Antoine Dechezlepretre, Matthieu Glachant and Yann Ménière

What drives the international transfer of climate change mitigation technologies?: empirical evidence from patent data

Article (Accepted version) (Refereed)

Original citation:
Dechezlepretre, Antoine, Glachant, Matthieu and Ménière, Yann (2013) What drives the international transfer of climate change mitigation technologies?: empirical evidence from patent data. Environmental and Resource Economics, 54 (2). pp. 161-178. ISSN 0924-6460

DOI: 10.1007/s10640-012-9592-0

What Drives the International Transfer of Climate Change Mitigation Technologies? Empirical Evidence from Patent Data

Antoine Dechezleprêtre*, Matthieu Glachant**, Yann Ménière**

* Grantham Research Institute on Climate Change and the Environment, London School of Economics

** Mines ParisTech, CERNA

Correspondence to: Matthieu Glachant, CERNA, Mines ParisTech; 60, Boulevard Saint Michel ; 75272 Paris Cedex 06, France ; ph: + 33 1 40 51 92 29, fax: + 33 1 40 51 91 45, glachant@mines-paristech.fr

What Drives the International Transfer of Climate Change Mitigation Technologies? Empirical Evidence from Patent Data

Abstract

Technology transfer plays a key role in global efforts to reduce greenhouse case emissions. In this paper, we characterize the factors which promote or hinder the international diffusion of climate-friendly technologies, using detailed patent data from 96 countries for the period 1995–2007. The data provides strong evidence that lax Intellectual Property (IP) regimes has a strong and negative influence on the international diffusion of patented knowledge. Restrictions to international trade and to foreign direct investment also hinder the diffusion of low-carbon technologies. A surprising insight is that local technological capabilities tend to reduce rather than promote the import of technology. We interpret this as evidence that local capabilities foster domestic innovation, and there is substitution between local and imported climate-friendly technologies.

Key words: Climate change, technology diffusion, technology transfer.

JEL Code: O33, O34, Q54

1 Introduction

The international diffusion of technologies for mitigating climate change is at the core of current discussions surrounding the post-Kyoto regime. Technology development and diffusion are considered strategic objectives in the 2007 Bali Road Map. North-to-South technology transfer is of particular interest since technologies have been developed mostly in industrialized countries and that these technologies are urgently required to mitigate GHG emissions in fast-growing emerging economies. A recent study looking at patents filed in thirteen climate change mitigation technologies shows that two-thirds of the inventions patented worldwide between 2000 and 2005 have been developed in only three countries: Japan, the USA, and Germany (Dechezleprêtre et al., 2011).

However, enhancing technology transfer involves considerable policy and economic challenges because developing countries are reluctant to bear the financial costs of catching up alone, while firms in industrialized countries refuse to give away strategic intellectual assets. This has led to an intense debate on policies that affect technology diffusion, with a particular focus on the role of intellectual property rights (IPRs) that developing countries view as barriers to technology diffusion (ICSTD, 2008). By contrast, industrialized countries advocate that IPRs provide innovators with incentives to disseminate their inventions through market channels, such as foreign direct investment and the international trade of equipment goods (Barton, 2007). They argue that developing countries can in fact promote transfers by increasing their capability to absorb new technologies.

This paper examines these issues by identifying the factors that promote or hinder the international diffusion of climate-friendly technologies. We focus the analysis on the most relevant questions in current policy discussions. First, how important is the recipient countries' capacity to absorb foreign technologies? What is the impact of the stringency of IPRs regimes on technology transfer? Do barriers to trade and foreign direct investment (FDI) significantly reduce the import of technologies? What is the impact of climate policies implemented in the recipient countries? We also investigate whether the answers to these questions are specific to climate-friendly technologies.

We address these questions using a data set of climate-related patents filed in 96 countries from 1995 to 2007, obtained from the World Patent Statistical Database (PATSTAT). We focus the analysis on ten technologies: three renewable energy technologies (wind, solar, and hydropower), three technologies related to energy conservation in buildings (energy-efficient lighting, thermal insulation, and energy-efficient heating), two emissions reduction technologies in regular fossil fuel power generation (carbon capture and storage and "clean coal"), a storage technology (fuel cells) and electric and hybrid vehicles. Although not all climate-friendly technologies are covered, our coverage spans across various sectors, including transportation, electricity and heat production, manufacturing, and the residential sector. Moreover, we build a benchmark dataset that includes all patents filed in any technology in order to compare climate change-related technologies with other patented technologies.

The literature dealing with the international diffusion of environment-related technology is limited but is growing rapidly[1]. Unlike the present work, this literature is mostly descriptive. Lanjouw and Mody (1996) presented the first patent-based empirical evidence for the international diffusion of environmentally responsive technology. Based on data from Japan, Germany, the USA, and fourteen developing countries, the paper identifies the leaders in environmental patenting and finds that significant transfers occur to developing countries. Focusing on chlorine-free technology in the pulp and paper industry, Popp et *al*. (2007) provide evidence that environmental regulation may promote international technology transfer. They observe for instance an increase in the number of patents filed by US inventors in Finland and Sweden after passage of tighter regulations in these countries. Several case studies discuss whether stricter patent protection promotes or hinders the transfer of climate-related technology to developing countries (see, for example, Barton, 2007; Ockwell et al., 2008).

[1] In contrast, the general empirical literature on international technology diffusion is well developed (for a good survey, see Keller, 2004).

Finally, PATSTAT data was recently used to describe the geography of innovation and international technology diffusion (Dechezleprêtre et al., 2011).

Our work is one of the first econometric studies in this area. Another very recent work is by Dekker et al. (2009) who study how sulphur protocols trigger invention and diffusion of technologies for reducing SO_2 emissions. A paper by Hascic and Johnstone (2009) is also related to our work. They use the same data to study the impact of the Kyoto protocol. Our focus is different since we deal with a broader set of policy variables including trade barriers and FDI control.

As a measure of diffusion, our approach is similar to that of Lanjouw and Mody (1996), Eaton and Kortum (1999), or Hascic and Johnstone (2009). We count the number of patent applications in recipient countries for technologies invented abroad. Because patent data include the inventor's country of residence, we know precisely the geography of technology flows and we can run regressions to understand what drives cross-border technology exchanges. This indicator is a proxy of technology transfer because holding a patent in a country gives the holder the exclusive right in that country to commercially exploit the technology. This does not necessarily mean the inventor will indeed execute their right.

