Intellectual Property Rights, Innovation and Climate Policy – Regional and Sectoral Implications on Energy Technologies Diffusion

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Abstract

In recent years the deployment of environmentally-friendly technologies has been an important subject in scientific contributions as well as in political discussions. Numerous studies analyze innovation in energy and climate-friendly technologies and their diffusion from developed to developing regions. Nevertheless, still too little is known about the drivers, in particular environmental and climate policies, intellectual property rights (IPRs), and private investments in energy technologies, and about the resulting economic and environmental performance of these innovations. This is mainly due to the lack of appropriate data. This paper summarizes comprehensive databases on environmental and climate policies as well as on IPR reforms and presents insights gained from these data that serve as cornerstones for the development of new indexes of environmental policy and intellectual property rights which, unlike previous available data, detail the policy framework of a large number of countries, distinguishing between industry, power sector, and, more broadly, energy policies. We subsequently develop industry-level indicators of energy and environmental performance for various countries, including BRIC (Brazil, Russia, India and China), to examine the impact of policy on these indicators. We find that the higher the stringency of policy (both environmental and technology), the lower is the carbon intensity of energy and of output in a given sector. The relationship between energy intensity and policy is, on the other hand, less straightforward. While this is a general conclusion, developing countries show very different trends from developed countries. These country-sector specificities need to be accounted for when drafting successful and efficient energy and environmental policies.

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Version as of May 3, 2012. During the conference an updated, more comprehensive version will be presented.

1. Introduction

The adoption and deployment of low-carbon and environmentally-friendly technologies has been at the center stage of recent climate negotiations. Technology diffusion from developed to developing countries can facilitate access to affordable and appropriate emission-reducing technologies. A number of recent contributions analyze innovation in energy and climate-friendly technologies and their diffusion across borders (Popp et al. 2010, Carraro et al. 2010). In a few cases, the analysis is extended to include developing countries (Verdolini & Galeotti 2011, Bosetti & Verdolini 2012, among others). However, no study links the innovation and diffusion of energy and environmental technology to a systematic analysis of economic and environmental performance across countries.

What is currently lacking is a comparative study looking at how efficient and environmentally friendly technologies impact the performance of different sectors in different countries. This is the result of a difficulty in finding appropriate data that can be easily compared. The broad available literature examining productivity trends and energy-augmenting technological change is mostly confined to country level data. Common approaches are cost function or factor demand frameworks (Jorgenson & Fraumeni, 1981, Sue Wing & Eckaus, 2007), which allow singling out the contributions of technological change, prices, and structural changes. A few sectoral studies exist (Sanstad et al. 2008, Kratena 2007), but are limited to selected countries.

Another strand of literature explores the drivers of energy intensity using a simplified approach that lacks a structural framework (Hübler & Keller 2009). The few contributions looking at the drivers of energy intensity and factor productivity using a structural approach are either limited to selected OECD countries (Carraro & De Cian 2012) or exploit very detailed micro-level data, but for just one country (Fisher-Vanden et al. 2004).

This paper uses a decomposition approach to analyse how technology and environmental policy relate to the environmental performance of different industries. The contribution is the development of industry-level indicators of energy and environmental performance for selected countries, including BRIC (Brazil, Russia, India and China). The remainder of the paper is structured as follows. Section 2 outlines a comprehensive database of environmental and climate policies and presents insights drawn from the data. Section 3 focuses on Intellectual Property Rights and presents indexes related to them. Section 4 explores the impact of environmental and climate policies on technology investments and environmental performance indicators. Section 5 concludes.

