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Ana Pueyo and Pedro Linares

Summary

Developing countries are experiencing unprecedented levels of economic growth. As a result, they will be responsible for most of the future growth in energy demand and greenhouse gas emissions. The development, transfer and use of renewable energy technologies are promising ways towards low-carbon development in these countries. However, the UNFCCC processes have had a limited success in promoting them. This is mainly due to their disconnection with national enabling factors and to their homogeneous approach for all developing countries. This paper addresses these pitfalls by analysing the differentiated performance of developing countries with regards to several indicators of enabling factors for technology transfer. Three quantitative analysis methodologies – principal component analysis, multiple regression analysis and cluster analysis – are used to identify the most important enabling factors of technology transfer and to create groups of developing countries according to their performance in these. Policy recommendations are then adapted to the specific needs of each of the defined groups.

Keywords: technology transfer, climate change, developing countries, multivariate analysis.

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1. Introduction

Developing countries are experiencing unprecedented levels of economic growth. As a result they will be responsible for most of the future growth in energy demand and greenhouse gas (GHG) emissions (IEA, 2012). The largest fast-growing countries, such as Brazil, China and India, will cover most of this growth.

Curbing GHG emissions in developing countries has therefore become one of the cornerstones of a future international climate change agreement under the United Nations Framework Convention for Climate Change (UNFCCC). However, setting caps for developing countries' GHG emissions is facing strong resistance in the current round of negotiations. Continued economic growth that allows poverty eradication is still the main priority of most developing countries, and caps are perceived as a constraint to future growth prospects. The development, transfer and use of low-carbon technologies have more positive connotations. Technology could guide the path towards achieving sustained growth without compromising the climate.

Since its inception, the UNFCCC has recognised the importance of technology transfer (TT) in achieving the stabilisation of global emissions. Unfortunately, so far the success of the UNFCCC process in promoting TT has been limited because the mechanisms it has created have either failed to materialise in actual TT or have led to progress on a project-by-project basis that has been unable to scale-up to the level required. Additionally, TTs are inherently difficult to define and measure (IPCC, 2000), which makes it difficult to assess the extent of the transfers and their effectiveness in achieving actual emissions reductions and contributing to the technological development of recipient countries. As a result, firms and developing country policymakers often complain about the long distance between the bureaucratic UNFCCC processes and their actual and urgent needs. Pueyo et al. (2012b) identify three main gaps of the UNFCCC approach to climate change TT: its detachment from the national enabling frameworks that encourage private investment in developing countries; its non-differentiated approach per (developing) country and technology characteristics; and the unavailability of clear measurements of the volume and effectiveness of TT.

This paper aims at informing an improved UNFCCC approach to TT to developing countries that takes into account their different needs according to their performance in a number of enabling factors. This approach can facilitate an international agreement through the proposal of appropriate and acceptable policies for the different countries involved in the negotiations. It is a significant contribution to the existing literature, as it uses for the first time quantitative empirical evidence for a large number of developing countries to inform differentiated technology policy priorities. This contribution is very relevant in the framework of the current efforts of the UNFCCC to design a Technology Mechanism, which was agreed as part of the Cancun agreements resulting from the 16th Conference of the Parties (COP-15) in 2010 and developed further in the recent COP-17 held in 2011 in Durban. Indeed, one of the authors has already informed the TEC on this topic.

The paper focuses particularly in renewable energy technologies and is structured in the following way. Firstly it presents the method used to measure renewable energy TT to developing countries and its enabling frameworks. The measurement of TT flows is required to analyse their relationship with enabling factors. Secondly, it presents the three multivariate analysis techniques that will be used: multiple regression, principal components and cluster analysis. Third, it presents the results of the analysis, showing the relationship between measurements of renewable energy TT and enabling factors at the national level, through multiple regression analysis; the interrelationships between the different indicators of enabling factors for TT, through principal components analysis; and the groups of developing countries that can be defined according to their performance in these indicators, through cluster analysis. The paper concludes by discussing the differentiated performance of developing countries as regards their enabling frameworks for TT and suggesting the relevant policy priorities that can be defined for groups of developing countries with similar performances.

2. Measuring renewable energy technology transfer and its enabling factors

2.1 Measuring technology transfer

The term "technology transfer" has been defined and measured in many different ways and by a wide range of disciplines. This paper is concerned with the "horizontal" or international perspective of technology transfer that enables developing countries to acquire, adapt, deploy and diffuse renewable energy technologies from overseas and further innovate as a result of the capabilities acquired through the technology transfer process.

Early research provided a narrow definition of technology as scientific and engineering knowledge and blueprints or their manifestation in artefacts. The transfer of this codified knowledge or its manufactured materialisation then constituted technology transfer. The concept has evolved and now technology is defined in broader terms as encompassing the corporate capacity to operationalise and use this knowledge effectively in production (Cantwell, 2009). Technology in this broader sense has two components: the potentially public element of technology, encompassing codifiable items as presented in scientific publications and engineering blueprints and designs, and the tacit element of technology that refers to firm-specific competence in production. Tacit corporate technological capabilities cannot be transferred through market-like exchanges and must instead be internally learned, with or without external assistance (Cantwell, 2009). There is therefore a clear difference between technology trade and real technology transfer, as the former is merely the import of equipment or the execution of projects on a turnkey basis, while the latter involves mastering the imported know-how of core technologies and the development and generation of technologies utilising scientific and technological capacities (Cohen, 2004).

Several authors have distinguished three different flows of transferred technological content, from lower to higher impact on the technological capabilities of the recipient (Bell, 1987; Wei, 1995; Ockwell et al., 2008). The first flow encompasses capital goods and equipment; increases the production capacity of the recipient but on its own does not enable the recipient to use the imported facilities efficiently or to generate technological change. The second flow includes skills and know-how for operating and maintaining equipment. It places the human resources of the importer at the technological level required to operate the imported technology efficiently, but without indigenous efforts beyond learning how to use the technology it would not enable technological change. The third flow encompasses knowledge and expertise for generating and managing technological change. It creates new technological capacity through TT and active independent learning, creation and innovation of the recipient.

Given the tacit nature of technology in its broader sense, measuring technology transfers is inherently difficult because technology has no measurable physical presence or a well-defined price (IPCC, 2000). Rather, it is embodied in products, intermediate inputs and processes (World Bank, 2008). Moreover, TT can occur through a diversity of channels for which data are not always available. Following Neuhoff et al (2009), a comprehensive way to measure technology transfer processes should comprise input, output and effect indicators. Input indicators can provide information on resources spent on activities to facilitate TT activities or on the channels that make foreign technological inputs available, some examples of which are expenditures in collaborative R&D, imports of equipment, FDI or the salaries of foreign staff specifically related to renewable energy. Output indicators can measure the results of technological inputs, for example, the number of patents issued, installed capacity of RE projects, production volume or value of renewable energy technologies. Finally, effect indicators can quantify the achievement of the long-term goals of the transfer or renewable energy technologies, such as CO2 emission reductions, technology cost reductions or knowledge spillovers through backward and forward linkages with local suppliers and clients. A challenge with output and effect indicators is how to attribute the part of them that is enabled by foreign, rather than local, technologies.

Unfortunately, compiling data for all developing countries for input, output or effect indicators is a daunting task. Indeed, there are no public data for most of the indicators mentioned above for developing countries and related to renewable energy technologies in particular. The lack of comprehensive data on the different aspects of TT confine quantitative research on TT to the study of measurable flows. In the field of climate change, the Intergovernmental Panel of Climate Change (IPCC, 2000) recommends the use, with caution, of several types of international financial flows as indicators of both levels of international TT and how these levels change over time. Empirical studies about the international distribution of the benefits from innovation have also identified trade and FDI as the main mechanisms via which technologies diffuse internationally (Keller, 2004). But even data on low-carbon financial flows is patchy when including developing countries. In this paper we use three different indicators of renewable energy technology transfer. One of the indicators reflects inputs of foreign technologies and the other two reflect the outputs of the technology transfer process.

The first indicator refers to imports of some renewable energy technologies, extracted through the Commodity Trade Statistics Database of the United Nations (COMTRADE[1]). COMTRADE contains data on the annual import and export values of different types of commodities for 139 countries, categorised according to the Commodity Description and Coding System (HS1996). In order to find data on imports of clean energy technologies we selected a total of seven products, as presented in Table 1. They do not represent the whole range of clean energy technologies, because it is difficult to separate general energy from renewable energy-related technologies from other COMTRADE commodity codes. Only 79 countries present available data for these categories of commodities.

[1] http://comtrade.un.org/db/

Table 2.1 Comtrade clean energy technology import and export data code description

Code	Name and description of commodity
841011	**Name**: Hydraulic turbines, water wheels, power < 1000 kW **Description**: Hydraulic turbines and water wheels :-- Of a power not exceeding 1,000 kW
841012	**Name**: Hydraulic turbines, water wheels, power 1000-10000 kW **Description**: Hydraulic turbines and water wheels :-- Of a power exceeding 1,000 kW but not exceeding 10,000 kW
841013	**Name**: Hydraulic turbines, water wheels, power > 10000 kW **Description**: Hydraulic turbines and water wheels :-- Of a power exceeding 10,000 kW
841090	**Name**: Parts of hydraulic turbines and water wheels **Description**: Parts, including regulators
841919	**Name**: Instantaneous/storage water heaters, not electric other **Description**: Instantaneous or storage water heaters, non-electric – other [solar water heaters]
850231	**Name**: Wind-powered generating **Description**: Other generating sets :-- Wind-powered
854140	**Name**: Photosensitive/photovoltaic/LED semiconductor devices **Description**: Photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels, light emitting diodes

The majority of technologies included are related to hydropower. The distinction was made between imports of all the commodities above and imports excluding hydro systems, but both variables were highly correlated. Therefore, it was decided to keep only the variable defined as imports of clean energy technologies for all the above categories.