This approach appears similar to the method based on patent citation analysis used in many studies seeking to measure the extent of international knowledge flows (see Jaffe et al., 1993; Peri, 2005), except for one important difference. Inventors file patents abroad to reap private benefits. Therefore, while citations made by inventors to previous patents are an indicator of *knowledge spillovers*, our indicator is a proxy for *market-driven knowledge flows*.

In this respect, our study also relates to the general literature on market channels for international technology transfers (see Keller, 2004, for a good survey). The literature identifies three main channels. The first is the trade of manufactured products, mostly machines and equipment which embody technology. Multinational enterprises also transfer firm-specific technology to their foreign affiliates through foreign direct investment (FDI). The licensing of patents is a third possible channel. Yet transfers via the latter is of much smaller magnitude in practice compared to trade and foreign direct investment, particularly for the environment-related technologies in which we are interested. We thus concentrate on FDI and international trade of equipment.

Prior works indicate that technology transfers through either channel involve patent filings in the recipient country, and therefore positively depend on the quality of its patent system (Maskus, 2000; Smith, 2001; Evus, 2010). Smith (2001) moreover highlights a possible substitution effect between both channels depending on the strength of patent protection. To account for these mechanisms, we develop a theoretical model which we test empirically to see how policy variables such as trade barriers, capital control and the strength of patent protection influence international flows of environment-related patents.

The paper is organized as follows: Section 2 discusses the use of patents as indicators of technology transfer. The data set is presented in Section 3. In Section 4, we develop a theoretical model that describes the diffusion of inventions between countries in order to derive predictions about the impact of barriers to FDI and to trade, and of IP rights on technology transfer. Econometric models and results are described in Section 5. A final section summarizes the main results.

2 Patents as indicators of technology transfer

In the empirical literature, scholars have proposed a number of solutions for the measurement of international technology transfers. Because major transmission channels of knowledge across countries include international trade and FDI, many studies use the inflows of intermediate goods or FDI as proxy variables for international technology transfer (for example, Coe and Helpman, 1995; Lichtenberg and van Pottelsberghe de la Potterie, 2001). Data on trade and FDI are easily available for a large number of countries, thereby allowing a very broad geographical coverage. However, these data are highly aggregated in terms of economic sectors, which prevents their use in measuring the flows of climate-friendly technologies. More generally, trade and FDI are only indirect vehicles of knowledge transfer.

As a results, the use of patent data has gained popularity in the recent empirical literature.[2] Patent data focus on outputs of the inventive process (Griliches, 1990). They provide a wealth of information on the nature of the invention and the applicant. Most important, they can be disaggregated to specific technological areas. Finally, they indicate not only the countries where inventions are made, but also where these new technologies are used. These features make our study of climate change mitigation technologies possible. Of course, patent data also present drawbacks, which we discuss below.

The intuition behind the use of patent data in this analysis lies in how the patent system works. Consider a simplified innovative process. In the first stage, an inventor from country *i* develops a new technology. She then decides to patent the new technology in certain countries. A patent in country *j* grants her the exclusive right to commercially exploit the innovation in that country. Patenting in country *j* indicates the inventor plans to use it there. The set of patents protecting the same invention in several countries is called a patent family.

In this paper we use the number of patents invented in country *i* and filed in country *j* as an indicator of the number of innovations transferred from country *i* to country *j*. As mentioned in the introduction, this indicator has already been used in previous work (see, for instance, Lanjouw and Mody, 1996; Eaton and Kortum, 1999). It differs, however, from indicators based on backward patent citation that are used in the literature measuring knowledge spillovers (see Jaffe et al., 1993).[3]

This approach is obviously not without drawbacks. The first limitation is that for protecting innovations, patents are only one of several means, along with lead-time, industrial secrecy, or purposefully complex specifications (Cohen et al., 2000; Frietsch and Schmoch, 2006). In fact, inventors may prefer secrecy to avoid the public disclosure of the invention

[2] Alternatively, Branstetter, Fisman and Foley (2006) and Smith (2001) use royalty payments and licenses. Such data provide an accurate view of the commercial value of technology transfers through a particular channel, namely IP licensing, but those data are available only for the U.S.A. Therefore it is not appropriate to assess global technology transfers through various channels.

[3] It is argued that the count of forward citations reflects the value of individual patents. This has been exploited in the literature to compute weighting coefficients. We could have done the same to control for the heterogeneity of patents' value. However, citations data are not available for most countries (with the exceptions of the U.S.A. and the European Union).

imposed by patent law, or to save the significant fees attached to patent filing. However, there are very few examples of economically significant inventions that have not been patented (Dernis and Guellec, 2001), although the propensity to patent differs between sectors, depending on the nature of the technology (Cohen et al., 2000) and the risk of imitation in a country. Such factors that influence the propensity to patent have a significant effect on our data, because patenting is more likely in countries that have strong technological capabilities and that strictly enforce intellectual property rights. The econometric models presented below partly control for this problem.

More generally, certain forms of knowledge are not patentable. Know-how or learning-by-doing, for example, cannot be easily codified, particularly because these are skills embodied in individuals. The nature of such knowledge limits the accuracy of our data. Nevertheless, research has shown that flows of patented knowledge and of tacit knowledge are positively correlated (Cohen et al., 2000; Arora et al., 2008).

A further limitation is that a patent grants the exclusive right to use the technology only in a given country; it does not mean that the patent owner will actually do so. This could significantly bias our results if applying for protection did not cost anything, so that inventors might patent widely and indiscriminately. But this is not the case in practice. Dechezleprêtre et al. (2011) show that the average invention is patented in two countries.[4] Patenting is costly, in both the preparation of the application and the administration associated with the approval procedure (see Helfgott, 1993; and Berger, 2005, for EPO applications). In addition, possessing a patent in a country is not always in the inventor's interest if that country's enforcement is weak, since the publication of the patent in the local language can increase vulnerability to imitation (see Eaton and Kortum, 1996 and 1999). Therefore, inventors are unlikely to apply for patent protection in a country unless they are relatively certain of the potential market for the technology covered. Finally, because patenting protects an invention only in the country where the patent is filed, inventors are less likely to engage in strategic behavior to protect their

[4] In fact, about 75% of the inventions are patented in only one country.

inventions abroad and prevent the use of their technology in the production of goods imported by foreign competitors in their domestic markets.

