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TÍTULO COMPLETO:

ARE THE BRICS MAKING THE TRANSTION TOWARDS CLEAN ENERGY SYSTEMS?

The role of global institutional frameworks on the emerging renewable energy systems of the BRICS countries.

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Abstract

This paper aims at exploring the impact of the global institutional frameworks on the process of diffusion of renewable energy technologies in the BRICS countries i.e. Brazil, China India, Russia and South Africa. We address empirically this issue making use of national aggregated data from the World Development Indicators and International Energy Agency, as well as from the United Nations Framework Convention on Climate Change. The paper shows that global international frameworks seem to support the efficient use of fossil fuels, but not the diffusion of renewable technologies. Higher education, as well as some natural endowments and national policy culture may support the diffusion of renewable technologies. Instead, economic and social development, technological capabilities, and internationalisation of national business support reliance on fossils and hold back diffusion of renewable technologies.

1. Introduction

The industrialisation of developing countries and fast growth of emerging economies poses a fundamental question for policymakers and researchers working on development, innovation and global environmental sustainability. The question is whether the industrial, economic and social transformation of developing and emerging countries will follow conventional trajectories intensive in greenhouse gases emissions or manage to strive towards more environmentally sustainable growth pathways. The catching up process of the Newly Industrialised Countries (NICs) has been characterized by intense technological learning centred initially on the imitation and adaptation by the NICs of the technologies and industrial practices of developed countries (e.g. Hobday, 1995; Kim, 1998). In that context, environmental sustainability concerns have often been left outside the economic development argument. This neglect has been considered as a necessary initial cost before the 'take off' to full industrialization status (O'Conner, 1996). Such a 'grow now, clean later' development path (O'Conner, 1996) was supposed to follow the Environmental Kuznet curve that shows a worsening of environmental indicators until developing countries reach a certain level of economic development (i.e. GDP), which is then followed by an improvement in environmental performance (World Bank 2003).

However, the viability of pursuing such an approach in the present has been put in question by growing environmental deterioration and concerns about the global impact of climate change. Besides, the economic, social, political and environmental contexts in which the developing countries are placed today are very different from those in which the industrialisation of the NICs has occurred. Interconnectivity of economic and social activities at the current global age is unprecedented. Regarding environmental sustainability, it has become evident that global cooperation is necessary to deal collectively with global issues such as climate change. This awareness has led to establishment of several global organizations and institutions such as the Commission for Sustainable Development and milestone policy documents and international agreements such as the Agenda 21 and the Kyoto Protocol. These international efforts are expected to contribute greatly in defining shared common visions on how to deal with environmental problems, while leaving the development pathways to be implemented differently but collectively among countries.

Those growing concerns about environmental sustainability and the central importance attributed to the transformation of energy systems towards renewable sources have motivated a blooming area of research on the emergence and dynamics of new technological innovation systems in renewable energy over recent years (e.g. Hekkert et al, 2007; Negro et al, 2007; Bergek et al, 2008; Jacobsson, 2008; Suurs and Hekkert, 2009). Such research concentrates on the main components of innovation systems, namely, actors, networks, institutions and technologies. A central element of the analysis is what the authors have identified as core system functions. Those include, for instance, the creation and diffusion of knowledge, the guidance of search, the supply of resources, the formation of markets, legitimization, and entrepreneurial experimentation (Jacobsson and Bergek, 2004). Another important dimension taken into consideration in the analysis is the type of blocking and inducing mechanisms influencing the formation of the systems (Bergek et al, 2008; Jacobsson, 2008). Empirical work guided by the technological innovation system framework has been concerned with the formation of renewable energy innovation systems in advanced industrialised countries, mainly in Europe (Jacobsson and Bergek, 2004; Suurs and Hekkert, 2009; Negro et al, 2007). Those studies have dealt with the initiation and shifts in systemic functions and the interactions and feedback loops among the functions in the development of the system from formative to mature stages.

However, empirical evidence on the formation of new technological systems and the diffusion of renewable energy technologies in emerging economies is still necessary. The major emerging economies, also known as the BRICS countries, i.e. Brazil, Russia, India, China and South Africa, with their accelerated economic growth and associated environmental burdens are at the forefront of the challenge in forging new pathways towards sustainable development. Yet, empirical evidence about the emergence of renewable energy innovation systems and the factors driving the process in those countries are still sparse. In the absence of such evidence, the differences and commonalities in formation patterns of systems or specific systemic functions in industrialising as contrasted to industrialised countries can only be speculated. This provides a limited information base to underpin the definition of policy measures to support renewable energy sources and associated innovation systems in those countries.

Besides, we lack understanding of the impact of influences that are external to the national technological innovation systems on system dynamics. Although, the impact of external factors in inducing or blocking system development has been clearly acknowledge (Jacobsson, 2008), we still need to know more about how particular factors that are external to the system, such as the global institutional framework, influence specific systemic functions. This is relevant because a major effort is being put in place to devise and implement global environmental regimes in the expectation that this will lead to desired changes in the behaviour of individual countries and their socio-economic systems. But until now, we simply do not know enough about the effectiveness of those measures in attaining such expectations. Building systematic and detailed empirical evidence about the workings of those global institutions and how they relate to the performance of system functions, such as the diffusion of more sustainable technologies represents a step in this direction. With that in mind, we aim to address in this study the following research question: What has been the impact of the global environmental institutional framework on the diffusion of renewable energy technologies in the BRICS countries?

Drawing on the literatures on technological innovation systems, diffusion and global institutions we analyse the diffusion of renewable energy technologies in the BRICS countries. In particular, we examine what has been the impact of the global institutional framework, specifically the Clean Development Mechanism and Joint Implementation Mechanism on the diffusion of the renewable energy technologies in those countries. We do so by using data on the CDM and JI projects in pipeline (UNFCC, 2009), as well as series data, from 1987 to 2004, on the energetic, as well as social, economic, technological characteristics of these countries, collected from the World Bank Indicators and International Energy Agency. Using descriptive statistic methods, we show that global international frameworks seem to support the efficient use of fossil fuels, but not the diffusion of renewable technologies. Higher education, as well as some natural endowments and national policy culture may support the diffusion of renewable technologies. Instead, economic and social development, technological capabilities, and internationalisation of national business support reliance on fossils and hold back diffusion of renewable technologies.

The paper is organised as follows. In Section 2, we propose a conceptual framework to analyse the technology diffusion function in the formation of new technological systems in emerging economies, and the influence of the global institutional framework in shaping the process. Section 3 describes the method and data sources. Section 4 presents the empirical evidence, and Section 5 concludes the paper.

2. The diffusion of technologies in evolving technological innovation systems in emerging economies and global institutional frameworks

This section introduces the conceptual framework underpinning the analysis of the diffusion of renewable technologies in the BRICS. We draw on the emerging technological innovation systems, technology diffusion and global institutions literatures to analyse the diffusion of renewable energy technologies in emerging economies. The framework entails three elements. Section 2.1 addresses the formation of new technological systems in terms of its main components and functions. Section 2.2 narrows down to one of the functions of those systems, namely the diffusion of technologies. Finally, Section 2.3 deals with the impact of the global institutional framework on the technology diffusion process.

2.1 The formation of new technological innovation systems in emerging economies

In this framework, we adopt the concept of emerging technological innovation systems (e.g. Jacobsson 2008). Based on Carlsson (1995:7) we define a technological innovation system as the networks of organisations interacting in a given technological field and operating under a specific institutional framework, which contribute to the generation, diffusion, utilization of technology or the creation of incentives to support these processes.

Deriving from that, a technological system entails the following main types of components. One component refers to organisations. Those include firms operating in different parts of the value chain (Jacobsson 2008:3). But it also comprises other types of organisations such as research institutes, universities, business associations, policy organisations and other actors that are involved either directly with the production and diffusion of knowledge, or enabling and supporting these activities through catalytic roles. The second element is networks which concern the different types of organisational arrangements connecting the organisations in the system. Also relevant is the institutional framework comprising the sets of rules regulating the behaviour and interactions of organisations. Finally, a fourth component corresponds to the knowledge base. Drawing on the concept of sectoral innovation systems (Malerba, 2005) we argue that different technologies are characterised by different knowledge bases and this forms an important constituent of the overall system.

The actions of organisations and the attributes of institutions, networks and knowledge bases correspond to the functioning of the technological innovation system. In particular, those actions and attributes are a measure of how the innovation system functions in relation to the processes – generation, diffusion, utilization of technology and creation of incentives for technology activities – that define an innovation system. In other words, those processes can be understood as the set of core functions with which an innovation system is concerned. Several slightly different approaches have been proposed which decompose the core functions in detailed sub-functions (Hekkert et al, 2007; Bergek et al, 2008; Jacobsson, 2008). Here we restrict ourselves to the four aggregate functions mentioned in our definition of a technological innovation system and concentrate specifically on one of the core functions, namely, the diffusion of new technology.

2.2 The diffusion of new technology in emerging technological innovation systems

The diffusion of new technologies is at the centre of the process of formation of new technological systems. The heterogeneously paced diffusion of new technologies in an economy and the growth of industrial activities centred on these technologies changes the industrial structure, with some sectors declining, as new ones emerge (Metcalfe, 2001; Montobbio, 2002; Metcalfe and Ramlogan, 2005). Furthermore, the diffusion of new and more sustainable technologies may lead to the replacement, at least partial, of less sustainable variants. Reflecting that central role of diffusion in system formation, the aggregate performance of a technological system has commonly been assessed by measuring technology diffusion (Markard and Truffer, 2008:692).

