	(0.095)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	23,055	24,037	23,583	25,666	22,469	17,839	18,679	23,791
Country-pairs	2,812	3,040	2,964	3,192	2,736	2,128	2,356	2,812

Notes: Robust standard errors in parentheses. * Significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level. All columns are estimated with the Pseudo Poisson Maximum Likelihood Estimator with all regressors lagged one year. The dependent variable is the number of inward FDI deals computed from Zephyr and Patstat data. The Intellectual property rights protection (IPR) index is the intellectual property rights index from the World Economic Forum's Executive Opinion Survey multiplied by the legal systems and property rights from the 2014 Economic Freedom Dataset published by the Fraser Institute. Absorptive capacities are measured by enrollment in tertiary education. Importer business regulations, labor market regulations, and controls of the movement of capital and people come from the 2014 Economic Freedom Dataset published by the Fraser Institute. The country-pair trade agreement equals 1 if both countries are in a free trade agreement or a custom union based on the WTO Regional Trade Agreements Information System. Environmental regulations are measured by the Environmental Performance Index from Yale University.

Robustness checks

Table 25: control function approach for IPR protection and trade in low-carbon capital goods

	Hydro	Solar PV	Solar Thermal	Wind power	Heating	Insulation	Lighting	Cleaner vehicles
Importer IPR protection	0.259	0.807***	0.083	0.925***	0.024	0.046	0.087	-0.279
	(0.211)	(0.220)	(0.104)	(0.284)	(0.044)	(0.044)	(0.088)	(0.232)
Importer Absorptive capacities	-0.699	-3.412**	-0.644	-1.085	-0.752***	-0.579***	0.117	1.829
	(0.778)	(1.391)	(0.495)	(0.922)	(0.232)	(0.223)	(0.295)	(1.688)
Importer Log (GDP)	1.932***	2.017***	0.805*	0.824	0.245	0.224	1.342***	0.141
	(0.639)	(0.506)	(0.480)	(0.647)	(0.207)	(0.158)	(0.297)	(0.862)
Importer Log (per capita GDP)	-6.098***	-1.262	-0.709	-2.011	0.279	0.837**	-1.537**	-0.793
	(1.087)	(1.237)	(0.820)	(1.902)	(0.356)	(0.336)	(0.675)	(1.558)
Importer Environmental Regulations	-0.013	0.069	0.063	-0.150*	0.021	-0.031***	0.013	0.109
	(0.058)	(0.056)	(0.040)	(0.077)	(0.015)	(0.011)	(0.025)	(0.089)
Importer Effectively Applied Tariff	-0.094***	-0.02	0.006	-0.025	-0.022**	-0.025**	-0.035***	-0.029**
	(0.034)	(0.055)	(0.024)	(0.039)	(0.010)	(0.012)	(0.010)	(0.012)
Importer Nr. of Non-Tariff Measures	0.002	-0.279***	-0.034	-0.112**	0.002	0.007	-0.024**	0.066
	(0.009)	(0.029)	(0.021)	(0.056)	(0.001)	(0.005)	(0.010)	(0.078)
Country pair in Trade Agreement (0/1)	-0.236	0.113	0.843***	0.029	0.337***	0.299***	-0.185	-0.079
	(0.353)	(0.151)	(0.276)	(0.840)	(0.099)	(0.095)	(0.181)	(0.423)
Exporter Log (GDP)	0.001	0.012	0.206***	0.06	0.014	0.063***	0.045	-0.059
	(0.083)	(0.091)	(0.057)	(0.132)	(0.031)	(0.023)	(0.052)	(0.106)
Exporter Log (per capita GDP)	-0.53	-0.602	-0.621	2.575*	0.102	-0.207*	0.463*	3.751***
	(0.462)	(0.485)	(0.513)	(1.557)	(0.206)	(0.118)	(0.274)	(1.246)
Exporter IPR protection	2.333***	3.278***	1.452*	-3.179	0.498	1.330***	0.19	-9.089***
	(0.821)	(0.921)	(0.825)	(2.483)	(0.355)	(0.266)	(0.462)	(2.934)
Exporter Environmental Regulations	0.078	-0.056	-0.042	0.248**	0.083***	0.017	0.02	0.065
	(0.052)	(0.041)	(0.027)	(0.109)	(0.016)	(0.018)	(0.039)	(0.131)
First-stage residual	0.488*	0.601**	-0.028	0.785*	-0.106*	0.096	0.251**	-0.231
	(0.271)	(0.283)	(0.146)	(0.417)	(0.056)	(0.060)	(0.112)	(0.372)
Year fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-pair fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Nr. Observations	15418	25274	16120	9404	27013	20813	19512	13219
Nr. Country pairs	1871	3097	1946	1092	3325	2525	2388	1651

Notes: robust standard errors clustered at the recipient country level in parentheses. * Significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level. The first-stage residual provides a heteroskedastic-robust Hausman test for endogeneity.