In addition, the value of individual patents is heterogeneous and its distribution is skewed: Since many patents have very little value, the number of patents does not perfectly reflect the value of innovations. This problem is probably less acute in this paper than in other works, as we focus on international diffusion. Exported technologies are of the highest value and make up only about a quarter of all inventions (Lanjouw et al., 1998). A possible solution to this problem would be to weight patents by their forward citations, but citation data is not yet available for all countries.

3 Patent data

Over the past several years, the European Patent Office (EPO), along with the OECD's Directorate for Science, Technology and Industry, have developed a worldwide patent database—the EPO/OECD World Patent Statistical Database (PATSTAT). PATSTAT is unique in that it covers more than 80 patent offices and contains around 70 million patent documents. PATSTAT data have not been exploited much until now because they became available only recently. Our study is the first to use PATSTAT data to explain the diffusion of climate change mitigation technologies.

We extracted all the patents filed worldwide in 10 climate-mitigation fields, the precise description of which can be found in Table 1. Our patent data dates back to as far as 1861 for some countries[5]. This represents 826,672 patent applications filed in 96 countries.[6] On average, climate-related patents included in our data set represent less than 1% of the total annual number of patents filed worldwide.

[5] Note that our estimations only span from 1995 to 2007. However we can use data back to as far as 1861 to construct the country-specific patent stocks.
[6] Note that Least Developed Countries are not present in our dataset, for two related reasons: Their patenting activity is extremely limited, and available statistics are not reliable.

Table 1. Description of the technology fields covered

Technology field	Description of aspects covered
CCS	Extraction, transportation, storage and sequestration of CO_2.
Insulation	Elements or materials used for heat insulation; double-glazed windows; energy recovery systems in air conditioning or ventilation.
Electric and hybrid vehicles	Electric propulsion of vehicles; regenerative braking ; batteries; control systems specially adapted for hybrid vehicles
Clean coal	Efficiency improving fossil fuel technologies for electricity generation: coal gasification, improved burners, fluidized bed combustion, improved boilers for steam generation, improved steam engines, super-heaters, improved gas turbines, combined cycles, cogeneration
Fuel cells	Fuel cells (electrochemical generators wherein the reactants are supplied from outside); manufacture of fuel cells
Hydro	Hydro power stations; hydraulic turbines; submerged units incorporating electric generators; devices for controlling hydraulic turbines.
Lighting	Compact Fluorescent Lamps; Electroluminescent light sources (LED)
Solar	Solar photovoltaic (conversion of light radiation into electrical energy), incl. solar panels; concentrating solar power (solar heat collectors having lenses or reflectors as concentrating elements); solar heat (use of solar heat for heating & cooling).
Heating	Heat pumps, central heating systems using heat pumps; energy recovery systems in air conditioning
Wind	Wind motors; devices aimed at controlling such motors.

Patent applications related to climate change mitigation are identified using the International Patent Classification (IPC) codes and the European classification codes (ECLA) available in PATSTAT. In order to identify the relevant IPC classes we rely on previous work by the OECD and the European Patent Office. The list of IPC and ECLA codes for climate-related technologies is now easily available online.[7] In addition to climate-friendly patents, other data

[7] A list of environment-related patent classification codes is available from the OECD's Environmental Policy and Technological Innovation (EPTI) website: www.oecd.org/environment/innovation. We gratefully

are also used, in particular in order to describe policies that may influence international patent transfers. These data are described in Section 5.

4 Modelling transfer channels

The ultimate goal of our study is to explain the technology flows between a pair of countries. In practice, these flows occur through exports of manufactured products or through FDI. Licenses to unaffiliated foreign firms indeed represented less than 0.1% of the total value of licenses, foreign direct investments and exports of manufactured products from the United States to the rest of the world in 1989 (Smith, 2001). Anand and Khanna (2000) moreover find that two about 68% of licensing contracts take place in only two sectors – chemicals and drugs (46%) and electronics and electrical equipment (22%) – of which neither overlaps with the environment-related technologies we examine in this paper. A recent study on the Chinese solar photovoltaic industry also confirms that patent licensing does not play any role in this sector, the key vectors being FDI and trade of manufacturing equipment (de la Tour et al., 2011). We can thus focus the entire analysis on trade and FDI.

Among the possible drivers of international flows, we are interested in testing the effects of policy variables such as trade barriers, capital controls or the strength of patent law in the recipient country that affect these channels. A problem is that the relationship between these variables is complex because FDI and trade are partly substitutes in technology transfer.

There is no doubt that the use of both channels positively depends on the strength of IP law in the recipient country, but not with the same intensity (Maskus, 2000; Smith, 2001; Evus, 2010). The reason is that the two channels neither entail the same amount of technology transfer, nor do they yield the same risk of being imitated. As stated by Smith (2001), exports of manufactured products induce less intensive technology flows than FDI, because technology transfers concern only product innovations while process innovations remain in the originating

acknowledge the continuous efforts of Nick Johnstone and Ivan Hascic to provide updated classification codes to the research community.

country. By contrast, FDI implies that the manufacturing technology is also transferred in the recipient country. Accordingly, the risk of being imitated is more important under FDI, because local competitors can access the technology not only through the reverse engineering of products, but also through the circulation of labor in the recipient country. The FDI channel is thus more affected by the strictness of IP law.

This has two consequences. First, as shown empirically by Smith (2001), foreign companies tend to substitute FDI for exports when patent protection increases in the recipient country. Second, opting for an FDI is likely to induce more patent applications than export in the recipient country, because corporations do not only transfer product innovations but also manufacturing technology. These mechanisms could lead to counter-intuitive outcomes.

In order to characterize thoroughly these complex mechanisms, we develop a model which will be used to derive predictions to be tested in the next section. The model features a set of firms which decide whether to transfer a technology in a foreign country or not and the transfer channel (trade versus FDI).

There are K_i heterogeneous firms in country *i*. Each has developed an innovative technology they seek to commercialize in country *j*. The technology can serve a market of size θ_j in country *j* which is drawn from a distribution F_j on the interval $[0, \theta_j^{max}]$. To simplify notations, we ignore the subscripts *i* and *j* in the following.

The technology is defined as an information set $\{a,b\}$ where *a* and *b* denote respectively a product invention and the related production process, both of which are patentable. If the firm with technology of type θ decides to enter country *j*, it can choose between two channels: 1) manufacturing the innovative product at home and exporting it in country *j*, or 2) investing directly in country *j* to set up a local production unit. In the first case, the manufacturing process *b* remains in country *i*, but competitors in country *j* can access the product invention *a* through reverse engineering. In the second case, both the product and manufacturing process are transferred in country *j*. Besides reverse engineering, local competitors have thus a chance to access the manufacturing process (for instance through labor circulation in the local labor market).