In this paper we take a similar approach looking at the diffusion of technology to evaluate the emergence of new technological systems. Based on Rogers (1995:5) diffusion is understood here as the process involved in the transmission of new technological knowledge via given communication and commercialisation channels through time among the integrants of a socio-economic system. The technological knowledge transmitted in the diffusion process includes two dimensions, namely, hardware or physical component, and a software component involving disembodied information and knowledge necessary for utilising or changing the technology. Diffusion is essentially a social process consisting of a complex system of decision making (Rogers, 2002). Each decision goes through (1) a phase of acquiring knowledge about the innovation; (2) forming an attitude towards the innovation; (3) the decision to adopt or reject the innovation; and finally to (4) the implementation of the new idea (Rogers, 2002). Ultimately, diffusion corresponds to the summative outcome of innumerable decision-making processes by potential adopters shaped by trade offs between the advantages of the new technology to be adopted as compared to the involved costs, all that in a context of high uncertainty and incomplete information (Hall and Hahn, 2003:1).

It has been widely observed that the process of diffusion follows an S-curve pattern and several models have been proposed to account for that observation (Geroski, 2000; Hall and Hahn, 2003). The most commonly accepted model is called Epidemic model. This stems from the idea that speed of usage of certain innovation is linked to the information availability on: methods of its use and knowledge on its function. In other words, this model tries to explain the spread of innovation only by the diffusion of information. Geroski (2000) instead considers it is important to look at distinction of 'understanding something' and 'being persuaded' following the Rogers (2002) decision making process. He tried to capture this by nature of technology through introducing 'hardware' and 'software' distinction. The recognition on importance of the process of 'being persuaded to adopt' from 'understanding' innovation opened various different potential explanatory variables such as 'risk and uncertainty' of benefiting from adapting the technology and the learning capacity that lead to difference in the speed of diffusion.

The Probit model adapts to the complexity of society in understanding diffusion process (Geroski, 2000). It opens to the diversity interesting and relevant characteristics of individual/firm that explain the better diffusion process such as Firm size. These variables are often what influence cost-benefit calculation of individual adopters. For example, the cost of adaptation of certain technology may differ due to supplier structures. The Probit model also identifies the more indirect costs such as *technological expectation,* which relates to *the cost of learning and searching* as well as *switching costs* and *opportunity costs*. This Probit model introduces longer list of explanatory determinants of diffusion process which allows understanding in detail on 'who' and 'why' decisions are made to adopt or reject the certain innovation.

Geroski (2000) applies the extension of the density dependent population growth model developed by Hannan and Freeman (1989), Hannan and Carroll (1992) amongst others for understanding diffusion. The original model explains the birth and death rate of organization overtime with two factors, "competition" and "legitimation". Geroski (2000) considers that in context of diffusion of innovation, "competition" emerges whenever resource constraints limit the number knowledge/innovation particular market or social setting. The "legitimation" is the process by which a new knowledge/innovation becomes accepted, institutionalized or simply just taken for granted. Both of these processes are influenced strongly with the *population density*. In other words, dynamic interaction of actors and the increase and decrease of population in both "competition" and "legitimation" will shape the overall trajectory of diffusion. For example, Geroski (2000) gives example of standardization being similar to legitimation process because the adapting to new standards would depend on *switching cost* that may require, *expectation of its use* based on density of new users and expectation about market growth and the future *opportunity cost* of adapting other technology—the network externality (David, 1985; Cabral, 2000). The competition and the speed of diffusion is closely related to the *expected* benefit or gain from the adoption of technology which again is influenced by the density of competitors; furthermore, it also influenced by "from who or what" the adopter is competing. The competition may have different effect depending upon the stages of innovation. For instance, earlier phase of innovation, competition would promote variety of technologies; however, as the technology matures, certain technology will be 'legitimized' and diffused (Cabral, 2000).

In the information cascade and path dependence model, the choice among alternate technologies in the diffusion process is taken into consideration (Geroski, 2003). Several technologies may be introduced initially and the chosen technology among the alternatives becomes established because it works and is better than the other options, or simply because its features have become in the meantime well known, legitimizing it. Adoption is driven by an information cascade flowing from early to late users. Once the adoption of "the" chosen technology increases, network externality effects support the further diffusion of that technology, and even lock in effects. This occurs irrespective of the inherent qualities of the technology and those of variants, because of previous investments in the technology and larger user base.

Moreover, diffusion rates and patterns are perceived as shaped by demand and supply factors (Najmabadi and Lall, 1995; Goldman et al., 1997; Teubal, 1997). Demand factors include the expectations about the costs and benefits incurring when firms and consumers adopt the new technology as well as firms' capabilities and skills, market competition and relations with customers. Supply factors encompass the incentives created by public policies, technical networks of organisations and the characteristics of the new technology (Hall and Khan, 2003). In particular, public policies can support the provision and dissemination of information about the new technology, provide subsidies to foster the intake of the technology in the socio-economical system, encourage the building up of various types of human capital or stimulate the emergence of innovative inputs markets (Justman and Teubal, 1996; Teubal et al., 1996; Teubal and Andersen, 2000). The examination of the influence of public policies on diffusions has focused on the impact of policies designed by national governments. However, policy frameworks have increasingly a supranational dimension. This raises questions about the impact of that specific policy dimension, namely the global institutional framework on the technology diffusion process.

2.3 Global institutional frameworks

The Globalization of production and markets and the rise of global institutions impact the governance structure—the collective decision making process among the relevant stakeholders on problems which require common solutions (Rhodes, 1996). Intensifying social relations and linking "distant locality in such a way that local happenings are shaped by event occurring many miles away and vice versa" (Giddens, 1990:64), globalization may be seen as a process of superterriotriality in decision-making (Held et al., 1999). In this context, the power of national governments may be allocated or transferred upwards to supranational bodies (i.e. WTO, GATT, EU, NAFTA etc) or downwards to more local levels of government (Lipsey, 1997). Consequently, nowadays national institutional capacity goes beyond the conventional jurisdiction of 'government' (Stoker, 1998; Stigliz, 2003).

Therefore, governance is increasingly understood as resulting from self-organizing networks, and from collective and individual actions of diverse set of institutions and actors, blurring of boundaries and responsibilities for social and economic issues. Global institutional frameworks, especially through collaborative agreements, are expected to be better performing at supporting diffusion of social, ethical and environmental standards than bilateral governmental agreements.

Global institutional frameworks are particularly relevant in discussing the global environmental sustainability and the key role is bestowed through global institutions. The solution for global environmental sustainability requires collective action among various countries to change use of natural and environmental resources to sustainable one. The earlier policy works in the 1990s by Tietenburg (1998), De Young (1996) and Spaagaren (2002) suggested that neither market nor government forces can guarantee the adoption of more sustainable energetic systems. Instead, more systemic changes with information disclosure across several organisations and institutions may be needed (Yong, 1982; De Young, 1993; Tietenburg, 1998; Sparagaren, 2002).

The interplay between institutions to bring about sustainable behaviour is an important concept in the issue of climate change where ways to meet the challenge are diverse due to economic activities and geographical conditions while consequences are shared among all the nations. In this context, Kyoto protocol is a central global framework requiring countries to limit or reduce their greenhouse gas emissions.[1] The global level agreement as such may create the 'vision', which makes it easier for countries to define the trajectories towards environmentally sustainable growth pathways.

The Kyoto protocol as well as Kyoto Mechanisms—Joint Implementation (JI), Clean Development Mechanisms (CDM) and Carbon Trading—created a framework, based on market and collaboration interactions among the stakeholders of different nations, to support signatories countries to meet the

[1] Greenhouse gases stand for the gases specified in Appendix A to the Kyoto Protocol, carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), partially halogenated hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6).

goal of limiting or reducing emissions. For the purpose of this paper, we will focus on CDM and JI mechanisms, which frame technology transfer and collaboration to carry out emissions reductions.

JI mechanism previews the joint carrying out of emissions reduction projects by two countries that belong to the framework of convention on climate change. Thirty-three countries are eligible to participate in JI mechanisms including most of the developed countries and Ex-URSS countries (UNFCC, 2009). JI allows a country to clam credit for emission reduction that arises from investment in other industrialised countries, which result in a transfer of equivalent reduction units between the countries. Instead, CDM mechanism foresees the carrying out of emissions reduction projects in a country not belonging to the framework convention on Climate Change. Developing countries are eligible to host CDM projects.[2] Hence, in particular, the CDM mechanism promotes the interplay between institutions and stakeholders between the North and the South. These mechanisms were launched in 2000, by the action Plan signed in Buenos Aires.

Under this global environmental framework, Russia is eligible for hosting JI projects, while Brazil, China, India and South Africa are eligible for hosting CDM projects. JI projects carried out to reduce emission in Russia in partnership with other signatory countries will be considered as transfer of emissions units to the investor country. Certified emission reductions achieved in Brazil, China, India and South Africa through CDM projects will be considered as emission reduction for the signatory countries that invested in them and supported technology transfer. Thus, BRICS do not have the same status under the global environmental institutional framework.