Table 26: control function approach for IPR protection and FDI in low-carbon technologies

	Hydro	PV	Solar thermal	Wind	Heating	Insulation	Lighting	Cleaner vehicles
Importer IP protection	0.114	0.22	0.214	0.12	0.235	-0.13	0.435**	0.308**
	(0.128)	(0.146)	(0.181)	(0.140)	(0.272)	(0.250)	(0.218)	(0.129)
Importer Absorptive capacities	1.236	0.577	0.923	1.803*	-0.968	1.702	-0.578	0.394
	(1.082)	(0.950)	(1.091)	(0.929)	(1.842)	(1.203)	(1.908)	(0.804)
Importer Log (GDP)	0.817***	0.813***	0.854***	1.041***	0.837***	1.045***	0.887***	0.870***
	(0.135)	(0.100)	(0.110)	(0.097)	(0.160)	(0.225)	(0.174)	(0.109)
Importer Log (per capita GDP)	-0.333	-0.026	-0.155	-0.727**	-0.151	0.071	0.35	-0.055
	(0.372)	(0.395)	(0.433)	(0.339)	(0.491)	(0.535)	(0.541)	(0.337)
Importer Environmental Regulations	-0.003	-0.036	-0.014	0.03	0.022	-0.015	-0.091*	-0.052*
	(0.032)	(0.033)	(0.037)	(0.029)	(0.048)	(0.043)	(0.048)	(0.030)
Importer business regulations	-0.099	-0.138	-0.141	0.078	-0.043	-0.02	-0.496	-0.452**
	(0.252)	(0.333)	(0.392)	(0.238)	(0.591)	(0.389)	(0.438)	(0.211)
Importer labor market regulations	-0.105	-0.215	-0.266**	-0.19	-0.528***	-0.041	-0.366**	-0.14
	(0.137)	(0.136)	(0.121)	(0.121)	(0.155)	(0.213)	(0.182)	(0.105)
Importer controls of capital and people movement	-0.123	-0.102	-0.13	-0.183	-0.175	0.001	0.099	-0.036
	(0.116)	(0.153)	(0.136)	(0.141)	(0.212)	(0.227)	(0.171)	(0.128)
Country pair in Trade Agreement	-0.950**	-1.223***	-1.497***	-1.234***	-1.987***	-1.590***	-1.180***	-1.080***
	(0.379)	(0.242)	(0.393)	(0.291)	(0.471)	(0.540)	(0.437)	(0.316)
Exporter IP protection	0.240*	0.274*	0.263*	0.200**	0.376***	0.604**	0.29	0.258***
	(0.129)	(0.151)	(0.143)	(0.101)	(0.125)	(0.280)	(0.215)	(0.092)
Exporter Log (GDP)	1.480***	1.458***	1.266***	1.339***	1.223***	1.612***	1.720***	1.342***
	(0.113)	(0.120)	(0.092)	(0.114)	(0.125)	(0.166)	(0.169)	(0.067)
Exporter Log (per capita GDP)	0.7	0.823	0.472	0.15	-0.159	1.958***	1.303	0.764*
	(0.568)	(0.546)	(0.648)	(0.481)	(0.684)	(0.634)	(0.863)	(0.397)
Exporter Environmental Regulations	-0.113***	-0.141***	-0.075*	-0.046	-0.047	-0.224***	-0.220***	-0.121***
	(0.042)	(0.030)	(0.041)	(0.037)	(0.042)	(0.044)	(0.046)	(0.024)
Contiguity	-1.244**	-1.529***	-1.069**	-1.053**	-1.679***	-1.387	-3.313*	-1.656***
	(0.487)	(0.518)	(0.445)	(0.421)	(0.641)	(2.235)	(1.988)	(0.402)
Common official language	0.774	1.067***	0.734*	0.929*	1.630***	0.838	1.691**	0.633
	(0.643)	(0.388)	(0.379)	(0.517)	(0.559)	(2.089)	(0.688)	(0.506)
Colonial relationship	-0.207	-0.183	-0.268	-0.232	-0.013	-1.227	-0.452	-0.09
	(0.513)	(0.431)	(0.417)	(0.548)	(0.760)	(3.434)	(0.702)	(0.372)
Log distance between most populated cities	-1.279***	-1.363***	-1.319***	-1.394***	-1.528***	-1.163***	-1.376***	-1.251***
	(0.139)	(0.113)	(0.106)	(0.113)	(0.182)	(0.206)	(0.246)	(0.103)
First-stage residual	0.107	0.133	-0.052	-0.034	-0.212	-0.252	0.29	0.166
	(0.246)	(0.185)	(0.183)	(0.165)	(0.366)	(0.415)	(0.204)	(0.240)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	23,055	24,037	23,583	25,666	22,469	17,839	18,679	23,791
Country-pairs	2,812	3,040	2,964	3,192	2,736	2,128	2,356	2,812