The second indicator refers to exports of renewable energy technologies. This indicator has been selected to represent the production of internationally competitive low-carbon technologies by developing countries, as specific production data for low-carbon technology does not exist in most developing countries. Exports data was sourced from the COMTRADE database for the same categories as for imports.

A third indicator of technology transfer inputs is the renewable generation capacity of a country, adjusted by the expected occurrence of technology transfer. Data on installed renewable generation capacity are available in the US Energy Information Database for a significant number of developing countries. However, it is not possible to discern which share of renewable energy generation capacity and production has required foreign technology transfer. Information of technology transfer for renewable electricity generation projects is available for CDM projects because as part of a UNFCCC-sponsored study on technology transfer in the CDM (Seres et al., 2010), a database was created indicating for every CDM project whether it claims foreign technology transfer or not. The database includes a total of 4,984 emission reduction projects, among which are 3,141 renewable energy-related projects, starting the CDM registration process between December 2003 and June 2010. There is a high correlation between the renewable energy generation capacity of a country (RECAP), the number of renewable energy CDM projects it hosts (CDMRE) and the estimated emissions reductions of these CDM projects (CDMRECO2). Table 2 shows the linear correlations between these variables. Emissions data on CDM projects take into account the size of the projects, as emission reductions depend on the amount of electricity produced.

Table 2.2 Correlations between re capacity, re electricity generation, CDM re projects and CDM re projects CO2 emission reductions

		RECAP	CDMRE	CDMRECO2
RECAP	Pearson	1	.922**	.942**
	N	130	73	73
CDMRE	Pearson	.922**	1	.969**
	N	73	73	73
CDMRECO2	Pearson	.942**	.969**	1
	N	73	73	73

The high correlation between renewable energy (RE) capacity and emissions reductions produced by renewable energy CDM projects allows us to use the technology transfer information on the CDM to estimate the technology transfer in total installed renewable energy capacity. Data on technology transfer in RE CDM projects are available for 54 developing countries.

Most countries claim some degree of foreign technology transfer in all of their RE CDM projects: the median of the share of emissions reductions by RE and non-hydro RE CDM projects that claim TT (CDMRETTCO2p) is 100%. The mean for RE projects is 91.7% and for non-hydro RE projects it is 93.3%.

Outliers claiming technology transfer well below 100% of their RE CDM projects are India, China, Colombia, Brazil and Armenia, which indicates the higher capability of BRICs[2] to develop their own technologies. On the other hand, most renewable energy CDM projects in Colombia and Armenia are hydro in nature, where the technology is considered normal in the country and therefore technology transfer is not claimed.

The percentages of TT claims obtained from CDM projects will be used to adjust the renewable energy capacity (RECAP) figures to reflect only the capacity estimated to have required technology transfer. For all the countries for which information is not available, the mean of TT claims in RE CDM projects, at 92%, will be used to adjust the figures for installed capacity. Countries for which no data are available for CDM TT claims include one BRIC country, Russia, and other emerging economies like Turkey, as well as least developed countries like Congo or Uganda. For this reason, the mean of 92% is considered more appropriate than the median, 100%, for estimating the expected needs of TT.

The three selected indicators, presented in Table 3, are expressed in per capita values to avoid the scale effect[3] when analysing their relationship with enabling factors, and are all transformed with logarithms to ensure a normal distribution of the observations.

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[2] The term “BRIC countries” was coined by Goldman Sachs to refer to Brazil, Russia, India and China as a group of large and fast growing economies

[3] The scale effect arises from the fact that large economies have larger absolute flows of technology transfer

Table 2.3 Technology transfer indicators

TT aspect	Variables	Description	Source	Data sample	Mean	Std dev.
Input	IMP	Ln of the value of imports per thousand population of a selected sample of non-hydro RE technologies in 2009	COMTRADE and UN population data	79	1.49621	2.239
Output	EXP	Ln of the value in US$ of exports per thousand population of a selected sample of non-hydro RE technologies in 2009	COMTRADE and UN population data	66	3.5476	2.79361
	RECAP	Ln of installed MW of renewable electricity generation adjusted per TT claims, per thousand population	US Energy Information Agency And UN population data	105	3.5705	1.74492

Note: Due to the large number of zero values we added 1 to the variable before taking logs.

The three selected indicators present some limitations worth highlighting. Due to data availability, only imports of some renewable energy technologies could be included as inputs into the process. There are many other channels through which foreign technologies can flow such as foreign direct investment, licensing, collaborative R&D or subcontracting. As regards outputs, exports and installed capacity are imperfect indicators because they are only proxies of the production of internationally competitive clean energy technologies and their use for electricity generation. As such, they cannot reflect many other outputs of the TT process. Also, it is difficult to estimate the importance of technology transfer in the final outputs measured as exports or renewable energy capacity. Besides, there are not widely available data on the effects of the TT such as technology cost reductions, improvements in productivity or innovation capacity, or emissions reductions in developing countries. A complete measurement of the TT process is therefore not possible due to lack of data. In any case, we believe that the proposed indicators still serve well the purpose of the paper, which is to map the performance of different developing countries in three particular measurements of technology transfer and to analyse the impacts of different enabling factors for TT in the performance of developing countries.

2.2 Enabling factors of technology transfer

Enabling factors were identified through an extensive literature review and the analysis of 10 case studies of renewable energy technology transfer processes (Pueyo, forthcoming). Enabling factors were classified in four categories:

- Economic and institutional: They can lower the transaction costs of TT channels such as imports, foreign direct investment or hiring foreign staff, enabling the flow of foreign technologies into the recipient country.

- Technology demand: They create a market for the transferred technology.

- Technology supply: They refer to the available stock of knowledge and infrastructures in the recipient country. They enable foreign technologies to be used efficiently and absorbed locally.

- Industry development: They facilitate knowledge spillovers through backward and forward links with local companies and enable a country to develop its own technologies.

A long list of up to 50 indicators of enabling factors was reduced to a more manageable short list, taking the following criteria into consideration: data availability, number of valid cases and correlations among variables of the same type. When variables were highly correlated (Pearson correlation r of 0.9 and above) only one of the variables would be selected.

Table 4 summarises the enabling factors that are used for our analysis, showing as well the aspect of technology transfer they are expected to influence (inputs, outputs or effects), our proposed indicators for their measurement and source. The definition and descriptive statistics of the variables are presented as part of the Annex.

Table 2.4 Enabling factors

TT aspect	Type of variable	Variable	Title	Source
Inputs	Economic and institutional framework	EDB	Ease of Doing Business rank, 2011	World Bank
		CPI	Corruption Perception Index score, 2010. Logarithmic transformation.	Transparency International
		IPR	Intellectual Property Rights index score, 2010	Property Rights Alliance
		INCOME TAX	Average income tax rate, 2011	Heritage Foundation and Wall Street Journal
		CRED	Domestic credit to private sector as a percentage of GDP, 2009. Logarithmic transformation.	World Bank
		TARIFF	Most Favoured Nation average applied tariff rates applied for non agricultural goods, 2009.	World Trade Statistics
		TRADEOP	Trade openness, 2009. Logarithmic transformation.	World Trade Statistics
		FDIOP	Foreign Direct Investment openness, 2009. Logarithmic transformation.	World Bank
		INVEST FREE	Index of investment freedom, 2011	Heritage Foundation and the Wall Street Journal
		LOG	Logistics performance index: Overall (1=low to 5=high), 2009	World Bank
Output	Technology demand	GDP	Gross Domestic Product in current Million US$ at purchasers' prices, 2009. Logarithmic transformation.	World Bank
		GDPg	Average GDP Growth between 2005 and 2009	World Bank
		GDPpc	GDP per capita in current US$. Logarithmic transformation.	World Bank
		CO2pc	CO2 emissions per capita in metric tons, 2007. Logarithmic transformation.	World Bank
		PDIES	Pump price for diesel fuel (US$ per litre) 2010	World Bank
		FOSSILpc	Production of fossil fuels, expressed as tons per million people, 2009. Logarithmic transformation.	US Energy Information Agency
		FIT	Countries that have implemented Feed-in tariffs or that provide guaranteed premiums to	IEA Policies and Measures

TT aspect	Type of variable	Variable	Title	Source
			renewable electricity generation, 2011. 1=yes, and 0=no feed-in tariffs	database,2011
Local inputs Technology effect	Industrial development	HTEXPC	High-technology exports as a percentage of manufactured exports. Logarithmic transformation.	World Bank
		ISO9pc	Number of companies with ISO 9001 certification, 2008. Values expressed as companies per Million people and with logarithmic transformation.	The ISO 9001 Survey
		TFP	Projections of Total Factor Productivity levels relative to the US for 2005. Logarithmic transformation.	UNIDO World Productivity database
		CIP	Competitive Industrial Performance score, 2009.	UNIDO World Industrial Development Report 2009
	Technology supply	PATFORpc	Total stock of patents filed by foreign inventors between 1883 and2009. Logarithmic transformation.	WIPO statistics and own calculation
		PATLOCpc	Stock of patents filed by local inventors during the period 1883-2009. Logarithmic transformation.	WIPO statistics and own calculation
		Enrol3	Tertiary education school enrolment ratio, as a percentage of population, 2008. Logarithmic transformation.	World Bank
		REACPC	Estimated annual renewable energy resources for solar, hydro, wind, different kinds of biomass and geothermal energy. Values expressed in toe per thousand people. Logarithmic transformation.	Buys et al, 2007
		WSHACCPC	Estimated renewable energy potential for wind, solar and hydro sources Values expressed in toe per thousand people. Logarithmic transformation.	Buys et al, 2007

3. Methodology

This research aims at grouping developing countries according to their performance in the enabling factors for the transfer of renewable energy technology transfer. After identifying and retrieving data on enabling factors and technology transfer, three multivariate analysis techniques were used: multiple regression analysis, cluster analysis and principal components analysis (PCA).