Assuming that a firm with type θ decides to enter in country *j*, its expected profit is

$$V_\gamma(\theta) = p_\gamma(ipr)\theta\pi_\gamma - c_\gamma \quad \text{with } \gamma = I, T \tag{1}$$

where *I* and *T* denote respectively the FDI and the trade channels for technology transfer. The other parameters are the profitability of the foreign market π_γ, a fixed cost of entry c_γ, and $p_\gamma(ipr)$ is the probability that the technology will not be counterfeited by local competitors. It depends on *ipr*, the stringency of patent law in country, with $ipr \in [0,\infty]$ and $p_\gamma(ipr) \to 1$ when $ipr \to +\infty$.

We now introduce assumptions which aim to capture two key differences between both channels. First, we assume that exports entail lower risks of imitation than FDI and are less responsive to patent strength, following previous papers (Smith, 2001),:

Assumption 1: *For any ipr,* $p_T(ipr) > p_I(ipr) > 0$; $0 < p'_T(ipr) < p'_I(ipr)$.

The second difference concerns the cost and benefit of each channel. We assume a higher entry cost if technology transfer takes place through a FDI, as it requires investing upfront in a new production unit. However, a FDI also makes it possible to reduce the variable cost of production, as exporting goods entails additional risk of variability in transportation costs, exchange rates, trade tariffs and, in some cases, higher manufacturing costs. Accordingly, we introduce:

Assumption 2 *The costs and profitability of trade and FDI are such that* $c_I > c_T$, $\pi_I > \pi_T$, $\pi_I/c_I > \pi_T/c_T$.

Under these assumptions, the choice between FDI and export basically depends on a tradeoff between the low cost of entry through trade and the economies of scale than can be achieved with FDI if the market is sufficiently large (θ is high). The last inequality imposes that trade will be preferred to FDI if the market is small enough.

From Assumptions 1 and 2 and Equation (1) directly follows the entry strategy of the firm:

Lemma 1 *The firm does not transfer the technology if* $\theta < \theta_0$. *It transfers the technology through trade if* $\theta_0 \leq \theta < \theta_1$ *and through FDI if* $\theta \geq \theta_1$ *with :*

$$\theta_0 = \frac{c_T}{p_T(ipr)\pi_T} \quad and \quad \theta_1 = \frac{c_I - c_T}{p_I(ipr)\pi_I - p_T(ipr)\pi_T}$$

Based on this lemma, we now derive N_{ij}, the number of patent flows from country *i* to country *j*. Let α and β denote the number of patents filed by a firm when using the trade or the FDI channel, respectively. Because FDI requires transferring both product and process inventions, while trade only requires transferring the former, we have $\alpha < \beta$. Assuming without loss of generality that *ipr* is large enough to have some FDI ($\theta^{max} \geq \theta_1$), it follows that the number of firms choosing each channel is:

- FDI : $K\,[1 - F(\theta_1)]$
- Trade: $K\,[F(\theta_1) - F(\theta_0)]$
- No entry: $K\,F(\theta_0)$

The number of patents filed in country *j* by inventors from country *i* is thus:

$$N_{ij} = K\,(\alpha F(\theta_1) - F(\theta_0)) + (\beta(1 - F(\theta_1)))$$

or, after rearranging:

$$N_{ij} = K\,(\beta - F(\theta_1)(\beta - \alpha) - \alpha F(\theta_0))$$

where $F(\theta_1)(\beta - \alpha)$ captures a substitution effect between export and FDI, while $\alpha F(\theta_0)$ captures a barrier to entry effect. This expression makes it possible to derive general predictions about the expected effects of policy variables such as the strength of patent law in country *j* (*ipr*), or barriers to trade or FDI in country *j* (reflected in c_I and c_T):

Proposition 1 *The policy variables have the following effect on the aggregate flows of patents from country i to country j:*

1. *Stronger patent protection in country j increases the incoming flow of patents*
2. *Higher barriers to FDI in country j decrease the incoming flow of patents.*

3. *Higher barriers to trade in country j have an ambiguous effect on the incoming flow of patents.*

Proof. To begin with, we look at the impact of *ipr*, c_I and c_T on the threshold values of θ. We have:

$\frac{\partial\theta_0}{\partial ipr} = -\frac{c_T}{(p_T)^2\pi_T}p_T' < 0$; $\frac{\partial\theta_0}{\partial c_T} = \frac{1}{p_T\pi_T} > 0$; $\frac{\partial\theta_0}{\partial c_I} = 0$; $\frac{\partial\theta_1}{\partial ipr} = -\frac{(c_I-c_T)(p_I'\pi_I-p_T'\pi_T}{(p_I\pi_I-p_T\pi_T)^2} < 0$; $\frac{\partial\theta_1}{d\partial} = -\frac{1}{p_I\pi_I-p_T\pi_T} < 0$; $\frac{\partial\theta_0}{\partial c_I} = \frac{1}{p_I\pi_I-p_T\pi_T} > 0$.

Then, we differentiate N_{ij}. $\frac{\partial N_{ij}}{\partial ipr} = -K\alpha f(\theta_0)\frac{\partial\theta_0}{\partial ipr} + K(\alpha-\beta)f(\theta_1)\frac{\partial\theta_1}{\partial ipr}$ is positive as $\alpha-\beta < 0$.

Then the sign of $\frac{\partial N_{ij}}{\partial c_T} = -K\alpha\, f(\theta_0)\frac{\partial\theta_0}{\partial c_T} + K(\alpha-\beta)f(\theta_1)\frac{d\partial}{\partial c_T}$ is ambiguous as the first term is negative while the second is positive. Finally $\frac{\partial N_{ij}}{\partial c_I} = K(\alpha-\beta)f(\theta_1)\frac{\partial\theta_1}{\partial c_T} > 0$■.

As would be expected, the model predicts that strong patent protection fosters incoming patent flows, as it promotes entry through exports, and substitutes patent-intensive FDI for less patent-intensive exports. This substitution effect similarly explains why barriers to FDI negatively impacts patent flows: firms in country *i* react to higher FDI barriers by substituting trade for FDI. By contrast, as for the impact of trade barriers to patent flows, net effect of substitution is ambiguous. Trade barriers obviously hinder technology transfer through exports, but exports could then be substituted by transfers through FDI. As FDI is more patent intensive, this may lead to increased patent flows across countries.