Notes: Robust standard errors in parentheses. * Significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level. The first-stage residual provides a heteroskedastic-robust Hausman test for endogeneity.

Table 27: IPR protection and trade in other economic sectors

	BEC 47 – All capital goods	CPC 0 - agriculture, forestry, and fishery products	CPC 1 - ores, minerals, electricity, gas and water
Importer IPR protection	0.072***	0.013	0.048
	(0.026)	(0.018)	(0.046)
Importer Absorptive capacities	-0.250	-0.096	-0.033
	(0.220)	(0.196)	(0.355)
Importer Log (GDP)	0.430***	0.392***	0.215
	(0.106)	(0.101)	(0.192)
Importer Log (per capita GDP)	0.120	0.623***	0.813**
	(0.216)	(0.187)	(0.374)
Importer Environmental Regulations	0.004	0.014	-0.013
	(0.014)	(0.010)	(0.021)
Importer Effectively Applied Tariff	-0.013	0.003	-0.008
	(0.010)	(0.002)	(0.013)
Importer Nr. of Non-Tariff Measures	-0.002	-0.002	0.045
	(0.014)	(0.014)	(0.029)
Country pair in Trade Agreement (0/1)	0.038	0.066	0.002
	(0.040)	(0.058)	(0.095)
Exporter Log (GDP)	0.014	-0.016*	0.024
	(0.012)	(0.010)	(0.035)
Exporter Log (per capita GDP)	0.410***	0.195**	0.412***
	(0.071)	(0.082)	(0.149)
Exporter IPR protection	0.509***	-0.077	-1.288***
	(0.120)	(0.172)	(0.469)
Exporter Environmental Regulations	0.034***	0.007	-0.01
	(0.006)	(0.009)	(0.016)
Year fixed-effects	Yes	Yes	Yes
Country-pair fixed-effects	Yes	Yes	Yes
Nr. Observations	84,939	79,876	58,348
Nr. Country pairs	11,839	10,854	7,638

Notes: robust standard errors clustered at the recipient country level in parentheses. * Significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level. CPC is the Central Product Classification and BEC is the Broad Economic Categories nomenclature.

Table 28: IPR protection and FDI in all sectors

	Number of FDI deals in all sectors
Importer IP protection	0.226***
	(0.061)
Importer Absorptive capacities	1.666***
	(0.635)
Importer Log (GDP)	0.843***
	(0.067)
Importer Log (per capita GDP)	-1.105***
	(0.198)
Importer Environmental Regulations	0.056***
	(0.017)
Importer business regulations	-0.043
	(0.120)
Importer labor market regulations	-0.117
	(0.083)
Importer controls of capital and people movement	-0.09
	(0.084)
Country pair in Trade Agreement	-1.771***
	(0.193)
Exporter IP protection	0.126
	(0.112)
Exporter Log (GDP)	0.820***
	(0.079)
Exporter Log (per capita GDP)	-0.801***
	(0.216)
Exporter Environmental Regulations	0.073***
	(0.022)
Contiguity	-1.389***
	(0.236)
Common official language	1.418***
	(0.274)
Colonial relationship	0.126
	(0.280)
Log distance between most populated cities	-1.522***
	(0.055)
Year dummies	Yes
Observations	28,998
Country-pairs	5,232

Notes: Robust standard errors in parentheses. * Significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.