Regression analysis is used to study the relationship between technology transfer and enabling factors. The explained variables and relevant explanatory variables are expressed in per capita values to avoid the scale effect. An OLS regression is performed using a cross-sectional dataset, with observations taken at a specific moment in time (2009 for dependent variables IMP and EXP, and 2008 for dependent variable RECAP) related to developing countries. Enabling factors deemed significant and important by the regression analysis are subsequently used to group developing countries using cluster analysis.

Cluster analysis is a useful technique for classifying developing countries according to their similar performance in the enabling factors identified by the regression analysis. Using different clustering methods leads to different clustering results. To test the robustness of results, we use two methods: the Wards agglomerative hierarchical method and the k-means non-hierarchical method. These methods have been previously used in the climate change field to classify developing countries according to their attractiveness for CDM projects (Jung, 2006) and to analyse the similarities among a group of global climate change policy proposals (Gainza et al., 2010).

Principal Components Analysis is used to complement and to increase the robustness of the results obtained through cluster analysis. The aim of principal components analysis (PCA) is to describe the variation in a set of correlated variables (in our case, the indicators of enabling factors for TT) in terms of a new reduced set of uncorrelated variables, which are called ‘principal components’ (PCs). Each principal component is a linear combination of the original variable, and the most informative is the first. PCA is useful in our case because the large number of indicators of enabling frameworks prevents a straightforward interpretation of developing country performances, which is solved by summarising the information conveyed by more than 20 indicators into just two or three results.

3.1 Relationship between enabling factors and renewable energy TT

The regression analysis shows the relationship between enabling factors and indicators of clean energy technology transfer. Tabulated model results are included in the Annex.

The best fitted model for the variable on imports of renewable energy technologies per capita (IMP) is defined by the following equation:

$$\mathbf{IMP = -1.108 + 0.668GDPpc + CRED\ 0.688}$$

Imports of clean energy technologies per capita can be explained by two single variables, which capture 60% of the variation of the dependent variable. Firstly, a high income per capita leads to higher imports of clean energy technologies, which may correspond to the Kuznets hypothesis of higher demand for environmental quality as income per capita increases. Secondly, the availability of credit for the private sector is also essential in achieving high levels of clean energy imports, which points to the importance of the private sector as a provider and consumer of clean energy technology.

The best fitted model for the variable exports of renewable energy technologies per capita (EXP) is defined by the following equation:

$$\mathbf{EXP = -7.227 + 0.889\ REACPC + 0.589\ IPR^* + 17.283\ CIP^* + 0.396\ GDP}$$ [4]

Four variables were found to explain around 70% of the variation of the exports of renewable energy technologies by developing countries, namely the exporter´s endowment of renewable energy resources, the level of protection of IPR, the competitive industrial performance and the size of its economy. The results indicate that countries with a favourable renewable energy endowment may have developed a competitive advantage in the production of technologies to exploit that potential at a low cost. The possibility of demonstrating local technologies in their own territory at a low cost improves the possibilities of learning by doing and scale effects benefitting further cost reductions.

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[4] To facilitate interpretation of the coefficients, variables not transformed with logarithms are highlighted with a star (*)

The high protection of IPR provides the right signals to local and foreign innovators to invest in new technologies that may not deliver profits at the earlier stages of development. The IPR index has a value between 8.5 for the best performers in the world (Finland and Sweden), or 7.3 for the best performer in our sample (South Africa), and 2.3 for the worst performers in our sample (Georgia and Moldova).

High industry competitiveness indicates that the exporter has in place an industrial infrastructure capable of producing new equipment and creating synergies across several industrial sectors. The high value of the coefficient indicates the importance of industry competitiveness to become a manufacturer of renewable energy technologies. An increase of 10% in the competitive industrial performance score increases by 173% the exports of hydro, wind and solar technologies per capita, all other factors remaining equal. A 10% increase in the CIP value would be equivalent to the improvement from the situation of Ethiopia (0.04) to that of Kenya (0.14), from Kenya to Morocco (0.242), from Morocco to Poland (0.33) or Mexico (0.379), and from these to Malaysia. Finally, the size of the economy indicates a local demand allowing for local demonstration and mass production to achieve cost reductions through learning-by-doing and scale effects. All the coefficients are significant at the 0.05 level, and all except IPR at the 0.01 level. The coefficients indicate that:

The best fitted model for the variable renewable generation capacity with technology transfer per capita (RECAP) is defined by the following equation:

RECAP = -5.336 + 0.814GDPpc+0.284 REACPC – 0.679 IPR* + 1.581 LOG* -0.132 FOSSILpc[5]

Five variables could explain 40% of the variation in renewable electricity generation capacity per capita involving TT in developing countries, adjusted per the percentage of capacity expected to have required foreign technology transfer. Firstly, income per capita, which, as in the case of imports, may indicate a higher demand for environmental quality in higher income countries. The renewable energy endowment of the host country is also significant, indicating that countries that have access to these resources at a lower cost are more likely to take advantage of their potential. IPR protection has a negative coefficient, which shows that high protection may deter the uptake of foreign clean renewable energy technologies (contrary to what we observed for exports, see later). A good logistical infrastructure also explains higher levels of renewable energy capacity, given the need to transport often large and heavy equipment to remote locations where the renewable energy resources reside. The logistics performance index can take values from 1 to 5. An increase by 1 point would be equivalent to moving from the situation of low performer Sierra Leone (1.97) to that of Vietnam (2.96), or from Vietnam to Japan (3.96). Finally, the production of fossil fuels per capita in the host countries has a negative coefficient, indicating that the availability of cheap fossil fuels can leave out of the market the often more expensive alternative renewable energies. All the coefficients are significant at the 0.05 level and all except LOG and FOSSILPC are significant at the 0.01 level.

The results show that different independent variables influence different aspects of renewable energy technology transfer. An interesting point about the results for output-related variables RECAP and EXP is the different sign of the IPR variable, depending on whether it is used to explain exports of renewable energy technologies or installed renewable

[5] idem

electricity capacity. IPR protection has positive sign for countries that have reached the stage of producing their own renewable energy technologies and sell them internationally. However, it has a negative effect on those countries that need to gain access to foreign renewable energy technologies to increase their electricity generation capacity.

It is also worth noting that no policy-related variables could be introduced into the models, mainly because data are not available for most developing countries about the levels of public R&D spending in clean energy technologies or other policies in place to promote them. The only available variable, namely the existence of feed-in-tariffs or guaranteed price schemes, obtained through IEA policies and measures database[6], did not prove to be significant in explaining exports, imports or the capacity of clean energy generation technologies. This is probably because the dummy variable created to account for policies cannot reflect the variety of schemes implemented in different developing countries. A certain part of the variation of the dependent variables that could not be explained by our explanatory variables may be explained by specific policies available in developing countries. A qualitative country-by-country analysis (as the one shown in Pueyo, 2012b) would therefore be required to understand fully the differences in performance between the countries in the sample.

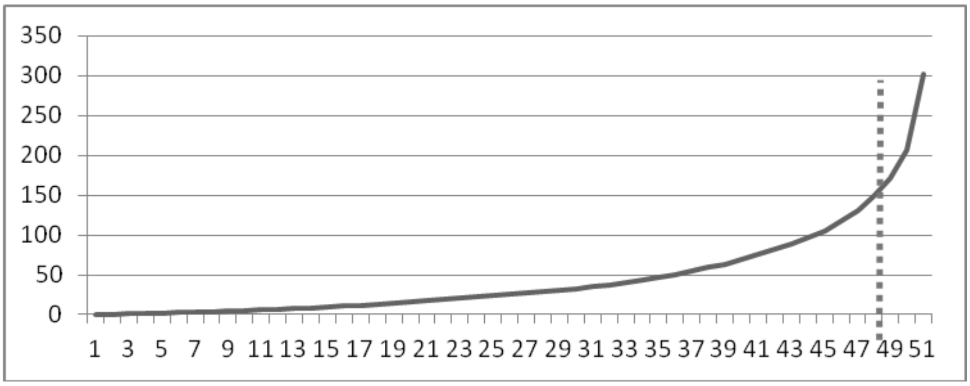
3.2 Clustering based on the performance in enabling factors

Both hierarchical (Wards) and non-hierarchical (k-means) methods have been used to derive clusters from a sample of 51 developing countries, taking as differentiating variables the eight enabling factors deemed important and significant as part of the regression analysis. As the data used in the analysis are measured on different scales, they are standardised using z-scores. Clustering techniques are particularly sensitive to outliers. These can be identified by running the k-means method for all the cases and classifying as outliers those observations that are placed in a single-case cluster. In our sample, outliers disappear when we transform with logarithms the variables GDP, GDPpc, REACpc and FOSSILpc.

The hierarchical Ward´s method was used to derive the first cluster formation. The squared Euclidean distance was used as the dissimilarity measure. To determine the optimum number of clusters, we observed the agglomeration coefficients showing the Euclidean distance between the clusters or cases aggregated, starting from stage 0, with one cluster per every country, and finishing with stage 51, clustering all countries in a single group. As shown in Figure 2.1, the distance is higher as we progress through stages. After four clusters, there are less pronounced leaps in the distances between clusters, which indicates that they are less clearly differentiated. We will therefore take four clusters as the optimal number, which also fits well with the need to keep the number of clusters within a manageable level.

[6] http://www.iea.org/textbase/pm/index.html

Figure 3.1 Agglomeration Coefficients



A one-way analysis of variance (ANOVA) was performed to identify the variables that are significant to differentiate between the groups. The between groups means were all found to be significant except in the case of the access to renewable energies REACCPClog. This indicates that access to renewable energies cannot reliably distinguish between the four clusters, but each of the remaining seven variables can clearly differentiate the groups. Besides, a Tukey post-hoc test was performed to show similarities and dissimilarities between the scores of the differentiating variables across clusters.

The means plot illustrates the differences in performance of the four clusters in each of the variables, excluding REACCpclog, which has been shown as not significant to differentiate between clusters.