3. Methodology and Data

The discussion in the previous section has highlighted the importance of demand and supply side factors as well as of global institutional frameworks on the process of technology diffusion. In particular, the objective of this paper is to analyse the impact of international frameworks set by Kyoto agreement framing technology transfer and collaborations between different capable organisations on the level of diffusion of renewable energy technologies and environmental performance of BRICS countries.

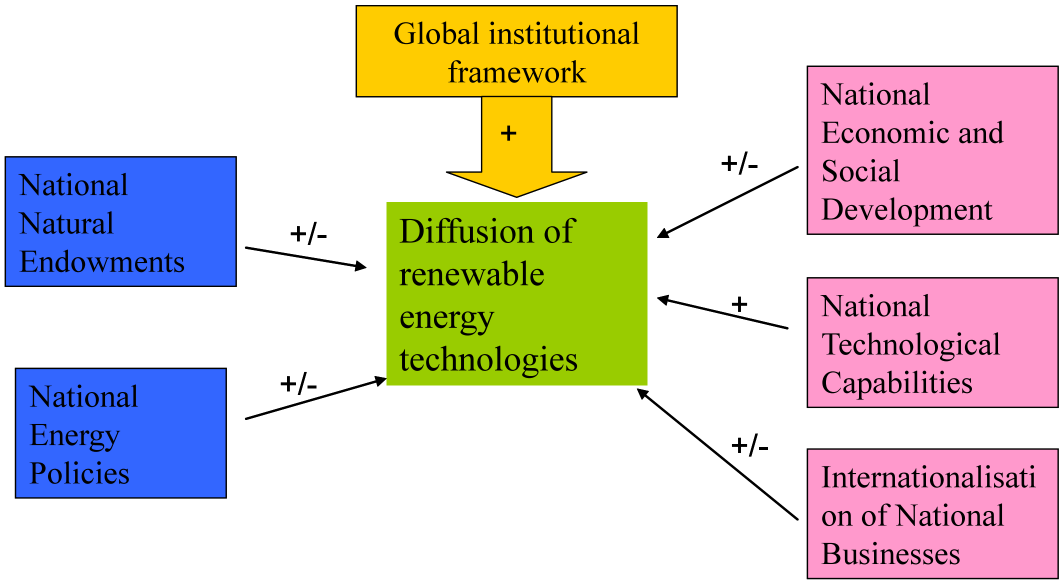
CDM projects hosted by developing or NIC countries and JI projects implemented and hosted by the Kyoto signatories' countries reflect the forms through which global institutional frameworks for a cleaner world (i.e. Kyoto Agreement) have framed the international agreements for emission reductions in developed and developing countries. Thus, to account for the impact of the global

[2] "the CDM allows emission-reduction (or emission removal) projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO2. These CERs can be traded and sold, and used by industrialized countries to a meet a part of their emission reduction targets under the Kyoto Protocol. The mechanism stimulates sustainable development and emission reductions, while giving industrialized countries some flexibility in how they meet their emission reduction limitation targets." (CDM, 2009)

frameworks on the level of diffusion of renewable energy technologies in the BRICS, we collected data on the number and budget of CDM and JI projects that each of the BRICS countries has been hosted in each year, as well as the technology focus of these projects.

As a measure for the level of diffusion of renewable energy technologies, we use the renewable sources on total energy sources, as well as the share of renewable combustibles on the total national energy production and consumption, as well as the share of hydroelectric electricity. As a measure of the environmental performance of the energetic systems, we use the level of CO2 emissions per capita and per unit of GDP. However, to infer the impact of international collaborations through CDM projects on the level of diffusion of renewable energy technologies and environmental performance of BRICS countries, we need to control for several factors related to natural resources endowments, economic and social development, technology capabilities, the internationalisation of national businesses, and to national policies. In Figure 1, we sketch how these factors may affect positively or negatively the level of diffusion of renewable energy technologies.

Figure 1: The demand, supply and global institutional factors affecting the levels of diffusion of renewable energy technologies



The national use of fossil and renewable energy technologies is inherently related to the characteristics of the national natural endowments. Among the national natural supply of inputs that are expected to support positively the use of renewable energies, we will take into consideration the internal freshwater sources, the share of forest on total land. Among the national natural supply of inputs discouraging the use of renewable energy technologies, we will take into consideration fuels as share of exports, and the share of land dedicated to agriculture. We will also account for the size of the country, and of the size and density of its population

The level of environmental concerns is expected to be highly correlated to the level of Economic and Social Development of the country. Therefore, we account for the level and the growth rate of the

GDP per capita, health expenditures, literacy rate, expenditure per student in primary and secondary education, share of children active, daily newspapers, users of internet, number of personal computers and vehicles per 1000 people, share of GDP in agriculture, industry and services. In particular, we expect that the greatest and quicker the economic and industrial development the more emissions the country will produce, but after a certain level of development the more environmental concerns may diffuse across the population and policy-makers.

The more internationalised are the national business activities, the more they will be exposed to mimetic sources towards the adoption of a managerial culture concerned with the environment( ). On the other hand, there might be a trade off between price and quality competition and environmental impact of business activities (). To account for the internationalisation of national businesses, we include the share of ISO certified firms, the share of FDI on GDP and the share of royalties on GDP paid abroad, and trademarks per 1000 people by residents and non-residents.

Other factor crucial for the diffusion of new technologies is the national technological capabilities to develop imitate and adapt international technologies to the national productive activities. Therefore, we include the share of high-technology exports, the share of R&D expenses on GDP, expenditure per student in tertiary education, share of royalties received on the GDP, and number of scientific papers, patents per 1000 people, research and technicians in R&D.

National policies also play a role in creating national incentives to the diffusion of renewable energy technologies. Still, policy capabilities in BRICS to design and launch these policies seem to be highly correlated to the level of national commitment to comply with global institutional frameworks and to the level of national involvement in international cooperation for technology transfer, but also to the characteristics of national natural endowments. Hence, it would be very difficult to identify whether national policies were designed and partly implemented to comply with international frameworks or really to try to establish cleaner energy systems. Moreover, policy capabilities seem to co-evolve with the national levels of economic and social development, technological capabilities and participation on the global markets. Therefore, for the purpose of this analysis, we do not include any measure for national energy policies implemented by the BRICS. Instead, we include variables to account for the national policy culture, i.e. military expenses, natural protected areas and investment in energy with private parts as % of GDP.

To analyse empirically this issue, we use data relative to the timing, the technology scope of the collaborative CDM and JI projects with the BRICS countries. These data were collected on the CDM and JI website (UNFCC, 2009). In addition, we use data from the World Development Indicators and International Energy Agency.

4. Empirical analysis

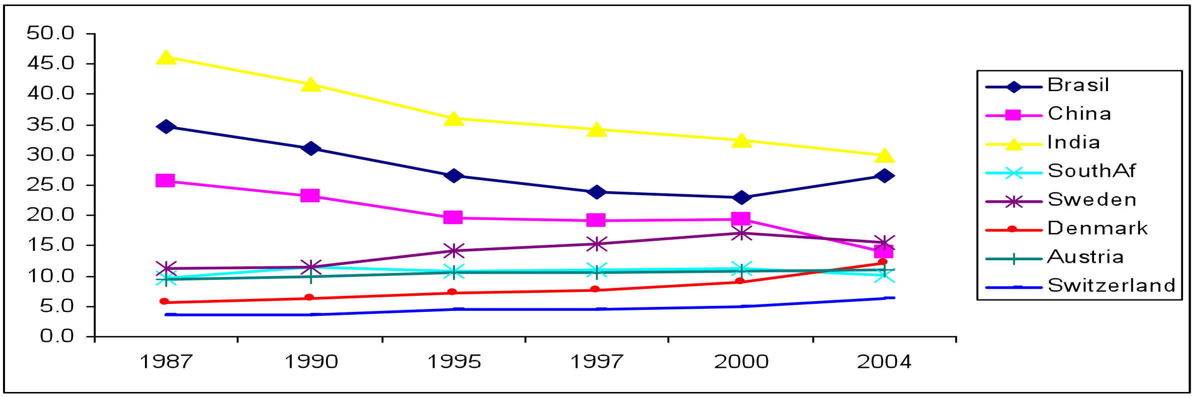
In this section, we analyse the impact of the global environmental institutions on the level of diffusion of renewable energy in the BRICS. First, the diffusion renewable and fossil energy technologies as well as the levels of environmental performance are analysed from 1987 to 2004 and compared with evolution in some developed countries. Second, the characteristics of the projects carried out in BRICS under the JI and CDM frameworks are analysed. Third, the impact of these projects in the level of performance and diffusion of renewable energy is explored.