5 Empirical issues

We have constructed a panel data set for each of the ten technology fields described in Section 3. This is a strong point of our study: estimating the model on each field allows us to control for technology-specific factors and to test the robustness of our results across a wide range of technologies.

5.1 Estimation equations

Our dependent variable, N_{ijt}, is the number of patents filed in country *j* by inventors from country *i.* As it only takes on non-negative integer values, we will assume that N_{ijt} follows a Poisson distribution. Accordingly, the single parameter of the distribution λ_{ijt} is the expected value of N_{ijt} given a set of explanatory variables. More specifically, we adopt the following specification:

$$N_{ijt} = \exp(\alpha \ln k_{jt-1} + \beta_1 ipr_{jt-1} + \beta_2 tariff_{jt-1} + \beta_3 fdi\_control_{jt-1} + \beta_4 policy_{jt-1} \\ + \gamma I_{it-1} + \delta \ln GDP_{jt-1} + \psi_{ij} + \chi' \varphi_t + u_{ijt})$$

Here, k_{jt-1} describes the recipient country's stock of knowledge, ipr_{jt}, $tariff_{jt}$ $fdi\_control_{jt}$ are variables describing respectively the strictness of patent law, the size of the tariffs restricting imports, and the barriers to FDI in the recipient country in year *t*. The variable $policy_{jt}$ captures the strictness of climate policies in the recipient country, I_{it-1} is the number of relevant inventions from the source country available for potential transfer, GDP_{jt} is the country *j*'s growth domestic product, ψ_{ij} is a time-invariant fixed effect, φ_t is a set of time dummies and u_{ijt} is a random term capturing unobserved heterogeneity such as differences in countries' propensity to patent. α, β_1, β_2, β_3, β_4, γ, δ and χ are the (vectors of) parameters to be estimated. We now describe in detail how we constructed the main independent variables.

The recipient country's stock of knowledge (k_{jt-1})

We seek to understand whether technology capabilities in the recipient country have an influence on the transfer of patents. This leads us to use the variable k_{jt-1} which is the discounted stock of previously filed patents in the same technology area at date t–1 by local inventors in the recipient country *j*. Note that, while absorptive capabilities are usually measured with broad cross-technology indicators (e.g.; level of education), this variable provides a very specific indicator of local technology capabilities for each technology. In contrast to more generic variables, it has an ambiguous effect because it also captures a potential competition effect between imported patents and patents already available in the recipient country.

Following Peri (2005), the patent stock is calculated using the perpetual inventory method. We initialize the stock for the year 1950[8] and use the recursive formula

$$k_{jt-1} = (1-d)k_{jt-2} + N_{jjt-1}$$

where N_{jjt} is the number of patented technologies invented by domestic inventors in year t. The value chosen for d, the depreciation of R&D capital, is 15%, a value commonly used in most of the literature (see Keller, 2002), but we check the robustness of our results to using lower or higher discount rates.

The strictness of patent law (ipr_{jt})

The variable ipr_{jt} is a country-specific index built by Park and Lippoldt (2008). Value lie between 0 and 10[9] and measures the strictness of intellectual property rights in the recipient country. As argued above, lax patent system can deter the import of foreign technologies, because of the fear of counterfeiting (see, for example, Maskus, 2000; Smith, 2001; and Barton, 2007). This issue is hotly debated in the political arena.

This variable relates to the propensity to patent in country *j*, which may make our results more difficult to interpret. Stricter IP rights can induce additional patent applications for technologies that would have been transferred anyway through trade or FDI. Using ipr_{jt} can thus lead us to an overestimation of the effect of IP rights on technology transfer.

Barriers to trade ($tariff_{jt}$)

The variable $tariff_{jt}$ captures the existence of potential barriers to international trade. We use the "Taxes on international trade" 0 to 10 index from the Economic freedom of the world 2010 report. This index has three sub-components: revenues from trade taxes as a share of exports and imports as provided by the International Monetary Fund, the mean tariff rate as

[8] We arbitrarily set the value of the patent stock in 1950 at 0. Note that the influence of the initial stocks is infinitesimal as we start estimations in 1995.

[9] The original index has values between 0 and 5 but we rescale it to ensure consistency with the trade and FDI variables which take values between 0 and 10.

reported by the World Trade Organization, and the standard deviation of tariff rates (compared to a uniform tariff as wide variation in tariff rates exerts a more restrictive impact on trade). Proposition 1 tells us that restrictions to trade may have an ambiguous effect on the transfer of technologies embodied in capital equipment goods.

Barriers to FDI ($fdi\_control_{jt}$)

The variable $fdi\_control_{jt}$ is an index of international capital market control based on data from the International Monetary Fund.[10] The IMF reports on up to 13 different types of international capital controls. The zero- to-10 rating is the share of capital controls levied as a share of the total number of capital controls listed multiplied by 10.

The strictness of climate policies ($policy_{jt}$)

Domestic climate policies increase the demand for climate technologies. Given the scope of our country dataset, it is extremely difficult to find a variable which measures in a comparable way the strictness of each recipient's country climate policy. If available, country and sector specific carbon prices would be an ideal variable here. But in its absence, as a second best option, we count the number of climate change related policies in place in each country using the International Energy Agency Climate Change Policies and Measures database[11]. While the explanatory power of this variable is admittedly limited, we expect that the implementation of a new climate-related policy should increase technology inflows. This approach is comparable to the use of dummy variables to represent introduction of new policies as done for instance by Johnstone et al. (2010).

The number of source country inventions available for potential transfer I_{it-1}

$I_{i,t-1}$ is the number of inventions patented by inventors from country *i* anywhere in the world in year *t*-1, *and not previously patented*. Any invention patented in several countries is thus only counted once. This variable measures the number of inventions available for transfer from

[10] The index of international capital market controls is available from the Economic Freedom of the World 2010 Annual Report. For both trade barriers and FDI controls, missing years were filled by interpolation.
[11] Available at http://www.iea.org/textbase/pm/index.html

country *i* to country *j* in year *i*. *Ceteris paribus*, more patents should be transferred from countries that have a higher number of technologies available to be patented in foreign markets.