Figure 3.2 Hierarchical clustering means plot

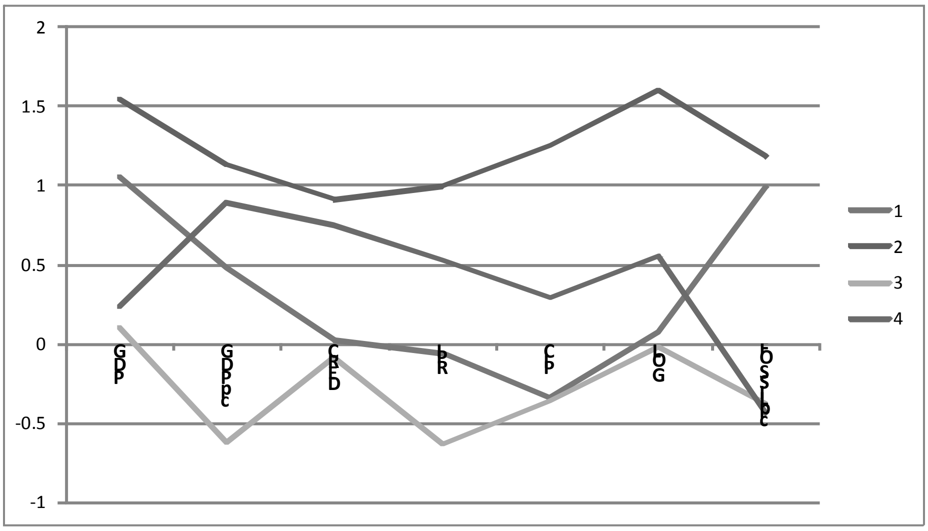


Table 2.1 shows the membership and main characteristics of each of the clusters. Country codes are included as part of the Annex.

Table 3.1 Cluster characterisation

Clust	Members*	Characteristics	Outliers**
1	DZA IDN BOL IRN COL PER ECU RUS EGY SYR	• Second highest GDP • Second lowest GDP per capita • Second lowest CRED • Second lowest IPR • Lowest CIP • Second highest FOSSILpc • Second lowest LOG	• Algeria does not reach the cluster mean's lower bound for CRED, IPR, CIP and LOG. It exceeds the cluster's mean upper bound for FOSSILpc • Bolivia does not reach the cluster's mean lower bound for GDP, GDPpc, IPR, CIP and LOG • Russia exceeds the cluster's mean upper bound in GDP, GDPpc, CRED, IPR and FOSSILpc
2	ARG OMN BRA QAT CHN SAU IND ZAF MYS THA MEX TUR	• Highest performance in all variables	• Argentina does not reach the cluster mean´s lower bound for CRED and IPR • China exceeds the cluster mean´s upper bound for GDP, CRED, CIP and LOG • Malaysia exceeds the cluster mean´s upper bound for CRED, CIP and LOG • South Africa exceeds the cluster mean´s upper bound for CREDlog, IPR and LOG
3	BGD MOZ BEN NPL CMR NGA CIV PAK GEO PRY GTM SEN HND TZA KEN UGA MDG VNM MDA ZMB	• Lowest performance in all variables except FOSSILpc	• Pakistan exceeds the upper bound of the cluster´s mean for GDPlog, CIP and FOSSILpclog • Vietnam exceeds the upper bound of the cluster´s mean for GDPlog, CREDlog, CIP, FOSSILpclog and LOG • Nigeria exceeds the upper bound of the cluster´s mean for GDPlog, CREDlog and FOSSILpclog • Guatemala exceeds the upper bound of the cluster´s mean for GDPpclog and CIP • Honduras exceeds the upper bound of the cluster´s mean for GDPpc, CREDlog and LOG
4	BWA JOR CHL LVA CRI PAN SLV TUN JAM URY	• Second lowest GDP • Second highest GDPpc • Second highest CRED • Second highest IPR • Second highest CIP • Lowest FOSSILpc • Second highest LOG	• Chile's performance exceeds the cluster's mean upper bound for all variables except CIP, however it could not be part of Cluster 2 because size related variables (GDP, Fossil pc) as well as CIP are much lower • El Salvador does not reach the cluster's mean lower bound for GDPpc, IPR and FOSSILpc, but exceeds the upper bound for CIP • Botswana does not reach the means' lower bound for GDP, CRED and LOG, but exceeds the upper bound for FOSSILpc • Jamaica does not reach the mean's lower bound for GDP, CRED, FOSSILpc and LOG, but exceeds the means upper bound for IPR

Notes:

* Country codes included as part of the Annex

** Outliers are considered as those countries showing a consistent under- or over-performance as compared to their peers.

The k-means cluster method requires the previous selection of the number of clusters. Four clusters were selected, as with the hierarchical method. In this case, the ANOVA showed that all variables were significant to differentiate between clusters, including REACCpc, deemed as not significant in the hierarchical analysis. The post-hoc Tukey analysis was also undertaken to analyse similarities and dissimilarities between clusters for each variable.

The means plot illustrates the performance of each cluster in each of the variables.

Figure 3.3 Non-hierarchical clustering means plot

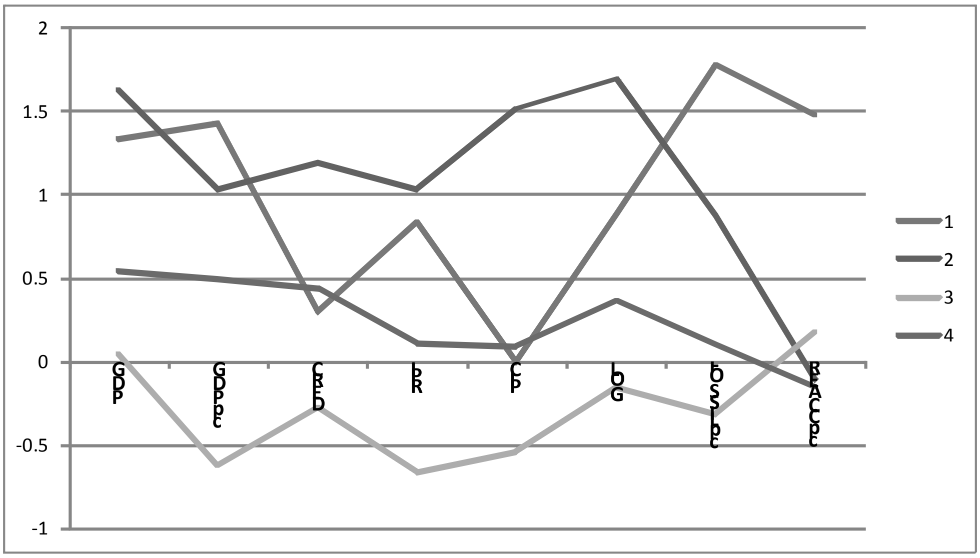


Table 3.2 shows each Cluster's members and characteristics, according to the means comparison with the ANOVA.

Table 3.2 Cluster formation with K-means

#	Members	Characteristics	Outliers
1	ARG RUS OMN SAU	• Second highest GDP • Highest GDPpc • Medium CRED • High IPR • Low CIP • The highest REACCpc • The highest FOSSILpc • Second highest LOG	None, as too small a group
2	BRA MEX CHL QAT CHN ZAF IND THA MYS TUR	• The highest GDP • The second highest GDPpc • The highest CRED • The highest IPR • The highest CIP • Low REACCpc • Second highest FOSSILpc • Highest LOG	• Chile is a significantly lower performer in GDP, CIP, FOSSILpc and LOG. It outperforms the group in REACCpc • Brazil outperforms the cluster in GDP and REACCpc • China outperforms in GDP, CRED, CIP and LOG • Malaysia outperforms the group in CRED, CIP and LOG

#	Members	Characteristics	Outliers
			• Mexico is a lower performer in CRED, IPR and LOG • South Africa outperforms in CRED, IPR and LOG • Turkey is a lower performer in CRED and FOSSILpc
3	DZA MDA BGD MOZ BEN NPL BOL PAK CMR PRY CIV SEN GEO TZA KEN UGA MDG ZMB	• The lowest performance in all variables except REACCpc	• Madagascar is an underperformer in GDP, GDPpc, CRED, and FOSSILpc. • The rest of the countries do not show a clear over or under performing pattern as compared to their peers
4	BWA JAM COL JOR CRI LVA ECU NGA EGY PAN SLV PER GTM SYR HND TUN IDN URY IRN VNM	• Second lowest GDP • Second lowest GDPpc • Medium CRED • Second lowest IPR • Low CIP • The lowest REACCpc • Second lowest FOSSILpc • Second lowest LOG	• Colombia is an over performer in GDP, GDPpc, IPR and FOSSILpc • Costa Rica is an over performer in GDPpc and CIP, but underperforms in FOSSILpc • Jordan outperforms the cluster in CRED, IPR and CIP, but underperforms in GDP • Tunisia outperforms the group in IPR and CIP • El Salvador is an underperformer in GDP, CRED, REACCpc and FOSSILpc, but outperforms in CIP • Honduras underperforms in GDP, GDPpc, CIP and FOSSILpc, but over performs in CRED • Jamaica underperforms in GDP, LOG, REACCpc and FOSSILpc but over performs in IPR • Syria underperforms in GDPpc, CRED and CIP but outperforms in FOSSILpc

The cluster structures obtained with hierarchical and non-hierarchical methods are different in some respects and show that some countries tend to remain together in the same clusters, while others show a higher mobility. Using both methods provides a more robust analysis. In both cases, there is a differentiated group of worse performers (Cluster 3 in both cases), with 20 members in hierarchical (Ward's) clustering and 18 members in non-hierarchical (k-means) clustering. Unstable members of cluster 3 of worst performers are Guatemala, Honduras Nigeria and Vietnam, which belong to Cluster 3 in the hierarchical method but are placed among 'second-worst' performing cluster 4 in the k-means method. Also Algeria and Bolivia, which belong to Cluster 3 in k-means but are placed in Cluster 1 by the hierarchical method, including oil-rich and relatively large countries with low performance in other indicators.