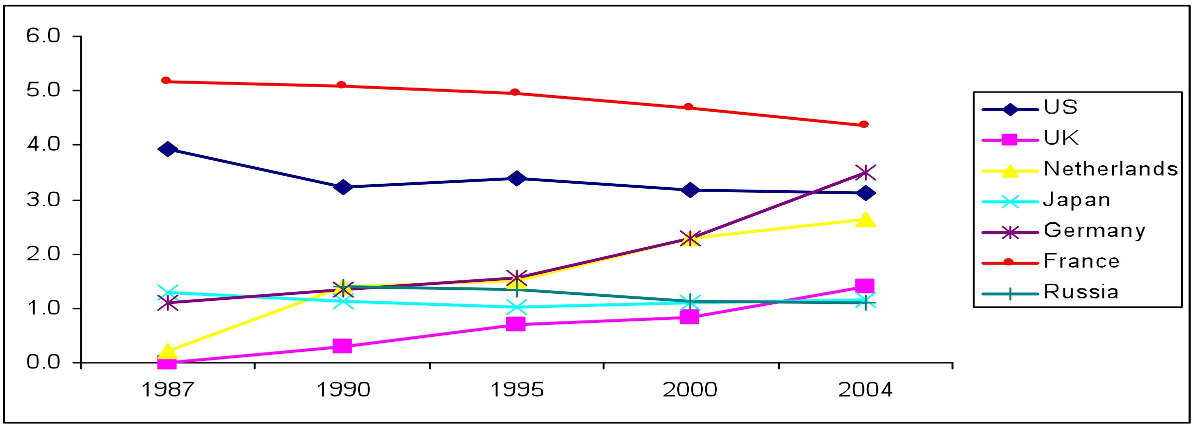
4.1 Diffusion of renewable energy technologies in BRICS countries

We start by analysing the levels of use of combustible renewable on total energy and fossil fuels on the electricity production, before analysing the share of renewable sources on total energy sources.

Graph 1 shows the share of combustible renewable and waste, which comprise solid biomass, liquid biomass, biogas, industrial waste, and municipal waste, measured, on total energy use in the BRICS and some developed countries, during the period 1987 to 2004.

Graph 1: Share of combustible renewable and waste on total energy, in the BRICS and some developed countries, 1987 to 2004





Source: World Bank Indicators. Note: Combustible renewables and waste comprise solid biomass, liquid biomass, biogas, industrial waste, and municipal waste, measured as a percentage of total energy use.

Results suggest that during the period of analysis, India observed the highest level of use of combustible renewable and waste on total energy, even that these levels experienced a great decrease. In 1990s, in India circa of 40% of the total energy used was renewable combustible, while in 2000s this ration decreased to 30%. Similarly in the 1990s, 30% (20%) of the energy used was renewable combustible in Brazil (China); while in 2000s it was about 25% in Brazil (13% in China). In Russia and South Africa, the levels of renewable combustible on total energy consumption were stable during the period, about 1% and 10%, respectively.

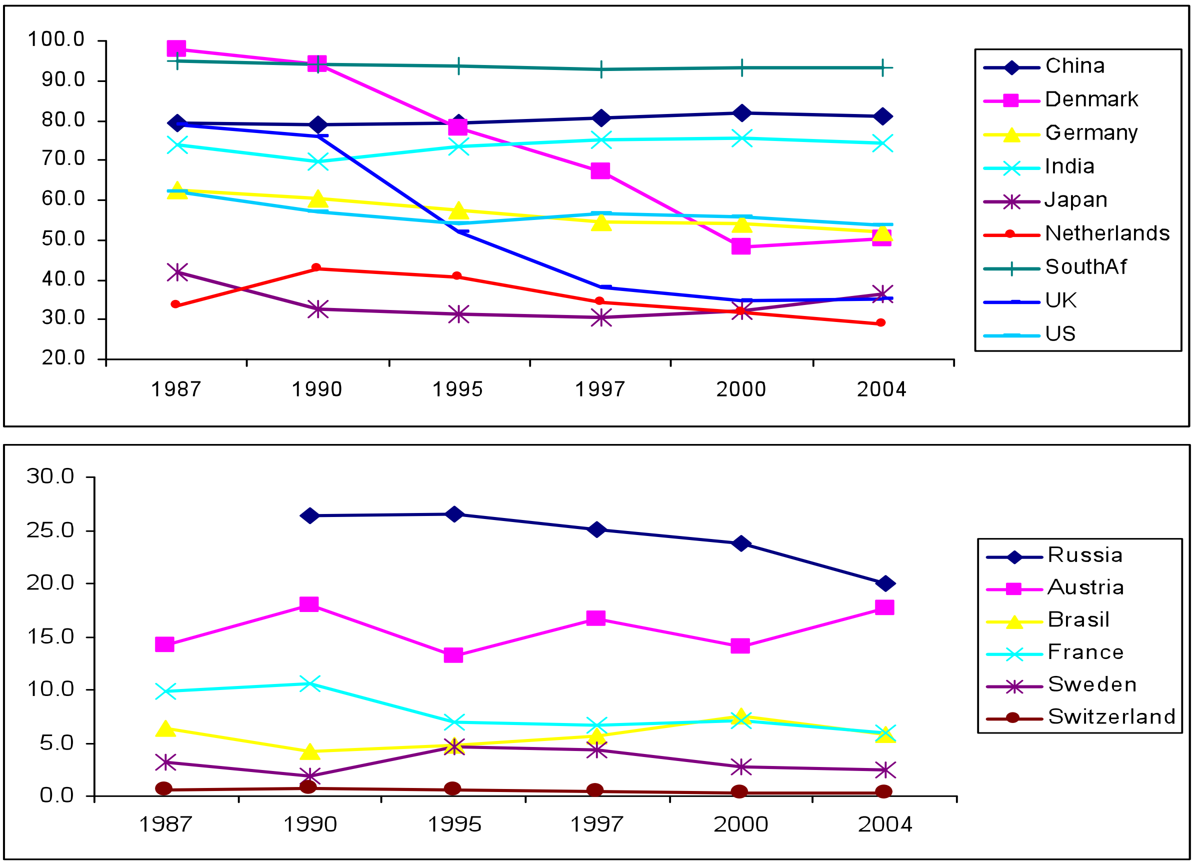
Interestingly India, Brazil and China are ahead all the developed countries considered in the use of renewable combustibles. Instead, the UK, Japan and Russia are the laggards in the use of these energy technologies. The diffusion of renewable and waste combustible technologies start diffusing in the Netherlands and the UK in the 1990s, reaching in 2004 about 3% and 1% respectively of total national energy use. Germany also managed to push forward the use of these technologies for energy production from 1% to about 4% of total energy used.

If we focus only on the fashionable biofuels, biodiesels and biogasoline combustibles technologies, results seem to be even more surprising. According to the International energy Agency (IEA), these renewable combustible have been produced and used in Brazil since 1990, representing 5% of total energy sources in Brazil. In 1990, biofuels, biodiesels and biogasoline combustibles represented 10% of the total energy production, from 2000 to 2004 their production decreased significantly, reaching only 5% of energy production in 2004, and from 2004 to 2006 it increased to 5 to 6% of total energy. China started the production of these renewable combustibles in 2001. The other three BRICS did not produce any of these combustibles. During the 1990s, only Austria, France, Germany and the US used these combustibles, representing 0.1% of total energy sources. In 2006, only in Germany these combustibles reach 3% of total energy sources.

Graph 2 shows the share of electricity production from coal and oil sources (% of total) and Graph 3 the share of electricity production from hydroelectric sources (% of total), in the BRICS and a group of developed countries from 1987 to 2004.

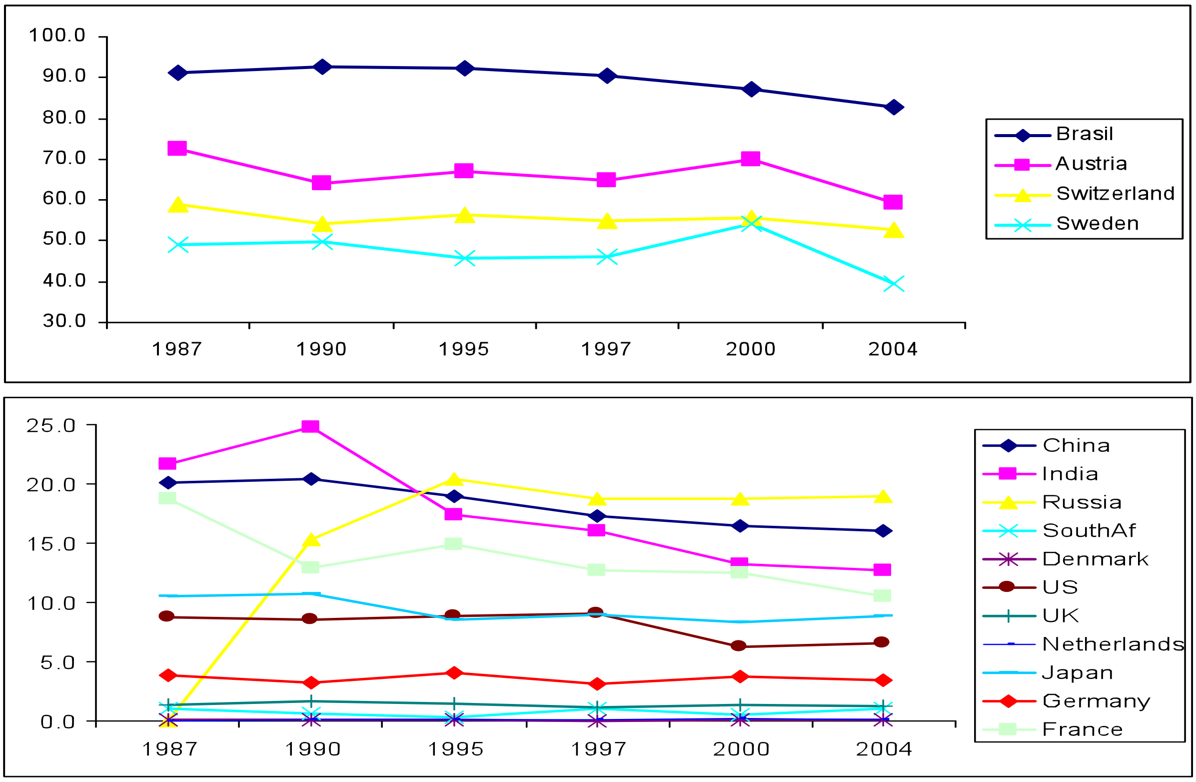
Graphs show that more than 90% of electricity produced and used in South Africa is based on coal (and oil) sources, less than 1% on hydroelectric sources and no use of natural gas. Instead, less than 6% of electricity production in Brazil uses coal or oil sources. Brazil relies significantly on hydroelectric sources for electricity production, even that this reliance became weaker during the period of analysis, as the use of natural gas increased. In the early 1990s more than 90% of Brazilian electricity was produced with hydro sources, while in 2005, 82% of electricity was hydroelectric. The use of natural gas for Brazilian electricity production seems to have started in mid 1990s, and in the 2005 represented almost 5%.