5.2 Estimation technique and sample

As explained above, we use a Poisson estimation because the number of patents transferred is a count variable. We could also use a negative binomial which relaxes the assumption that the mean of the error term is equal to its variance. But, as we compute standard errors that are robust to heteroskedasticity and clustered by country-pair in all our models[12], the exact functional form of the error distribution is not crucial. In order to deal with fixed effects at country-pair level, we follow the Hausman et al. (1984) approach and estimate by conditional maximum likelihood.[13] Our panel runs from 1995 to 2007[14] and includes 11,766 country pairs over that period. Note that since we use a fixed-effects Poisson estimator, the final estimation samples include fewer country-pairs because the number of patent transfers between some country pairs is always equal to zero and these pairs get dropped from the estimation sample. Table 3 and 4 present summary statistics for the dependent and independent variables used in the estimations.

Table 3. Descriptive statistics for independent variables

Variable	Observations	Mean	Std deviation	Min	Max
P_{ij},	Depending on the technology (see table 4)				
k_{jt-1}	Depending on the technology				
ipr_{jt}	127359	6.94	1.77	2.16	9.76
$tariff_{jt}$	127359	7.62	1.54	0.90	10.00
$fdi\_control_{jt}$	127359	4.94	3.28	0.00	10.00
$policy_{jt}$	62964	8.68	16.46	0.00	147.00
I_{it-1}	Depending on the technology				

[12] Note that STATA cannot produce robust and clustered standard errors for the fixed effect negative binomial estimator (although one can always bootstrap standard errors).
[13] This is implemented by the xtpoisson, fe command in STATA.
[14] 1995 is the first year for which we have data on trade policies, while 2007 is the last reliable year in the September 2009 version of the PATSTAT database.

GDP_{jt}	125610	5.17	1.60	1.87	9.42

Table 4. Descriptive statistics for the dependent variable, by technology

Technology	Obs	Mean	Std. Dev.	Min	Max
CCS	11177	2.14	5.72	0	83.80
Clean coal	20005	5.26	17.39	0	254.50
Fuel cells	16254	9.36	37.65	0	906.33
Electric/ hybrid	13728	6.17	25.74	0	526.28
Heat pumps	10989	1.41	4.11	0	53.00
Hydro	10451	0.70	1.92	0	28.00
Insulation	12906	2.35	7.33	0	103.86
Lighting	15131	9.84	37.11	0	1120.00
Solar	18300	2.48	9.08	0	142.30
Wind	16953	2.19	9.33	0	173.17

6 Results

We report the main results in Tables 3. Estimates across technologies are relatively similar: coefficients exhibit the same signs, although the size may be different. This allows a common interpretation. Control variables exhibit expected signs: the number of inventions from the source country available for potential transfer and GDP_{jt} , which controls for the size of the recipient country, both raise technology flows. We focus the discussion on six policy-relevant questions.

1) Does accumulated knowledge facilitate the import of technology? The variable k_{jt-1} has a significantly negative impact in 7 out of 12 regressions. The negative sign may seem counterintuitive at first as higher technology absorptive capacities in general better facilitates incoming technology transfers. Yet it makes economic sense given the technology-specific indicator that we use: previous inventions in a given technology area might be complements or substitutes to imported inventions in that same area. They are complements if they improve the local capabilities to absorb new inventions; they are substitutes if they compete with imported inventions. Table 3 shows that the competition effect prevails. The aggregate effect is however not that high: elasticities range between -0.16 to -0.30[15]. That is a 10 % increase of k_{jt-1} – which is large as it is a stock variable – induces 1.6 – 3.0 % less patent flows.

2) Do strict intellectual property rights promote technology transfer? As mentioned earlier, this issue is very high in the political agenda. Our results confirm Proposition 1's predictions: a significant positive influence of strict IP rights on technology transfer in all regressions.

The impact is large: increasing by one unit the zero-to-ten rating induces between 27% and 60% more patent imports[16]. Note that we may over-estimate the influence of IPR on *actual* technology transfer as part of the induced patenting could reflect a substitution between patented and non-patented knowledge flows, rather than additional technology flows.

3) Do restrictions on international trade hinder technology transfer? Recall that Proposition 1's theoretical predictions were ambiguous about barriers to trade were reducing the transfer of knowledge through trade, but this effect could be compensated by the substitution of trade by FDI, which is a more patent-intensive channel. Estimations show that the former outweighs the latter: higher tariff rates have a statistically significant negative impact on patent flows in six regressions. This suggests that transferred technologies are frequently incorporated in equipment goods.

It is possible to compare the impact of barriers to trade with IPR by looking directly at the size of the coefficients as the two variables are zero-to-ten ratings. Trade barriers have much less influence: a one unit increase leads to 7-15 % less imports whereas the positive impact of IPR strictness on patent inflows lies in the range of 27-60 %.

---

15 Since the variable is logged, the coefficient can be interpreted as an elasticity (see Cameron and Trivedi, 2010).

16 The coefficient of continuous variables in Poisson estimations can be interpreted as a semi-elasticity (again, see Cameron and Trivedi, 2010). Semi-elasticities as reported by the margins command is Stata indeed give extremely close results.

4) Do restrictions on foreign direct investments hinder technology transfer? We confirm Proposition 1's predictions: controls over international capital flows significantly hinder patent imports in all regressions by 4.5-8 % for a one unit increase of the FDI variable. Again this is much less than the impact of the strictness of patent law enforcement.

5) Do climate policies promote technology transfer?

We find evidence of a positive answer in 5 regressions, in line with expectations. That the coefficient is not significant in the other regressions could be a result of the variable – the count of climate policies in the recipient country – being an imperfect proxy of the strictness of climate policies in the different technology areas.

6) Do climate technologies represent a specific case?

We also investigate whether the case of international transfer of climate technologies behave differently from other types of technologies. If climate technologies behave in a specific manner, this could justify specific adjustments of policies governing trade, IPR or FDI. In Table 4 we compare two models: In column 1, the dependent variable is the count of all climate related patents. In column 2, we use the number of patent transfers in all technologies as the dependent variable. This variable is constructed based on the 60 million patents available from PATSTAT. Although, arguably, the variable $policy_{jt}$ does not influence the international flows of non-climate technologies, we keep it in the second model in order to avoid any bias in the coefficients of ipr_{jt}, $tariff_{jt}$, and $fdi\_control_{jt}$ which could be induced by spurious correlations with $policy_{jt}$. We find that the coefficients of the policy variables are very similar across the two models. Thus we conclude that climate-friendly technologies do not behave differently from other technologies.