Both methods also show groups of best performers. In the hierarchical method, these are placed in Cluster 2, with 12 members outperforming the other clusters in all variables. In the k-means method, there are two groups of best performers with different characteristics. K-means Cluster 2, with 10 members, shows a better performance in GDP, CRED, IPR, CIP and LOG. K-means Cluster 1, with only 4 members show a better performance in GDPpclog and in variables related to availability of resources FOSSILpc and REACCpc.

Cluster 1 in the hierarchical method, with 10 members, includes relatively large economies with high production of fossil fuels per capita, but bad performance in all the other enabling factors.

Finally, Cluster 4 in the hierarchical method, with 10 members, includes relatively small economies with good performance (but lower than Cluster 2) in all enabling factors for technology transfer and low production of fossil fuels per capita. K-means Cluster 4, with 20 members, includes relatively small economies, with low access to renewable energy and fossil fuel sources per capita, but better performance than Cluster 3 in all enabling factors and better than Cluster 1 in CREDlog and CIP.

3.3 Checking the robustness of the clusters with PCA

Principal components analysis (PCA) is used in parallel to cluster analysis to contribute to a better definition of the groups of developing countries according to their TT policy needs. The advantage of PCA as compared to cluster analysis is that it can summarise the information of a wider number of enabling factors to map developing countries' performance.

Only those variables with a high correlation with the rest of variables and a small number of missing values for the countries in the sample were selected for PCA, resulting in a sample of 61 countries and 14 variables of enabling frameworks for TT highly correlated between each other. All variables were standardised to get variables with 0 mean and 1 standard deviation, since they were collected from different sources and endowed with varying scales, units and ranges.

The results of the analysis showed that three principal components could explain 72% of the variance of the 14 variables. The Scree plot confirmed the selection of three principal components for further analysis, as after the third component the curve of eigenvalues tended to flatten.

The Component Matrix shows the 'load factors' or correlations of each of the initial variables with the three components. Only correlations above 0.3 are considered significant. Those below are shaded in grey in the component matrix. Most of the items load quite strongly (above 0.4) on the first component, which therefore represents a combination of all the identified variables that can have an impact on clean energy technology transfer. The number of variables with strong loading is reduced to three in the last component.

Component Matrix[a]

Zscore	Component 1	2	3
ISOPC	.906	-.007	.163
CO2PC	.859	-.077	-.308
GDPpc	.828	-.159	-.173
LOG	.751	.074	.329
GDP	.721	.525	.037
CRED	.698	-.322	.314
EDB	-.688	.438	-.148
PATLOCPC	.650	.354	.183
FOSSILPC	.644	.454	-.434
PATFORPC	.628	.607	.399
CPI	.465	-.565	.407
TARIFF	-.398	.507	.096
PDIES	-.436	-.113	.767
INCOMETAX	-.448	.429	.537

The load factors of the different variables provide a straightforward interpretation of the principal components obtained:

- The first principal component is higher, per order of importance, for countries with a large number of high quality private businesses, high levels of CO2 emissions per capita, high levels of income per capita, a good logistics system, a large economy, credit availability for the private sector, ease of doing business, a large stock of patents filed by local inventors per capita, large fossil fuel resources per capita, a large stock of foreign patents, low corruption, low income taxes, low diesel prices and low tariffs. Countries with a high value for the first PC are therefore expected to be particularly well suited to receive large amounts of technology transfer in general.

- The second principal component is high, per order of importance, for countries with a large stock of foreign patents per capita, high levels of corruption, large economies, high tariffs, large fossil fuel resources per capita, where it is difficult to do business, income taxes are high, there is a large stock of local patents and it is difficult to get credit for the private sector. Countries with a high value for the second PC would be expected to face some barriers to achieving large levels of TT and would require reforms to reduce their level of corruption and improve their environment for foreign investment. Besides, the large fossil fuel resources per capita may render alternative energies uncompetitive in the absence of supportive demand-pull policies.

- The third principal component is higher, per order of importance, for countries with high fossil fuel prices, high taxes on workers' income, low fossil fuel resources per capita, low corruption, a large stock of foreign patents per capita, a functioning logistics system, access to credit and low CO2 emissions per capita. These countries are expected to have a significant demand for clean energy technologies, given the high prices of fossil fuels, as well as a favourable business environment. They are countries that show favourable conditions to receive significant levels of TT.

Countries with high performance in PC 1 and 3 would be considered as the most likely to benefit from foreign clean energy technology transfer, in per capita values. This is because high scores in PC1 show good enabling conditions for TT in general, whereas high scores in PC3 show good enabling conditions for renewable energy TT in particular, as it rates higher for countries with low production of fossil fuels and high fossil fuel prices..

The top and bottom performers in each of the principal components are presented in Table 3.3.

Table 3.3 Top and bottom performers in the three principal components

	PC 1	PC 2	PC 3
Top 10 performers	Saudi Arabia Qatar Malaysia Bahrain China South Africa Kazakhstan Chile Russian Federation Thailand	Iran Russian Federation China Algeria Brazil India Congo, Rep. Argentina Mexico Indonesia	Turkey China Chile South Africa Thailand Uruguay Brazil India Mauritius Vietnam
Bottom 10 performers	Zambia Nepal Uganda Madagascar Tanzania Cambodia Burkina Faso Congo, Rep. Mali Sierra Leone	Lebanon Georgia El Salvador Costa Rica Namibia Botswana Oman Bahrain Qatar Mauritius	Azerbaijan Syria Bolivia Algeria Saudi Arabia Bahrain Yemen Oman Qatar Angola

The results of the PCA are compared with those of the cluster analysis to inform a decision about the best cluster structure. We analyse in particular how cluster structures relate to country performance in the first and third principal components.

Figure 2.4 shows that clustering results obtained with the k-means method match well with the results of PCA. Countries in Cluster 2 of best performers are placed in the first quadrant (top-right), with the exception of India, in the fourth quadrant (top left), but close to the divisive line and Qatar, in the second quadrant (bottom-right). Countries in the first cluster are mostly placed in the second quadrant, with the exception of Argentina in the fourth, which indicates that factors such as low fossil fuel prices, high fossil fuels production or high corruption may be preventing a higher uptake of clean energy technology transfer. Clusters 3 and 4 are placed in the third and fourth quadrants, with countries in Cluster 4 performing better in the first principal component, indicating better conditions overall for receiving and absorbing clean energy technology transfer.

Figure 3.4 Comparison of PCA and non-hierarchical clustering results

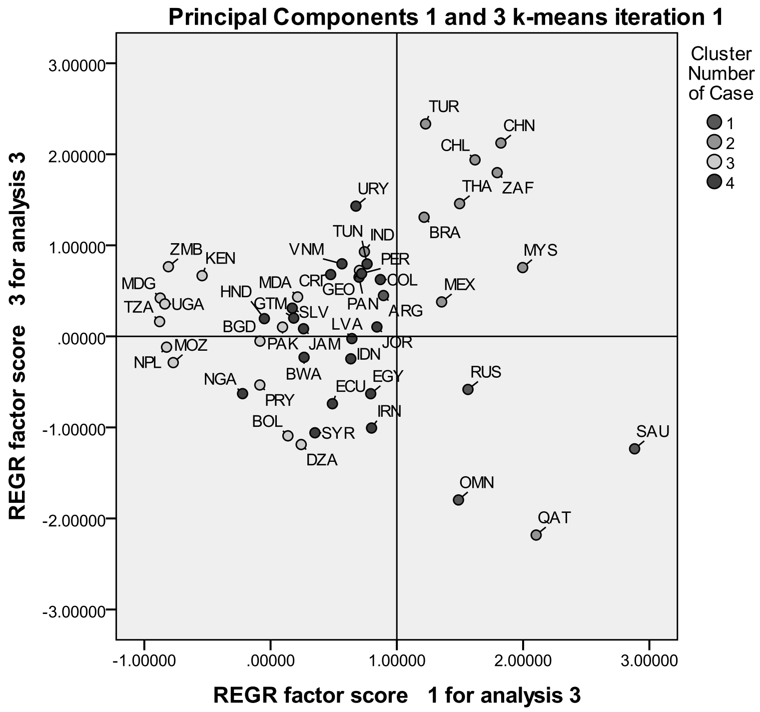
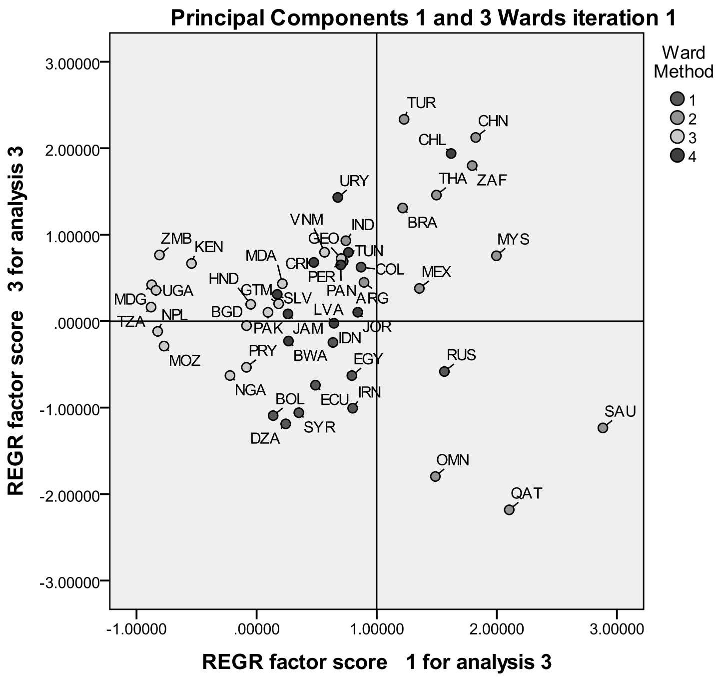


Figure 3.5 Comparison of PCA and hierarchical clustering results



3.4. Grouping developing countries to derive renewable energy technology transfer policy priorities

Finally, we combine all the information presented above to create more homogeneous groups as regards the definition of TT policies. A certain level of judgement is required from the researcher as each of the methods provides slightly different results. Four main groups of host countries for renewable energy technology transfer have been defined. These four differentiated groups are presented in Figure 2.6. Those countries that are not clearly attributable to one cluster, but are placed between two of them, are identified with a different colour in their relevant clusters.