Graph 2. Electricity production from coal and oil sources (% of total), in the BRICS and some developed countries, 1987 to 2004



Source: World Bank Indicators

Graph 3. Electricity production from hydroelectric sources, in the BRICS and some developed countries, 1987 to 2004



Source: World Bank Indicators

In the early 1990s, in China and India, 70% of electricity was produced with coal and about 20% with hydroelectric sources. In India the share of electricity produced from coal maintained (70%), the use of oil maintained (4%), hydroelectric sources decreased to about 13%, and natural gas increased from less than 2% to 9%. In China reliance in coal increased to almost 80%, reliance on hydroelectric decreased to 15%, on oil decreased from 10% to 3%, and use of natural gas is still lower than 0.5%. About 45% of electricity production in Russia depends on natural gas; reliance on hydroelectric sources increased from 15% to 18%; coal increased to from 15% to 17%, and oil had decreased from 10% to 3%.

In sum, natural gas is the main input for electricity production in Russia, while coal is the main input for electricity production in South Africa, China and India, and hydroelectric technology for electricity production in Brazil.

It is interesting to note that except for Brazil, the other countries with the lowest levels of reliance on coal and oil, i.e. Switzerland, Sweden and France, rely extensively on nuclear sources, 40%, 50% and 70% respectively on total electricity produced. Reliance in nuclear technologies is low in BRICS, about 2-3% of the electricity produced in Brazil, China and India in 2005 relied on nuclear sources, 4% in South Africa and 15% in Russia. Instead, from the group of developed countries analysed only Denmark and Austria do not rely on nuclear sources for electricity production, all the others rely on nuclear for at least 20-30% of their electricity production. Brazil is the country in which reliance on hydroelectric technologies is higher, followed by Austria, Switzerland and Sweden. Instead, the Netherlands, Denmark, France, Germany, UK and South Africa are the countries in which hydroelectric technologies are less diffused.

BRICS countries have an electricity production capacity above their consumption needs, and to a greater or lower degree all they increased their electricity production in relation to their consumption levels. In 1990, electricity consumption in Brazil was 97% of production and in 2006 it is 93%. South Africa and China maintained their consumption to production ratios in 94% and 93%. In India, the excess of production to consumption raised 6 points, while in Russia it raised 4 points. In India, the ratio consumption to production decreased from 81% to 75%; while in Russia it decreased from 91% to 87%.

Similarly, the developed countries produce enough electricity for internal consumption, except for the Netherlands. France is the greatest producer of electricity producing about 20% more than consumption. Switzerland and Denmark instead decreased their production excess during the period of analysis. In particular, the reduction of production surplus allowed Denmark reducing reliance on coal and oil for electricity production. The British electricity production became less reliant on coal and oil, mainly due to shift towards natural gas.

Thus, it seems that the use of hydroelectric, nuclear, natural gas and coal and oil technologies for production of electricity, as well as the use of renewable and waste combustibles is uneven across countries. Developed countries seem to use more intensively nuclear technologies and to a lesser extent natural gas as source for electricity. Besides these exceptions, there is not a major divide between developed and BRICS on the use of most of these technologies for electricity production. In terms of reliance on renewable combustibles, BRICS seem to rely more intensively on the renewable and waste combustibles than developed countries, even that some developed countries; in particular the UK, the Netherlands and Germany put efforts on the development and use of these technologies in the 1990s.

After having analysed the diffusion of renewable combustibles and renewable in electricity production, we examine now the overall level of use of renewable sources on total energy sources (Table 1). In 2006, Austria presents the highest level of reliance on renewable sources, 69% of total energy sources are renewable. Brazil and Sweden follow with a bit less than 50%, and India 40% and Switzerland with 34% of total energy sources being renewable. The greatest efforts on the use of renewable sources have been made by Germany, followed by the UK, and the Netherlands. France and Denmark seem not have put enough efforts on the diffusion of renewable energy technologies. Thus, there are not major differences between BRICS and developed countries on the reliance on renewable energy sources.

Table 1. Share of Renewable sources on Total energy sources in the BRICS

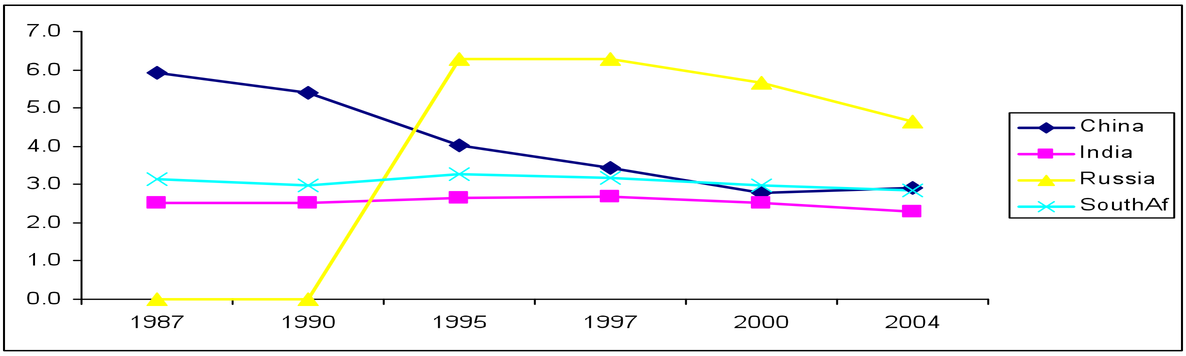
	1990	1995	1997	2000	2004	2006
Brazil	63%	61%	58%	49%	49%	48%
China	24%	21%	21%	22%	17%	15%
India	48%	44%	42%	43%	40%	39%
Russia	2%	2%	2%	2%	2%	2%
South Afr.	9%	9%	9%	9%	9%	9%
Austria	61%	67%	68%	68%	67%	69%
Sweden	39%	40%	42%	48%	38%	44%
Switzerland	33%	36%	35%	35%	35%	34%
France	14%	14%	13%	13%	12%	12%
Denmark	11%	9%	8%	7%	8%	9%
United States	6%	6%	6%	6%	6%	7%
Germany	3%	4%	5%	7%	11%	15%
Netherlands	1%	1%	2%	2%	2%	3%
UK	0%	1%	1%	1%	1%	2%

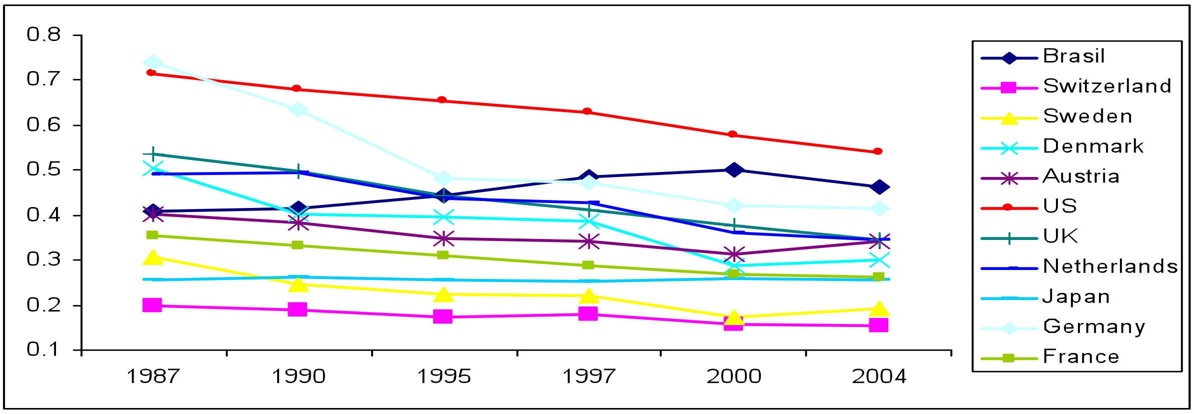
Source: IEA

4.2 Performance of the energy systems in BRICS countries

To examine the performance of the energy sectors in BRICS and in a group of developed countries, we analyse data on the CO2 emissions from 1987 to 2004, per unit of GDP at constant prices in 2000 and per capita, respectively in Graph 5 and 6.