7 Conclusion

In this paper we use the PATSTAT database in order to analyze the international diffusion of patented inventions in ten climate-related technologies between 1995 and 2007. This allows us to draw conclusions about the factors which promote or hinder international technology transfer.

Regression results show that technology-specific absorptive capacities of recipient countries reduce technology transfers. Although awkward at first glance, the result is not that surprising as these capabilities are both complements and substitutes to foreign inventions. To understand why, recall that we measure the technological capabilities with the stock of patents previously filed in the recipient country by local inventors (as is usually done in the literature). Capabilities are then complements because local technology users are better equipped to absorb foreign technologies. But they can also reduce transfers because patents protecting local technology can substitute for foreign technologies.

We also assess the impacts of different policy barriers. The results stress that restrictions to the international trade of equipment goods—high tariff rates—and barriers to FDI both negatively influence the international diffusion of patented knowledge. Lax intellectual property regimes have the same negative effect for most technologies.

But the size of the effects is different: depending on the technology, a one unit increase of trade and FDI barriers (on a common 1-to-10 scale) respectively leads to 7-15 % and 4.5-8 % less imports. In contrast, reducing the positive impact of IPR strictness by one unit cuts transfers by 27-60 %.

Finally, climate policies have a positive impact as expected, but the impact is significant only in 5 technologies. This probably stems from the quality of the variable: due to data constraints, we could only measure the strictness of these policies by counting the number of policies in place, which does not say much about the strictness of these policies.

Our results have clear policy implications. First, relaxing IPR for green technologies as advocated by certain developing countries appears not to be a good idea. This claim is reinforced by the fact that, by looking only at patent flows (for data reasons), we do not take into account a further effect of weakening IP: this raises innovators' incentives to rely on secrecy to protect their inventions, which is bad news for the international diffusion of knowledge as secret inventions diffuse less in the recipient economy. Similarly, raising barriers to trade or to FDI seems also detrimental to international technology diffusion, although the impact is not as strong.

Another policy message is that climate technologies do not respond differently than the average technology to changes in trade, IP or FDI policies. This suggests that there is little ground to design policies specifically targeted at climate-related technologies in this area, at least on the supply side. If any, the specificity of climate technologies rather lies on the demand side. Because they represent cleaner alternatives to established technologies, their profitability largely depends on the existence of environmental policies that internalize the social cost of pollution.

Finally, the fact that stronger local technology-specific capabilities tend to decrease technology flows should not lead to disregard capacity building policies. Indeed, we interpret this result as suggesting that higher absorptive capabilities also mean more local inventions, which can substitute for technology imports.

Table 3. Main results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Technology	CCS	Clean coal	Fuel cells	Electric & hybrid	Heating	Hydro	Insulation	Lighting	Solar	Wind
$\ln k_{jt-1}$	-0.301***	-0.228*	-0.088	-0.246***	-0.163	-0.206***	-0.212***	-0.161	-0.223***	-0.161***
	(0.071)	(0.117)	(0.068)	(0.071)	(0.099)	(0.077)	(0.072)	(0.103)	(0.068)	(0.062)
ipr_{jt}	0.416***	0.435***	0.588***	0.606***	0.492***	0.269***	0.462***	0.514***	0.519***	0.447***
	(0.066)	(0.070)	(0.070)	(0.094)	(0.076)	(0.075)	(0.052)	(0.081)	(0.054)	(0.081)
$fdi\_control_{jt}$	-0.063***	-0.067***	-0.071***	-0.056***	-0.077***	-0.078***	-0.069***	-0.065***	-0.068***	-0.045***
	(0.017)	(0.015)	(0.014)	(0.017)	(0.018)	(0.015)	(0.011)	(0.017)	(0.014)	(0.013)
$tariff_{jt}$	-0.036	-0.124**	-0.111**	-0.029	-0.142**	-0.106***	-0.077*	-0.147***	-0.046	-0.046
	(0.041)	(0.048)	(0.048)	(0.060)	(0.064)	(0.039)	(0.040)	(0.046)	(0.040)	(0.036)
$policy_{jt}$	-0.000	-0.001	0.008***	0.003**	0.000	0.009***	0.001	0.003*	-0.003	0.008*
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)
I_{it-1}	0.460***	0.504***	0.717***	0.428***	0.888***	0.875***	0.497***	0.703***	0.756***	1.097***
	(0.041)	(0.059)	(0.043)	(0.057)	(0.046)	(0.041)	(0.038)	(0.066)	(0.051)	(0.042)
$\ln GDP_{jt}$	0.605	1.239**	0.719	1.074**	0.248	0.648	1.082***	1.070	0.306	0.146
	(0.600)	(0.489)	(0.443)	(0.518)	(0.507)	(0.441)	(0.331)	(0.667)	(0.481)	(0.438)
Observations	9295	16434	13684	11781	9405	8877	10912	12881	15411	14542
Country pairs	845	1494	1244	1071	855	807	992	1171	1401	1322

Note: *=significant at the 10% level, **=significant at the 5% level, ***=significant at the 1% level. The dependent variable is the number of patents transferred from country i to country j in year t. All columns are estimated using a fixed-effects Poisson and include a full set of year dummies (not reported for brevity). Standard errors clustered at country-pair level in parentheses.

Table 4. Comparison with non-climate technologies

	(1)	(2)
Technology	Climate techs	All techs
$\ln k_{jt-1}$	-0.173	-0.113
	(0.108)	(0.128)
ipr_{jt}	0.543***	0.513***
	(0.056)	(0.052)
$fdi\_control_{jt}$	-0.064***	-0.065***
	(0.013)	(0.013)
$tariff_{jt}$	-0.095**	-0.089**
	(0.041)	(0.038)
$policy_{jt}$	0.002	0.001
	(0.002)	(0.001)
I_{it-1}	0.584***	0.220**
	(0.067)	(0.096)
$\ln GDP_{jt}$	1.031**	0.872**
	(0.444)	(0.409)
Observations	26950	51975
Country pairs	2450	4725

Note: *=significant at the 10% level, **=significant at the 5% level, ***=significant at the 1% level. The dependent variable is the number of patents transferred from country i to country j in year t. All columns are estimated using a fixed-effects Poisson and include a full set of year dummies (not reported for brevity). Standard errors clustered at country-pair level in parentheses.

References

Anand, B., Khanna, T., 2000. The Structure of Licensing Contracts. *Journal of Industrial Economics*, 48: 1, pp. 103-135.