Figure 3.6 Groups of developing countries for renewable energy technology transfer

TECHNOLOGY DEVELOPERS	TECHNOLOGY IMPLEMENTERS	STRUCTURAL CHANGES	AID RECIPIENTS
Brazil (UM)	Botswana (UM)	Algeria (UM)	Bangladesh (L)
China (LM)	El Salvador (LM)	Russia (UM)	Bolivia (LM)
India (LM)	Jamaica (UM)	Oman (U)	Benin (L)
Mexico (UM)	Uruguay (UM)	Qatar (U)	Cameroon (LM)
Turkey (UM)	Costa Rica (UM)	Saudi Arabia (U)	Côte d´Ivoire (LM)
Malaysia (UM)	Jordan (LM)	Ecuador (LM)	Georgia (LM)
South Africa (UM)	Lebanon (UM)	Egypt (LM)	Guatemala (LM)
Thailand (L)	Panama (UM)	Iran (LM)	Honduras (LM)
Chile (UM)	Tunisia (LM)	Syria (LM)	Kenya (L)
Argentina (UM)	Colombia (UM)	Indonesia (LM)	Madagascar (L)
	Vietnam (L)	Argentina (UM)	Moldova (LM)
	Chile (UM)	Colombia (UM)	Mozambique (L)
	Peru (UM)	Peru (UM)	Nepal (L)
			Nigeria (LM)
			Pakistan (LM)
			Paraguay (LM)
			Senegal (L)
			Tanzania (L)
			Uganda (L)
			Zambia (L)
			Vietnam (L)

Note: UM: Upper-middle income, LM: Lower-middle income; L: Low income

Firstly, the group of potential technology developers includes countries which are capable of succeeding in the three elements of TT, defined in Section 2. i.e. attracting foreign flows of technologies, efficiently operating and maintaining foreign equipment and generating and managing technological change through indigenous efforts to absorb foreign technologies. Countries in this group are characterised by large economies, with relatively high income per capita, high availability of credit for the private sector, high IPR protection, good industrial competitiveness and a well-functioning logistical infrastructure. The cluster includes mostly upper-middle income countries but also lower-middle income China and India and low-income Thailand, which shows an excellent industrial competitiveness and credit availability for the private sector. Among members of this cluster, Argentina clearly under-performs in terms of credit for the private sector and IPR protection, and it is placed in between the group of technology developers and that of countries in need of structural changes. Chile under-performs in the size of its economy and its industrial competitiveness, and is placed between this group and the 'technology implementers' group.

Secondly, clean technology implementers have relatively small economies but high levels of income per capita, good levels of credit availability for the private sector, IPR protection and a good environment for private investment. However, their industrial competitiveness and logistical infrastructure are still far from the levels of the group of technology developers. These countries usually show very low levels of fossil fuel production per capita, which would reflect in high fossil fuel prices, creating the necessary demand-pull signals for investments in clean energy technologies. The group includes mostly upper-middle income countries in Africa, Latin America and the Middle East, but also lower-middle income Latin American and Middle Eastern countries. It may also include Vietnam, a low income country but with better performance in several enabling factors and TT indicators than low income countries in the group requiring foreign aid. Chile´s performance exceeds other cluster members for all differentiating variables except industrial competitiveness, which is why it is placed in between the group of technology developers and technology implementers. This cluster is not expected to develop high-tech clean energy technologies, as it lacks sufficient internal demand that allows scale effects and learning-by-doing and lacks a competitive industrial sector. However, it is expected to attract significant levels of foreign TT per capita, as a result of its relative wealth, its need for energy security and, in many instances, good renewable energy endowment. This is already shown in their current levels of clean energy technologies imports.

Third, there is a group of countries requiring structural changes to improve their business environment and create clear demand signals favouring clean energy technologies over widely locally available fossil fuels. This group includes relatively large economies with high levels of fossil fuels production per capita, good levels of income per capita, but low industrial competitiveness, credit availability for the private sector and, in most cases, low IPR protection, low logistical performance and an unfavourable environment for private investment. They are mostly high income or upper-middle income countries, although they also include lower-middle income countries such as Ecuador, Egypt, Iran and Indonesia. Although many of these countries have economies large enough and good levels of income per capita to attract foreign investment, they are not be expected to attract large amounts of foreign clean energy technologies per capita, due to the lack of clear demand signs. As large fossil fuel providers, fossil fuel prices are low in comparison to other countries. This renders renewable energies uncompetitive. Besides, there is not an incentive to promote clean energy for energy security and geopolitical reasons. Additionally, their economies do not provide a good environment for private investment, showing high levels of corruption and low ease of doing business. Russia outperforms the rest of the cluster members in terms of total and per capita income, credit availability and IPR protection. As a result, it also outperforms other cluster members in terms of imports and exports of clean technologies per capita.

Finally, the group denominated ‘aid recipients’ includes countries needing foreign aid to create the building blocks for successful TT. This group is formed from mostly low income and lower-middle income countries from Africa, as well as low and lower-middle income countries from Asia and Latin America. Their poor performance in most of the enabling factors for clean energy TT indicates very low attractiveness for foreign technology suppliers. These countries lack a sufficient demand and the economic and institutional frameworks that attract private investment to clean energy technologies, as well as the technological capabilities to implement foreign technologies and the industrial fabric to develop their own technologies. Vietnam is an outlier in this cluster, and could also belong to the ‘technology implementers’ cluster. Vietnam shows good performance in terms of economy size, credit availability for the private sector, industrial competitiveness and logistic infrastructure, and it also outperforms its peers in terms of imports and exports per capita of clean technologies.

Of course, the composition of the different groups is subject to changes as their performance evolves and they implement policies to improve their main pitfalls. Therefore, this exercise should be included in a dynamic framework.

4. Policy recommendations

Based on the classification of countries according to their enabling factors for renewable energy TT, we can now provide different combinations of policies that can be implemented to strengthen their receptiveness for renewable energy technology transfer.

Our policy recommendations are classified in four main groups that reflect our four types of enabling factors: improving economic and institutional frameworks, demand-pull policies, technology-push policies and industrial policy. The delimitation of policies for technology development and deployment to fit these groups is far from clear but it provides us with a useful framework for analysis. We acknowledge the insights of innovation studies literature that stress the importance of active learning processes, indigenous capabilities and the links between the different actors of a National Innovation System for the direction and relative success of technology transfer activities (Freeman and Soete, 1997; Freeman, 2002; Watson and Byrne, 2011). More recently, the literature on Technological Innovation Systems emphasises a range of 'functions' such systems need to fulfil in order to maximise the chances of successful innovation and diffusion. These functions include the creation and diffusion of new knowledge; the supply of resources such as capital and competences; the creation of positive external economies; the formation of markets and the guidance of the direction of search among users and suppliers of technology (Jacobson and Bergek, 2004). Economic and institutional frameworks can be enhanced through sound macroeconomic policies and solid institutions, trade openness, regional integration, the government brokerage of TT processes, the support of interest groups associated with the new technology, or the promotion of links between the different actors of the TT process.

Technology demand and supply factors can be enhanced through the so-called demand-pull or technology-push policies (Mowery and Rosenberg, 1979). Demand-pull policies affect the size of the market for a new technology by raising the payoffs of innovation and deployment (Nemet, 2009). Some examples of demand-pull policies in the field of climate change include carbon markets, tax credits and rebates for consumers of new technologies, technology mandates, energy efficiency standards, feed-in tariffs, renewable energy portfolios, taxes on competing technologies and government procurement (Nemet, 2009). The rationale of government intervention is the expectation of cost reductions through a variety of learning processes as the installed capacity increases (Grubb, 2004).

The most common examples of technology-push policies are government-sponsored R&D, tax credits for companies that invest in R&D, support for education and training, infrastructure development, technological standards and funding demonstration projects (Nemet, 2009). Positive knowledge spillover externalities and the reduction of uncertainty provide the rationale for government intervention.

Industrial policy can remove barriers of entry and create protected spaces for new indigenous technologies, where learning processes can take place, the price and performance of the technology can be improved and new customer preferences can be formed (Jacobson and Bergek, 2004). Industrial policy also plays a role in promoting the entry of firms in different parts of the value chain of the new technology so that highly linked low-carbon technological systems can emerge. Some examples of industrial policy are local content requirements and differentiated fiscal and tariff regulations.

The four groups of developing countries highlighted by our analysis require a differentiated emphasis on these types of policies, with some high level recommendations provided below:

The four groups of developing countries highlighted by our analysis require a differentiated emphasis on these types of policies, with some high level recommendations provided below:

- **Technology developers**. Policies in these countries depend on the specific stage of clean energy technological development of each country, but in general terms they should start with effective demand-pull policies that attract investments in clean technology complemented by technology-push policies that increase the local capacity to use and maintain the technologies and transcend foreign knowledge to create their own endogenous technologies. The results of the regression analysis show that IPR protection is required to protect local developers of renewable energies and to encourage foreign developers to produce in developing countries. Results also show that a pre-existing competitive industry is required. This group can learn from the success stories of India, with leading wind turbine manufacturers, China, with leading wind turbine and solar PV technologies manufacturers, and Malaysia, leaders in biomass energy technologies. Some level of industrial policy could be required to support local infant industries, as has been shown by the experiences of China and India (Lewis 2007; Lewis 2011; Wang, 2010; Zhang et al., 2009). The large demand size and growth of these countries offer high potential gains for foreign technology providers, which could be willing to accept restrictive industrial policies. These policies should only be temporary or otherwise risk creating uncompetitive industries.