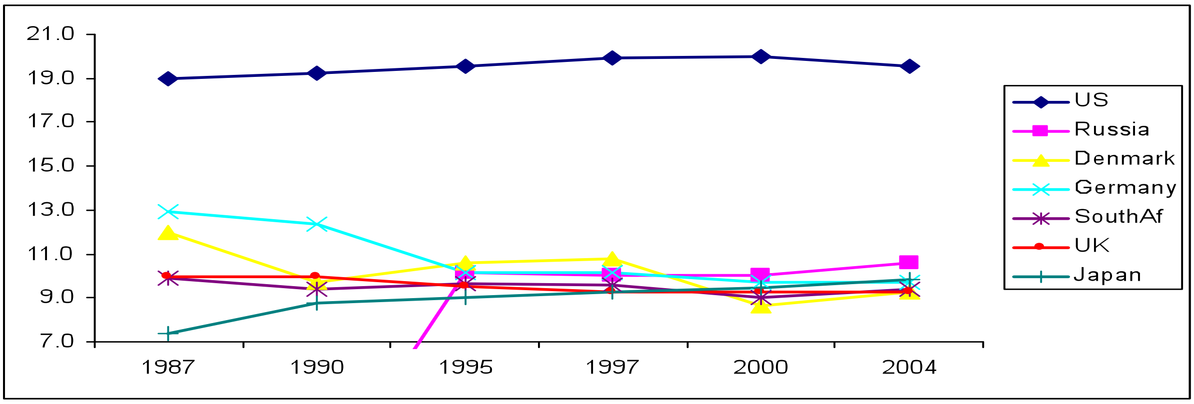
Graph 5. CO2 emissions (kg per 2000 US$ of GDP) in the BRICS and some developed countries, 1987 to 2004

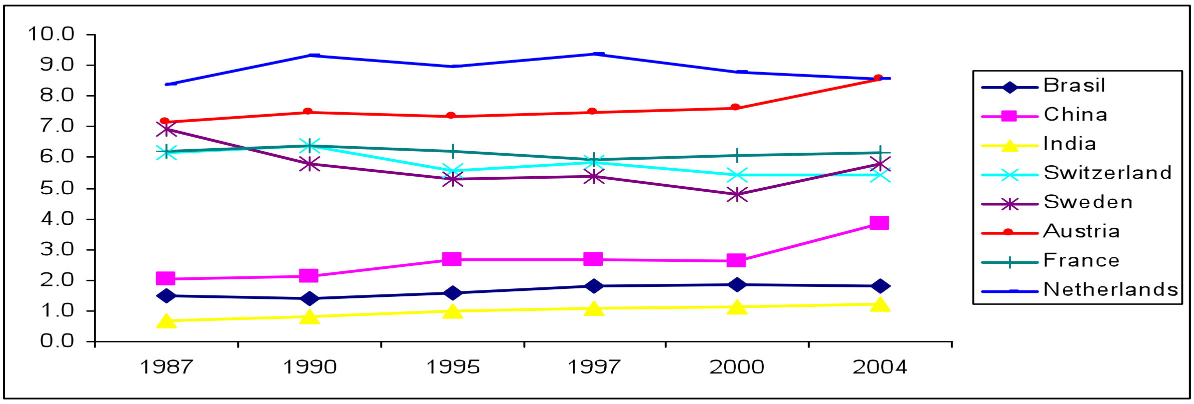




Source: World Bank Indicators

Graph 6. CO2 emissions (metric tons per capita) in the BRICS and some developed countries, 1987 to 2004





Source: World Bank Indicators

Graph 5 suggests that during the period of analysis Brazil was the country with the lowest levels of emissions per unit of GDP. India and South Africa were mid-raked in terms of the environmental impact per unit of GDP and they experienced a very slight improvement. In the early 1990s, Russia and China produced the highest level of emissions per unit of GDP. In 2004, Russia had still the most pollutant unit of GDP, while the Chinese unit of GDP became as cleaner as those of the mid-ranked group of countries.

China, India, Russia and South Africa have greatest levels of emissions for unit of GDP followed by the US. Until the mid 1990s, Germany, Netherlands, and the UK followed the US, producing more emissions per unit of GDP than Brazil. However, these countries decreased significantly their emissions per unit of GDP during the period, and in 2004, Brazil produced more emissions per unit of GDP than any other developed country, except for the US. Switzerland, Sweden, Japan and France are instead the countries with fewer emissions per unit of GDP. All countries, but Brazil, decreased the level of emissions per unit of GDP: In particular, China, Germany, Denmark, Sweden, the UK observed reductions of at least 30%.

Examining the level of CO2 per capita, shown in Graph 6, a slight different overall picture of the performance levels of the energy systems of these countries emerges. Among BRICS, China and India seem now to have much cleaner energy systems; however, these two countries also reveal the highest growth of CO2 per capita from 1987 to 2004. Brazil is now the second cleanest country, following India with the lowest levels of CO2 emissions per capita. China follows. South Africa and Russia are the countries with the highest level of emissions per capita.

The US produces during the whole period the highest level of emissions per capita, while Brazil, China and India produce the lowest levels of emissions per capita. Russia and South Africa are in the group of highest levels of emission per capita after the US, together with Denmark, Germany, the UK and Japan. Among the countries that reduced substantially the levels of emission per capita is Germany with reduction of 25%. Japan instead increased 33% the level of national emission per capita.

Overall, reductions have been observed in the levels of emissions per capita and per unit of GDP. However, these reductions, especially those per capita, seem to have mainly occurred before the Kyoto protocol in 1997.

The greatest reductions on the level of emissions per capita from 1997 to 2004 were observed in Denmark (14%), Netherlands (8%) and Switzerland (7%) and Germany (4%). Instead, China (45%), India (15%), Austria (14%) Sweden (8%), Russia and Japan (6%) are the countries in which emissions per capita increased most from 1997 to 2004.

Concerning the emissions per unit of GDP from the period 1997 to 2004, all the countries, except for Austria and Japan, experienced a reduction. Russia observed the greatest reduction of emissions per

GDP (26%), followed by Denmark (22%), the Netherlands (19%), The UK, China, India and the US (15%), and by Germany, Switzerland and Sweden (12%).

4.3. Characteristics of CDM and JI projects in BRICS countries

As seen in section 2.3, under the Kyoto global environmental framework, Russia is eligible for hosting JI projects, but not CDM projects. Brazil, China, India and South Africa are eligible for hosting CDM projects. In this section, we will analyse the characteristics of the projects for emission reductions that BRICS are involved under the Kyoto framework.

Number and location of JI and CDM projects

In May 2009, there were 209 ***Joint Implementation projects*** in pipeline. 102 of these 209 projects (48%) were implemented in Russia, 34 (16%) Ukraine, 59 (28%) other Eastern European countries, 7 (3%) Germany, 6 (3%) New Zeeland, and 1 in France (CDM, 2009). While 48% of JI projects were implemented in Russia, 61% of the expected emission reductions in 2012 resulting from all the JI projects are expected to benefit Russia.

In May 2009, there were 4733 ***Clean Development Mechanisms projects*** in the pipeline; 2935 in the process of validation, 1596 already registered, and 209 in the registration process. 60% of these CDM projects in the pipeline aim at reducing between 10 and 100Kt CO2 per year; 25% aims at reducing between 100 and 500Kt CO2 per year, 10% aims at less that 10 KT CO2 emission reduction per year.

Concerning the location of the hosting countries, almost 80% of CDM projects are hosted in Asian countries, 18% in Latin American countries and 2% in African countries. Reduction of emissions is more difficult to be achieved in Latin America than in Asia or Africa. Still, it is in LA where greater carbon emissions reductions per capita are expected by 2012. Table 2 shows the geographic distribution of CDM projects in pipeline in terms of number of projects and carbon emission reduction.

Table 2. Geographical distribution of total CDM projects in the pipeline

	Number of projects		% total CER	% CER 2012	Population	CER per capita in 2012
Latin America	873	18.4%	12.8%	14.4%	449	0.94
Asia & Pacific	3657	77.3%	82.0%	80.4%	3418	0.69
Europe and Central Asia	48	1.0%	0.7%	0.6%	149	0.12
Africa	102	2.2%	3.3%	3.3%	891	0.11
Middle-East	53	1.1%	1.2%	1.2%	186	0.20

Total	4733	100%	630156	2931813	5093	0.58

Source: CDM website; Note: CER- certified emissions reduction

Table 3 shows the total number of CDM projects issued, registered and in validation in 2009 in the BRICS countries. Results suggest that the share of CDM projects that target China seems to be increasing, as the share of issued projects hosted by China is lower than the share of projects in pipeline (including also projects that are still to be validated and registered) to be hosted by China. Instead, the share of projects targeting Brazil and India seem to be in decrease. Finally, South Africa maintains the very low level of attraction of CDM projects.

Table 3. CDM projects issued, registered and in pipeline in BRICS in May 2009

	Issued		Registered			Pipeline		
	% total projects	% total CER	% total projects	% total CER	% CER 2012	% total projects	% total CER	% CER 2012
Brazil	18%	11%	10%	7%	8%	8%	5%	6%
China	23%	44%	33%	58%	53%	37%	56%	54%
India	36%	23%	26%	12%	14%	26%	16%	16%
South Africa	1%	0%	1%	1%	1%	1%	1%	1%
% Total	78%	78%	70%	78%	76%	72%	78%	77%

Source: CDM website; Note: CER- certified emissions reduction

In terms of number projects and Certified Emission Reduction (CER) previewed on these projects, China is expected to benefit from more than half of the total registered or in-pipeline CDM projects. China is followed by India and Brazil. These 3 countries are also the ones expected to benefit most in terms of CER under the CDM framework. Instead, South Africa has a lower position in the ranking of countries benefiting from CER, benefiting less than 1% of the CER previewed on the total CDM registered or in pipeline projects.