Arora, A., Ceccagnoli, M. and W.M. Cohen, 2008. R&D and the Patent Premium. *International Journal of Industrial Organization*, 26: 5, pp. 1153-1179.

Barton, J., 2007. Intellectual Property and Access to Clean Energy Technologies in Developing Countries. An Analysis of Solar Photovoltaic, Biofuel and Wind Technologies. ICTSD Programme on Trade and Environment, Issue Paper No. 2.

Cameron, A. C. & P. K. Trivedi, 2010. "Microeconometrics Using Stata, Revised Edition" Stata Press books, StataCorp LP

Coe, D., Helpman, E., 1995. International R&D Spillovers. *Europea Economic Review* 39:5, pp. 859–87.

Cohen, W.M., Nelson, R.R., Walsh, J.P., 2000. Protecting their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not). NBER Working Paper no. 7552.

Dechezleprêtre, A., Glachant, M., Hascic, I., Johnstone, N., Ménière, Y., 2011. Invention and Transfer of Climate Change Mitigation Technologies: a Global Analysis, Review of Environmental Economics and Policy, 5(1), pp 109-130, doi: 10.1093/reep/req023.

De la Tour, A., Glachant, M., Ménière, Y., 2011. Innovation and International Technology Transfer: the Case of the Chinese Photovoltaic Industry. *Energy Policy*, 39(2), pp. 761-770.

Dekker, T., Vollebergh, H. R.J., De Vries, F. P., Withagen, C. 2009. Inciting Protocols - How International Environmental Agreements Trigger Knowledge Transfers. Presented at the EAERE Conference, June 25-27, Amsterdam.

Dernis, H., Guellec, D., 2001. Using Patent Counts for Cross-Country Comparisons of Technology Output, *STI Review* 27

(http://www.oecd.org/LongAbstract/0,3425,en_2649_33703_21682516_1_1_1_1,00.html).

Eaton, J., Kortum, S., 1996. Trade in ideas Patenting and productivity in the OECD. *Journal of International Economics*, vol. 40(3-4), pages 251-278, May

Eaton, J., Kortum, S. 1999. International Technology Diffusion: Theory and Measurement. *International Economic Review*, vol. 40(3), pages 537-70, August.

Frietsch, R., Schmoch, U. 2006. Technological structures and performance as reflected by patent indicators. in Schmoch, U.; Rammer, C.; Legler, H. (eds.) *National Systems of Innovation in comparison. Structure and performance indicators for knowledge societies*. (Dordrecht: Springer)

Griliches, Z., 1990. Patent Statistics as Economic Indicators: A Survey. *Journal of Economic Literature*, Vol. 28, No. 4, pp. 1661-1707.

Hascic I. and N. Johnstone. 2009. The Kyoto Protocol and International Technology Transfer: An Empirical Analysis Using Patent Data. Presented at the EAERE Conference, June 25-27, Amsterdam.

Helfgott, S., 1993. Patent filing costs around the world. *Journal of the Patent and Trademark Office Society*, July, pp. 567-580.

ICSTD, 2008. Climate Change, Technology Transfer and Intellectual Property Rights. Background paper oft he Trade and Cimate Change Seminar, June 18-20. Copenhagen, Denmark.

Ivus, O., 2010. Do Stronger Patent Rights Raise High-Tech Exports to the Developing World?, *Journal of International Economics*, 81, pp. 38-47.

Jaffe, A., Tratjenberg, M., Henderson R., 1993. Geographic localization of knowledge spillovers as evidenced by patent citations. *The Quarterly Journal of Economics* 108(3), pp. 577-98.

Keller; W., 2002. Geographic localization of international technology diffusion, *American Economic Review*, 92, 120-142.

Keller, W., 2004. International technology diffusion, *Journal of Economic Literature*, 42(3), pp. 752-782.

Lanjouw, J.O., Mody, A., 1996. Innovation and the International Diffusion of Environmentally Responsive Technology. *Research Policy*, Vol. 25, pp. 549-571.

Lanjouw, J., A. Pakes and J. Putnam (1998), "How to Count Patents and Value Intellectual Property: Uses of Patent Renewal and Application Data", *The Journal of Industrial Economics*, Vol. 46 (4), pp. 405-432.

Lichtenberg, F., van Pottelsberghe de la Potterie, B., 2000. Does Foreign Direct Investment Transfer Technology Across Borders? *Review of Economics and Statistics,* vol. 83(3), 490-497

Maskus, K. E., 2000. Intellectual Property Rights in the Global Economy. Institute for International Economics, Washington D.C.

Park, W. G., Lippoldt, D. C., 2008. Technology Transfer and the Economic Implications of the Strengthening of Intellectual Property Rights in Developing Countries, OECD Trade Policy Working Papers 62, OECD Trade Directorate.

Peri, G., 2005. Determinants of knowledge flows and their effect on innovation. *Review of Economics and Statistics* 87 (2), 308– 322.

Smith, P. J., 2001. How do foreign patent rights affect U.S. exports, affiliate sales, and licenses? *Journal of International Economics*, 55, 411-439.

Appendix: List of countries included in the dataset

Algeria, Armenia, Argentina, Austria, Australia, Azerbaijan, Bosnia and Herzegovina, Belgium, Bulgaria, Brazil, Belarus, Canada, Croatia, Chile, China, Colombia, Costa Rica, Czechoslovakia, Cuba, Cyprus, Czech Republic, Germany, Denmark, Dominican Republic, Ecuador, Estonia, Egypt, Spain, Finland, France, Georgia, Ghana, Greece, Guatemala, Hungary, Indonesia, Ireland, Israel, India, Iceland, Italy, Japan, Kenya, Kyrgyzstan, Korea, Kazakhstan, Sri Lanka, Lithuania, Luxembourg, Latvia, Morocco, Monaco, Moldova, Macedonia, Mongolia, Malta, Malawi, Mexico, Malaysia, Nicaragua, Netherlands, Norway, New Zealand, Panama, Peru, Philippines, Pakistan, Poland, Portugal, Paraguay, Romania, Russia, Sudan, Sweden, Singapore, Slovenia, Slovakia, San Marino, Salvador, Switzerland, Syria, Thailand, Tajikistan, Turkey, Taiwan, Ukraine, United Arab Emirates, United Kingdom, USA, Uruguay, Uzbekistan, Venezuela, Vietnam, South Africa, Zambia, Zimbabwe