- **Technology implementers**. Due to their relatively small size and lack of a strong industrial sector, technology implementers should concentrate their policy efforts on a reduced group of technologies to reach affordable costs through economies of scale and learning by doing (Pueyo, 2011). The decision should take into account the country's sources of competitive advantage, which can come from their renewable energy endowment, accumulated knowledge, infrastructures and existing industrial sectors. Demand-pull policies should be introduced to increase the implementation of clean technologies and improve internal capabilities through learning-by-doing. Technology-push policies can enhance local capabilities and facilitate the emergence of local service providers to renewable energy project developers. Industrial policy can support the creation of value-added by the existing industry and facilitate cross-sectoral spillovers for the development of low-carbon technologies. However, these countries have a more narrow scope to implement industrial policy than the group of 'technology developers'. Demonstration projects would contribute to reduce the perceived technical risks of renewable energy projects.

- **Countries in need of structural changes.** These countries should improve the economic and institutional conditions favourable to private investment. Previous research on barriers to investment in renewable energies in the Middle East and North Africa (MENA) has pointed at the importance of stable and predictable regulations, particularly as regards to long-term power purchase agreements (PPA) and a transparent and efficient bureaucratic state apparatus (Komendantova et al, 2012; Trieb et al, 2011). Innovative financing schemes such as public-private partnerships and guarantees of the PPA by international insurance entities could reduce the risk for private investors. Countries in this group should also create the appropriate demand signals for clean energy technologies. Demand signals are currently distorted as many of these countries rely on fossil fuel subsidies to provide cheap energy to their population. Removing fossil fuel subsidies or using fossil fuel rents to diversify their electricity generation portfolio could contribute to create a level playing field for renewable energies. The development of local capabilities could start with an improvement of the capabilities to operate and maintain installed technologies, which complemented with other policies and active internal learning may eventually lead to independent innovation.

- **Aid recipients**. Appropriate capabilities, infrastructures and institutions need to be in place for countries in this group to reap the benefits of renewable energy technology transfer. Clear targets for renewable energy penetration, coordinated energy policies, stable institutional frameworks, reduced bureaucracy or appropriate power purchase agreements (PPA) have been recommended by previous researchers in Sub-Saharan Africa (Gboney, 2009). Capacity building programs including government decision makers, industry and local end-users are also essential to create solid foundations for technology transfer. The choice of renewable energies should take into account the existing knowledge in host countries and the potential for locally sourced maintenance and repairs to avoid excessive dependence from foreign suppliers (Barry et al, 2011; Karekezi and Kythioma, 2003; Acker and Kammen, 1996). Experiences of grassroots innovation or scarcity-induced innovation for the provision of small-scale renewable energy in Least Developed Countries (LDC) have shown that local resources and capabilities, often hidden, scattered, or badly utilized are essential for successful innovation and diffusion processes (Srinivas and Sutz, 2008). National and international policy should aim at empowering communities to take advantage of this potential. The role of women in particular for the design and dissemination of sustainable home energy technologies is an emerging issue (Köhlin et al, 2011). For larger scale projects, the The initial demand required for the transfer of renewable energy could be created through finance for demonstration projects. International finance will be essential to create solid foundations for renewable energy technology transfer.

General policy recommendations are provided at the national level, but we are aware that significant differences exist at the sub-national level. Hence, the recommended policies for ‘aid recipients’ could be applicable to regions inside countries in other groups which suffer from a lack of access to modern energy sources for the poor. The lack of available data about enabling factors for technology transfer at the regional level in most developing countries has prevented a sub-national analysis.

5. Conclusions

This paper has followed a quantitative approach to identify the factors that enable clean energy technology transfer to developing countries. It has subsequently classified developing countries according to their performance in these enabling factors and suggested policy priorities for each of the resulting groups. The results of the analysis could be used to inform the definition of priorities by international funders of technological actions in developing countries. This approach could be particularly used by the Technology Mechanism of the UNFCCC, in line with its manifested ‘country-driven approach’. Indeed, this research has already been presented to the Technology Executive Committee in September 2012.

The paper provides a wide perspective about the performance of a large number of developing countries as regards enabling frameworks for renewable energy technology. This is an important contribution to the existing body of literature that usually focuses on a few developing countries, mainly China, India and Brazil. The proposed methodology to group developing countries according to their performance in enabling factors for TT is also an important contribution to the existing body of literature on technology transfer, which is mainly qualitative.

Our approach has of course some limitations which invite to further research in the area. Firstly, we could only use a limited number of indicators of renewable energy technology transfer, due to data unavailability. Some additional indicators such as patent data or renewable energy foreign direct investment could also be used to explore relationships between technology transfer and enabling frameworks. Secondly, our analysis is static, but dynamic relationships could be analysed to explore the impact of policy actions on enabling conditions and subsequently flows of technology transfer. Third, we provide only high level policy recommendations for the four groups of developing countries. More detailed policy recommendations for each of the groups could be provided on the basis of a qualitative, country-level review of what has and has not worked in several countries of each group. Finally, our analysis is made at the national level, but we are aware that there are significant regional differences in the enabling conditions for technology transfer. A country by country analysis of regional performance would be required, due to the unavailability of regional data for our selected indicators of enabling environments.

Annexes

6.1 Definition of enabling factor variables

Variable	Description
EDB	Ease of Doing Business measures a combination of nine aspects: Starting a Business, Dealing with Construction Permits, Registering Property, Getting Credit, Protecting Investors, Paying Taxes, Trading Across Borders, Enforcing Contracts, Closing a Business. Countries with the lowest rank are the best performers.
CPI	The Corruption Perception Index ranks countries according to perception of corruption in the public sector. The most corrupt countries have the lowest scores.
IPR	The Intellectual Property Rights index score has three components: Protection of Intellectual Property Rights, Patent Protection and Copyright Piracy. This index also feeds the more general index of Property Rights. The higher the score of the IPR index, the higher the protection.
INCOMETAX	The average income tax rate, is used for the calculation of the Index of Economic Freedom.
CRED	Domestic credit to private sector refers to financial resources provided to the private sector, such as through loans, purchases of non-equity securities and trade credits and other accounts receivable, that establish a claim for repayment. For some countries these claims include credit to public enterprises.
TARIFF	A high rate of most favoured nation average applied tariff applied for non agricultural goods represents high protection.
TRADEOP	Trade openness is calculated as imports plus exports divided by GDP.
FDIOP	Foreign Direct Investment openness is calculated as FDI net inflows divided by GDP.
INVESTFREE	The index of investment freedom evaluates a variety of restrictions typically imposed on investment. Points are deducted from the ideal score of 100 for each of the restrictions found in a country's investment regime. High scores mean high levels of freedom.
LOG	The logistics performance index: Overall (1=low to 5=high), reflects perceptions of a country's logistics based on efficiency of customs clearance process, quality of trade- and transport-related infrastructure, ease of arranging competitively priced shipments, quality of logistics services, ability to track and trace consignments, and frequency with which shipments reach the consignee within the scheduled time.
GDP	Gross Domestic Product in current Million US$ at purchasers' prices, 2009
GDPg	Average GDP Growth between 2005 and 2009
GDPpc	GDP per capita in current US$.
CO2pc	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.
PDIES	Fuel prices refer to the pump prices of the most widely sold grade of diesel fuel. Prices have been converted from the local currency to U.S.

Variable	Description
	dollars.
FOSSILpc	Overall production of primary coal, dry natural gas and oil, converted to heat values by the author using the gross heat content values of every fuel per country
FIT	Countries that have implemented Feed-in tariffs or that provide guaranteed , 2011 premiums to renewable electricity generation. 1=yes, and 0=no feed-in tariffs. Values taken from IEA policies and measures database, as countries that have implemented these policies in or before 2011.
HTEXPC	High-technology exports are products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery.
ISO9pc	Number of companies with ISO 9001 certification, 2008. Values expressed as companies per Million people and with logarithmic transformation.
TFP	The most recent Total Factor Productivity data available is from 2000, 2005 values were projections. Correlation between real 2000 data and projections for 2005 is very high (Pearson correlation of 0.961 significant at the 0.01 level), therefore we take the latest data. UNIDO´s calculation based on the default capital stock (K06), based on the perpetual inventory method (PIM) with an annual depreciation rate of 6% and an initial capital stock including ten years of investment.
CIP	The Competitive Industrial Performance index combines four main dimensions of industrial competitiveness: industrial capacity, manufactured export capacity, industrialization intensity and export quality. A high value indicates good performance
PATFORpc	The total stock of patents filed by foreign inventors between 1883 and 2009 is calculated using the perpetual inventory method with a 10% discount rate. Values are expressed per capita as number of patents per million inhabitants.
PATLOCpc	The stock of patents filed by local inventors during the period 1883-2009 is calculated following the perpetual inventory method with a 10% discount rate. Values expressed per capita as number of patents per million inhabitants.
Enrol3	Gross enrolment ratio is the ratio of total enrolment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Tertiary education, whether or not to an advanced research qualification, normally requires, as a minimum condition of admission, the successful completion of education at the secondary level.
REACPC	Estimated annual renewable energy resources for solar, hydro, wind, different kinds of biomass and geothermal energy. Values expressed in toe per thousand people. For solar, wind and geothermal, low, intermediate and high scenarios are available. Only intermediate scenarios are taken to estimate the potential availability.
WSHACCPC	**Title:** Estimated renewable energy potential for wind, solar and hydro sources Values expressed in toe per thousand people. Logarithmic transformation. The differentiation is made because we only count on imports data for wind, hydro and solar technologies and it may be useful to count on the specific potential of these sources to find relationships between the variables.