Table 4 summarises the number of JI and CDM projects that have been implemented, validated or are still to be validated to be hosted by each BRICS. BRICS host about 70% of the CDM and JI projects.

Table 4. Evolution of total number of CDM and JI projects by BRICS

	2004	**2005**	**2006**	**2007**	**2008**	**2009***	**Total**
Brazil	18	86	79	62	100	16	361
China	2	25	221	680	667	171	1766
India	11	198	268	304	375	95	1251
South Africa	1	6	9	7	4	2	29
Russia			12	43	37	7	99
Total CDM	60	473	837	1409	1561	393	4733

Total JI			23	84	84	13	204

* May 2009; Note: CER- certified emissions reduction

Technological and Sectoral scope of JI and CDM projects

Table 5 below provides details on technological and sectoral scope of the total JI projects in pipeline as well as JI projects hosted in Russia. When, comparing the technological and sectoral scope of projects hosted in Russia with the total JI projects, we find one main difference. Projects hosted in Russia address more often issues of energy efficiency in manufacturing rather than on the supply side.

Table 5. Technological and Sectoral scope of total JI projects and JI hosted in Russia, May 2009

	% total JI projects	**% total CER**	**% JI projects hosted in Russia**
Fugitive	33%	46%	**33%**
EE (efficiency energy) supply side	11%	6%	2%
Biomass energy	10%	2%	**10%**
Fossil fuel switch	10%	5%	**10%**
Landfill gas	8%	5%	**8%**
N2O	7%	16%	**7%**
Energy distribution	5%	1%	5%
Hydro	4%	1%	4%
HFCs	3%	3%	3%
EE industry	2%	2%	**11%**
Coal bed/mine methane	2%	11%	2%
Biogas	1%	0%	1%
Cement	1%	1%	1%
CO2 capture	1%	1%	1%
PFCs	1%	1%	1%

Source: UNFCC (2009), JI (2009)

Table 6 provides information on the sectoral and technological scope of projects in pipeline in Brazil, China, India and South Africa, as well as of all the CDM projects of issued, registered and pipeline independently of their host country. Overall, these results (Table 4 columns 6, 7and 8) suggest an increasing general tendency towards the diffusion of hydro and biogas technologies, as the share of projects in pipeline addressing these technologies is higher than the share of issued or registered projects. Instead, a decreasing tendency may be spotted towards the diffusion biomass or energy efficiency in agriculture might be observed.

Examining the technological scope of CDM projects host by BRICS and comparing it with that of all CDM projects, some national specificities are found:

- Projects hosted in Brazil address more often issues of biomass energy, energy efficiency in agriculture, and, to a lesser extent, landfill gas, and fossil fuel switch.
- Projects hosted in China focus more intensively on coal mine and hydro technologies, and to a lesser extent, on energy efficiency.
- Projects hosted by India focus more intensively on energy efficiency in manufacturing and services, cement, as well as on biomass and wind technologies.
- Projects hosted by South Africa address more often energy efficiency of households, N2O, coal mining, fossil fuel switch and landfill gas.

Table 6. Sectoral and technological scope of CDM projects, issued, registered and in the pipeline in Brazil, China, India and South Africa, in May 2009

	Brazil	**China**	**India**	**South Africa**	**World**		
	pipeline	**pipeline**	**pipeline**	**pipeline**	**issued**	**registered**	**pipeline**
Hydro	21%	**47%**	**10%**	**7%**	19%	25%	27%
Biomass energy	**32%**	4%	27%	14%	21%	16%	15%
Wind	**3%**	19%	24%	**0%**	18%	14%	15%
EE own generation	3%	15%	10%	3%	6%	7%	9%
Landfill gas	11%	3%	2%	**21%**	7%	8%	8%
Biogas	2%	2%	3%	**10%**	1%	6%	6%
Agriculture	**16%**	0%	0%	0%	8%	8%	5%
EE industry	1%	1%	12%	3%	4%	3%	4%
Fossil fuel switch	5%	2%	4%	**14%**	4%	2%	3%
N2O	1%	2%	0%	**14%**	2%	3%	1%
Coal bed/mine methane	0%	4%	0%	7%	1%	1%	1%
EE supply side	1%	1%	2%	0%	1%	1%	1%
Cement	0%	0%	2%	0%	1%	1%	1%
Reforestation	1%	0%	1%	0%	0%	0%	1%
Fugitive	1%	0%	1%	3%	1%	1%	1%
Solar	0%	0%	0%	0%	0%	1%	1%
HFCs	0%	1%	1%	0%	3%	1%	0%
Geothermal	0%	0%	0%	0%	0%	0%	0%
EE households	0%	0%	0%	3%	0%	0%	0%
EE service	0%	0%	1%	0%	0%	0%	0%
Transport	0%	0%	0%	0%	0%	0%	0%
PFCs	1%	0%	0%	0%	0%	0%	0%
Energy distribution	1%	0%	0%	0%	0%	0%	0%
Afforestation	0%	0%	0%	0%	0%	0%	0%
CO2 capture	0%	0%	0%	0%	0%	0%	0%
Tidal	0%	0%	0%	0%	0%	0%	0%
Total	361	1766	1251	29	500	**1596**	**4733**

Source: UNFCC (2009), CDM (2009)

Results suggest that JI and CDM projects have different technological focus. 80% of JI projects focus on fugitive emissions from fuels, energy efficiency in supply side, biomass energy, fossil fuel switch, landfill gas and N2O. 80% of CDM projects focus on hydro energy, biomass energy, wind, energy efficiency own generation, landfill gas, biogas, agriculture, and energy efficiency in industry. Except for biomass and landfill gas, the priorities on each type of frameworks are different.

Buyers of JI and CDM projects

We focus now the examination of the major buyers of CDM projects in pipeline in 2009 by the BRICS (Table 7).

Concerning ***Joint Implementation projects***, the major buyers are the Netherlands, the UK, followed by Austria, Denmark and Japan. These 5 countries are responsible for more than half of the total JI projects (JI, 2009). When analysing the countries involved in JI projects hosted by Russia, we find that 25% of the Russia projects were proposed by the UK, 9% by Denmark, 5% Austria, 5% Netherlands and 4% Sweden. The remaining projects are attributed to either national or international organisations.

Concerning the ***Clean Development Mechanism projects***, the major buyers are the UK, Switzerland, the Netherlands and Japan. These four countries are involved in about 66% of projects hosted in Brazil, 53% of projects hosted by South Africa and China, and 23% of projects hosted by India. Switzerland does not participate in individual projects hosted in China, and that Germany and Sweden are also important buyers (16%) of the projects hosted in China. Moreover, it should be noted that about 75% of projects hosted in India have been proposed by international or national organisations.

Table 7. Main buyers of CDM and JI projects in pipeline hosted by BRICS, in 2009

	CDM projects				JI projects
	Brazil	China	India*	South Africa	Russia
Austria	0%	3%	0.40%	0%	6%
Denmark	0%	1%	0%	4%	9%
Germany	2%	6%	3%	4%	0%
Japan	7%	15%	2%	4%	2%
Sweden	1.4%	10%	0.40%	0%	4%
Switzerland	21%	11%	6%	7%	2%
The Netherlands	10%	15%	2%	18%	5%
United Kingdom	28%	33%	13%	29%	25%
Total	69%	94%	27%	66%	53%

Source: UNFCC (2009), CDM (2009), JI (2009)

Finally, we explore whether or not a scope specialisation of buyers can be identified. Table 8 provides information on the participation of Japan, Netherlands, Switzerland and the UK in CDM projects with some of most common technological scopes of CDM in pipeline in 2009, hosted by the BRICS. Three main surprising results emerge.

Table 8. Participation of Japan, Netherlands, Switzerland and the UK in CDM projects in the most common scopes of CDM in pipeline in 2009, hosted by the BRICS.