6.2 Descriptive statistics of enabling factor variables

Table 6.1 Descriptive Statistics of Explanatory Variables

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
EDB	120	11	183	112.57	46.866
CPI	122	.34	2.04	1.0728	.35233
IPR	79	2.30	7.30	4.5443	.99779
CRED	107	1.57	4.99	3.3353	.76305
GDP	122	4.85	15.42	9.7930	2.06761
GDPpc	122	5.07	11.15	7.6085	1.20167
CO2PC	123	.02	4.03	.9652	.83004
PDIES	110	.01	2.03	.9022	.36764
HTEXPC	87	.01	4.20	1.5296	.96382
ISOPC	124	.00	8.59	2.1882	1.91104
TFP	81	.01	.73	.2444	.12939
CIP	74	.04	.47	.1974	.08600
ENROL3	76	.15	4.80	2.6390	1.13522
PATLOCPC	98	.00	8.06	2.2224	2.16733
PATFORPC	98	.00	9.72	2.6480	2.46631
TRADEOP	115	3.12	6.36	4.3651	.52970
TARIFF	119	.00	25.59	10.1704	4.95389
FDIOP	122	-.01	.28	.0407	.04594
LOG	105	1.70	3.63	2.6242	.35949
INCOMETAX	120	.00	60.00	28.1125	11.37459
WSHACCPC	124	.00	6.29	.9088	.89814
REACPC	124	.00	14.24	7.6351	2.28096
FOSSILPC	122	.00	15.01	3.9260	3.62730
GDPg	124	-4.93	21.21	5.2405	3.35853
INVESTFREE	120	.00	90.00	42.1250	21.13047
Valid N (listwise)	21				

6.3 Regression analysis

Table 6.2 Model results: exports of renewable energy technology per capita

	I	II	III	IV	V	VI	VII
Dependent variable	EXP	EXP	EXP	EXP	EXP	EXP	EXP
N	54	54	54	53	54	54	42
Constant	**-7.227*** (1.322**)	-5.982*** (1.704)	-6.555*** (1.628)	-5.415*** (1.583)	-7.262*** (1.381)	-8.929*** (1.679)	-7.222*** (1.533)
WSHACCPC	**.889*** (0.251)**	**0.856*** (0.252)**	**0.894*** (0.275)**	**0.836*** (0.246)**	**0.898*** (0.270)**	**0.919*** (0.248)**	**0.883*** (0.291)**
CIP	**17.283*** (3.085)**	**16.403*** (3.169)**	**20.440*** (3.079)**	**18.158*** (3.034)**	**17.388*** (3.288)**	**19.280*** (3.283)**	**17.150*** (3.589)**
GDP	**.396*** (0.127)**	**0.381*** (0.127)**		**0.286** (0.135)**	**0.402*** (0.140)**	**0.595*** (0.176)**	0.356** (0.171)
IPR	**.589** (0.229)**	0.539** (0.233)	0.604** (0.252)	**0.651*** (0.225)**	**0.585** (0.236)**	0.590** (0.226)	0.607** (0.269)
EDB		-0.006 (0.005)					
GDPpc			0.330				

			(0.227)				
PDIES				-1.269* (0.647)			
PATLOCPC					-0.013 (0.134)		
PATFOR						-0.254 (0.158)	
ENROL3							0.125 (0.280)
R-Square	0.691	0.699	0.646	0.714	0.691	0.707	
Adjusted R-Square	0.667	0.669	0.618	0.685	0.660	0.677	
F	27.986	22.801	22.825	24.436	21.947	23.607	

Note: Standard errors in parentheses;*** p<0.01, ** p<0.05, * p<0.1

Table 6.3 Model results: imports of renewable energy technologies per capita

	I	II	III	IV	V	VI	VII
Dependent variable	IMP	IMP	IMP	IMP	IMP	IMP	IMP
N	71	71	71	64	71	68	67
Constant	-1.108 (0.756)	-0.427 (1.309)	-0.845 (0.945)	-1.620* (0.826)	-0.909 (0.817)	-0.881 (0.790)	-1.730* (0.938)
GDPpc	**.668*** (0.109)**	**0.639*** (0.119)**	**0.656*** (0.113)**	**0.629*** (0.115)**	**0.619*** (0.133)**	**0.645*** (0.113)**	**0.619*** (0.120)**
CRED	**.688*** (0.172)**	**0.624*** (0.200)**	**0.673*** (0.176)**	**0.591*** (0.185)**	**0.711*** (0.176)**	**0.619*** (0.183)**	**0.580** (0.199)**
EDB		-0.002 (0.003)					
TARIFF			-0.012 (0.025)				
IPR				0.249* (0.131)			
FOSSILpc					0.026 (0.039)		
PATFOR						0.066 (0.052)	
LOG							0.514 (0.435)
R-Square	0.593	0.596	0.595	0.616	0.596	0.603	0.602
Adjusted R-Square	0.582	0.578	0.577	0.597	0.578	0.585	0.583
F	50.340	33.407	33.252	32.620	33.429	32.927	32.272

Note: Standard errors in parentheses;*** p<0.01, ** p<0.05, * p<0.1

Table 6.4 Model results: renewable generation capacity with TT per capita

	I	II	III	IV	V
Dependent variable	RECAP	RECAP	RECAP	RECAP	RECAP
N	70	70	70	70	70
Constant	**-5.336*** (1.866)**	**-2.667 (1.643)**	**-4.377* (2.426)**	**-6.271*** (1.977)**	**-5.802*** (2.101)**
GDPpc	**.814*** (0.186)**	**0.912*** (0.175)**	**0.756*** (0.209)**	**0.784*** (0.186)**	**0.830*** (0.189)**
IPR	**-.679*** (0.191)**	**-0.574*** (0.190)**	**-0.682*** (0.192)**	**-0.666*** (0.190)**	**-0.707*** (0.201)**
REACPC	**.284*** (0.084)**	**0.159** (0.77)**	**0.282*** (0.085)**	**0.304*** (0.085)**	**0.304*** (0.094)**
LOG	**1.581** (0.626)**		**1.506** (0.641)**	**1.982*** (0.689)**	**1.745** (0.712)**
FOSSILPC	**-.132****		**-0.126****	**-0.138****	**-0.130****

	I	II	III	IV	V
Dependent variable	RECAP	RECAP	RECAP	RECAP	RECAP
	(0.062)		**(0.063)**	**(0.061)**	**(0.062)**
PDIES		0.768 (0.542)			
EDB			-0.003 (0.004)		
FIT				-0.903 (0.664)	
PATLOCpc					-0.51 (0.104)
R-Square	0.406	0.344	0.409	0.422	0.408
Adjusted R-Square	0.360	0.304	0.354	0.368	0.352
F	8.871	8.642	7.388	7.797	7.347

Note: Standard errors in parentheses;*** p<0.01, ** p<0.05, * p<0.1

6.4 Country codes

Afghanistan	AFG
Algeria	DZA
Angola	AGO
Argentina	ARG
Armenia	ARM
Azerbaijan	AZE
Bahrain	BHR
Bangladesh	BGD
Belarus	BLR
Belize	BLZ
Benin	BEN
Bhutan	BTN
Bolivia	BOL
Botswana	BWA
Brazil	BRA
Burkina Faso	BFA
Burundi	BDI
Cambodia	KHM
Cameroon	CMR
Cape Verde	CPV
Central African Rep	CAF
Chad	TCD
Chile	CHL
China	CHN
Colombia	COL
Comoros	COM
Congo, DR	ZAR
Congo, Rep.	COG
Costa Rica	CRI
Côte d'Ivoire	CIV

Georgia	GEO
Ghana	GHA
Guatemala	GTM
Guinea	GIN
Guinea-Bissau	GNB
Guyana	GUY
Haiti	HTI
Honduras	HND
India	IND
Indonesia	IDN
Iran	IRN
Iraq	IRQ
Jamaica	JAM
Jordan	JOR
Kazakhstan	KAZ
Kenya	KEN
Kiribati	KIR
Korea, DR	PRK
Kyrgyz Rep	KGZ
Lao PDR	LAO
Lebanon	LVA
Lesotho	LSO
Liberia	LBR
Libya	LBY
Madagascar	MDG
Malawi	MWI
Malaysia	MYS
Mali	MLI
Mauritania	MRT
Mauritius	MUS

Pakistan	PAK
Panama	PAN
Peru	PER
Philippines	PHL
Qatar	QAT
Russian Fed	RUS
Rwanda	RWA
Samoa	WSM
São Tomé and Principe	STP
Saudi Arabia	SAU
Senegal	SEN
Seychelles	SYC
Sierra Leone	SLE
Solomon Islands	SLB
Somalia	SOM
South Africa	ZAF
Sri Lanka	LKA
Sudan	SDN
Suriname	SUR
Swaziland	SWZ
Syria	SYR
Tajikistan	TJK
Tanzania	TZA
Thailand	THA
Timor-Leste	TMP
Togo	TGO
Tonga	TON
Tunisia	TUN
Turkey	TUR
Turkmenistan	TKM

Cuba	CUB
Djibouti	DJI
Dominica	DMA
Dominican Rep	DOM
Ecuador	ECU
Egypt.	EGY
El Salvador	SLV
Equatorial Guinea	GNQ
Eritrea	ERI
Ethiopia	ETH
Fiji	FJI
Gabon	GAB
Gambia, The	GMB

Mexico	MEX
Micronesia	FSM
Moldova	MDA
Mongolia	MNG
Morocco	MAR
Mozambique	MOZ
Myanmar	MMR
Namibia	NAM
Nepal	NPL
Nicaragua	NIC
Niger	NER
Nigeria	NGA
Oman	OMN

Uganda	UGA
Ukraine	UKR
United Arab Emir.	ARE
Uruguay	URY
Uzbekistan	UZB
Vanuatu	VUT
Venezuela, RB	VEN
Vietnam	VNM
West Bank and Gaza	WBG
Yemen, Rep.	YEM
Zambia	ZMB
Zimbabwe	ZWE

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