HOST	Technological SCOPE	N. Projects hosted	Japan	Netherlands	Switzerland	UK	These 4 countries on total projects
Brazil	Agriculture	**59**	0%	0%	43%	40%	124%
	Biomass energy	**114**	27%	49%	19%	40%	69%
	Coal bed/mine methane	0	0%	0%	0%	0%	0%
	EE own generation	11	0%	0%	0%	0%	0%
	Fossil fuel switch	18	4%	0%	5%	4%	50%
	Hydro	76	38%	26%	15%	13%	57%
	Landfill gas	41	23%	14%	7%	1%	41%
	Wind	11	0%	0%	3%	1%	27%
	Total	**91%**	**92%**	**89%**	**92%**	**99%**	
	Total projects	**361**	**26**	**35**	**74**	**102**	
China	Agriculture	1	0%	0%	0%	0%	100%
	Biomass energy	76	1%	3%	3%	8%	80%
	Coal bed/mine methane	63	4%	5%	4%	6%	103%
	EE own generation	257	13%	3%	19%	18%	72%
	Fossil fuel switch	32	2%	0%	2%	3%	78%
	Hydro	829	60%	65%	0%	30%	61%
	Landfill gas	56	2%	3%	4%	3%	66%
	Wind	337	7%	16%	20%	26%	74%
	Total	**93%**	**89%**	**95%**	**51%**	**93%**	
	Total projects	**1766**	**260**	**273**	**194**	**580**	
India	Agriculture	3	0%	0%	0%	0%	0%
	Biomass energy	336	11%	30%	51%	41%	35%
	Coal bed/mine methane	0	0%	0%	0%	0%	0%
	EE own generation	123	4%	17%	18%	10%	29%
	Fossil fuel switch	51	0%	3%	0%	3%	12%
	Hydro	127	18%	17%	1%	9%	20%
	Landfill gas	26	0%	0%	1%	2%	15%
	Wind	298	39%	10%	10%	12%	14%
	Total	**77%**	**71%**	**77%**	**81%**	**77%**	
		1251	**28**	**30**	**73**	**165**	
South Africa	Agriculture	0	0%	0%	0%	0%	
	Biomass energy	4	0%	0%	0%	13%	25%
	Coal bed/mine methane	2	0%	0%	0%	0%	0%
	EE own generation	1	0%	0%	50%	0%	100%
	Fossil fuel switch	4	0%	20%	0%	0%	25%
	Hydro	2	0%	20%	0%	0%	50%
	Landfill gas	6	0%	20%	0%	25%	67%
	Wind	0	0%	0%	0%	0%	
	Total	**66%**	**0%**	**60%**	**50%**	**38%**	
	Total projects	**29**	**1**	**5**	**2**	**8**	

Source: UNFCC (2009), CDM (2009)

The first surprising finding relates the massive participation of Japan, the Netherlands and the UK in CDM projects aimed at transfer of hydroelectric technologies, when these countries, in particular the UK and the Netherlands, make such a reduced use of them in their home country.

The second surprising finding refers to heavy focus of CDM projects on biomass energy technologies, when on section 4.1 we have seen that in BRICS these technologies are much more diffused than in developed countries. In particular, in section 4.1, we have seen that the UK and the Netherlands start using renewable and waste combustible technologies in the 1990s. Moreover, we saw that Brazil is the leader in BRICS on the use of these technologies, which are used on 10% of total energy used. Still Brazil hosts relatively more CDM projects on biomass energy technologies than average. Then how should be interpreted the great involvement of these two developed countries into CDM projects in biomass energy technologies? We may guess that these countries have invested in CDM projects in biomass energy in order to get access to existing production facilities to test new technologies, and/ or to access local knowledge on existing biomass and biofuel productive technologies.

The third interesting result is that the participation of buyers in specific technological scope differ according to the host country. In other words, buyers are not specialised into a specific technological scope. For example, Switzerland participates in no hydro project in China, and only 1% of its projects hosted in India are on hydro technologies, while 15% of its projects hosted in Brazil are in hydro technologies. 27% of Japanese projects hosted by Brazil are in biomass energy, but only 1% of projects hosted by China. These 4 countries participate in 27% of wind energy projects in Brazil, but they participate in 74% of wind projects in China. None of these countries has a project on energy efficiency own generation hosted in Brazil, but they participate in 72% of projects with the same scope in China.

Of course that the natural, energetic and industrial conditions of the host countries, as well as national policy influence the scope of the project to be located there and the buyers involved in the projects. Still, these four countries are not expected to be the owners of the best technologies in these 8 largest projects' scopes analysed.

Indeed, several contributions highlight that the CDM mechanism might not be so beneficial for improving impact on the environmental. These contributions stress that CDM framework allows developed countries buying cheap and easily emissions units. More important, these criticisms focus on the fact that often projects do no support sustainable development. For instance, projects for the building of dams in protected natural environments tend to involve deforestation and massive damages to natural ecosystems and indigenous populations. Other often referred cases are biomass and biofuels projects that force deforestation to expand arable land, and use pollutant agriculture methods to raise crops.

4.3. Impact of CDM on the level of diffusion of renewable energy technologies.

Table 9 provides the summary of the correlation analysis performed with data from 1987 to 2005 for the BRICS.

Table 9. Summary of correlation analysis on the different groups of factors affecting the diffusion of renewable energy technologies and on environmental performance of BRICS from 1987 to 2004

		GDP per unit of energy use (PPP $ per kg of oil equivalent)	% Combustible renewables and waste on total energy	% Renewable sources on total energy sources	% Fossil fuel energy consumpti on on total
National Natural endowments	Fossil resources	-	-	-	+
	Population (size and density)		+	+	-
	Water resources				-
	Forest resources			+	
National economic and Social Development	Literacy, expenses per student, Health expenditures	-	-	-	
	GDP per capita	-	-	-	+
	Vehicles & computers		-	-	+
	Government debts	+			
	Growth GDP per capita		+		
	GDP industry	-	-	-	+
	GDP agriculture	-	+	+	-
	GDP services		-		
Internationalisation of National business	FDI, ISO certification				
	Export as import capacity; Royalties paid abroad % GDP		-	-	+
	Trademarks non residents		-		+
	Trademarks residents	+			
National technological capabilities	Expenses per student in tertiary education		+	+	
	% of Computer, communications and other services on services Secured servers	+	+	+	-
	High-technology exports; R&D expenditures as % GDP; Patents residents per 1000 people; Researchers and technicians in R&D; Royalties received as % GDP; Scientific papers per 1000 people	-	-	-	+
National policy culture	Investment in energy with privates % GDP				
	National protected areas	+		+	-
	Military expenditures % GDP	-	-	-	+
Global international frameworks	Number of CDM and JI projects	+			-
	CER registered				

Results suggest that national natural endowments definitely create strong and diverse incentives to the use of specific energy technologies. National endowments in fossil fuels are associated with greater levels of emissions and reduced levels of adoption of renewable energy technologies, contrary to endowments in renewable internal freshwater and forest resources. Moreover, size and density of national population seem to create incentives for the diffusion of renewable energy sources.

These results also suggest that during the 1990s, in the BRICS, economic development and industrialisation relied extensively on fossil fuels. To a certain extent this result is consistent with the literature. Similarly, the levels of internationalisation of national business activities did not favour the development of a managerial attitude more environmentally friendly in BRICS, revealing that environmental concerns are not yet truly a management fashion in the global business environment.

The national technological capabilities of BRICS have not been supporting the development of sustainable technologies, but instead reliance on fossil fuels. In particular, the improvement on national technological capabilities focused on production activities more energy-demanding, revealing that the technological goals in BRICS are still in technical advances related to energy-demanding industries. Only higher education and competent service sectors enhance diffusion of renewable technologies.

As expected, in an economy in which national policy culture is concerned with protecting natural areas, the diffusion of renewable energy technologies tend to be quicker. Contrary, military focus may divert attention from environmental concerns.

Finally, the number of CDM and JI projects has only an impact on the use of efficient use of fuel energy rather than on the use of renewable sources of energy.

5. Conclusions

This paper has aimed at examining the impact of the global institutional frameworks on the process of diffusion of renewable energy technologies in the BRICS countries i.e. Brazil, China, India, Russia and South Africa. In particular, we take into consideration Kyoto protocol and mechanisms for emission reductions in developed and developing world. We address empirically this issue making use of national aggregated data from the World Development Indicators and International Energy Agency, as well as data from UNCCC (2009).

Our analysis suggest that there are not major differences in diffusion of renewable energy sources between BRICS and developed countries, especially those analysed who are the main buyers of CDM and JI projects. Moreover, some of renewable technologies are used for a longer time in the BRICS than in developed countries.

Analysing the geographical distribution of CDM and JI, we find that 70% of these projects are hosted by BRICS, being more than 50% hosted by China. The question is then why are the other developing countries so unattractive for these projects. Still, we also find a great concentration on the side of the investors in JI and CDM projects.

Examining the technological scope of these projects, we find that CDM and JI projects have different technological priorities. JI focus mainly on fugitive emissions from fuels (33%), followed by energy efficiency in the supply side, biomass energy and fossil fuel switch (10%), landfill gas (8%) and N2O(7%). CDM projects instead concentrate on hydro (25%) and biomass (16%) energy, wind (14%), landfill gas (7%), biogas (8%), agriculture (6%) and industry energy efficiency (8%).

Moreover, we found national specialisation in attraction of specific projects. Brazil hosts more biomass energy and energy efficiency in agriculture; China coal mine and hydro technologies; India energy efficiency in manufacturing and services, and biomass and wind energies; Russia energy efficiency in manufacturing.

Japan, The Netherlands, Switzerland and the UK are responsible for more than 50% of investments in the BRICS. This result raises a question, are these four countries the owners of the best technologies in such a wide range of technological scopes? However, we do not find any investor specialisation in a topic. Moreover, we find involvement of these countries in implementing projects in technologies that do not seem very used in their home countries, such as biomass and hydro energy. Additionally, we find surprising that being Brazil one of the analysed countries with great use of biomass and bioliquids energy sources, to be exactly the one that attracts so many projects on biomass. We may guess that the objective of these projects are not merely to buy emission credits, other technological and market reasons may be needed to justify this finding.

Finally our empirical analysis suggests that the natural endowments of the country, higher education and the national policy culture are the factors that support the diffusion of renewable technologies. National economic and social development, internationalisation of national business and national technological capabilities instead support reliance on fossils and hold back diffusion of renewable technologies. Global international frameworks seem to support efficient use of fossil fuels, but not the diffusion of renewable technologies.

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