2. Database on Climate and Environmental Policies

To account for the various climate and environmental policies, we make use of the Policies and Measures Databases provided by the International Energy Agency (IEA, 2011). They consist of three different databases: Global Renewable Energy, Energy Efficiency, and Policy

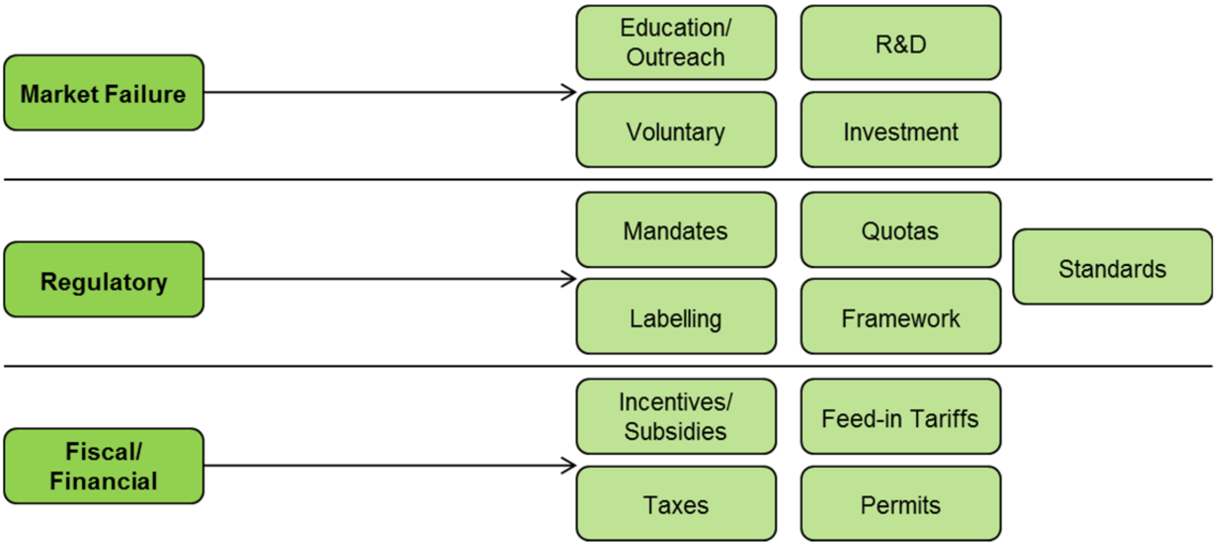
Measures Addressing Climate Change. Altogether, these databases contain data on more than 3,600 policies and yield information on all types of policy measures for some 50 countries with the earliest of these policy measures taking place in 1973. The information inherent in the databases encompasses indicators such as the sector the policy is targeted at (e.g. electricity, appliances, buildings, industry), the respective technology – in particular, renewable technologies are included in a detailed way –, the jurisdiction level, i.e. whether the policy is implemented on a subnational, national or international level, and the policy type (e.g. R&D investments, standards, taxes or permits).

However, in order to answer the research questions of this paper, these databases do not come to be used in a straightforward manner. Instead, a thorough data cleaning process is required which involves several steps. First, the three separate databases have to be merged so that our analysis relies on a single ground. Second, many policies include more than one characteristic of an indicator. For instance, a policy might be targeted at solar PV, wind and bioenergy, or it might contain the implementation of R&D investments and standards simultaneously. Furthermore, many policies are assigned to items such as "Multi-sectoral Policies". For these cases, an intensive search in the description of the single policy measures – which is available for many policies – was necessary. Given that for some database entries important characteristics, e.g. the year of implementation, is not available and given that even after the manual search for some policies no specific information on any indicator was existent, we had to drop some observations leaving us with approximately 3,200 policy measures that we could use for the analysis. Third, for the policy types and for the targeted technologies within the energy sector we constructed multi-level structures in which we assigned the types and technologies appearing in the original database to superior instances.

Figure 1 and Figure 2 present these structures for the policy types and for the technologies, respectively. In Figure 1 the three groups are arranged with increasing stringency of the policy measures. Whereas the first group mainly supports relatively lax policy actions focusing primarily on voluntary participation without legally binding rules, policy actions in the group "Fiscal/Financial" impose rather strict mechanisms which involve in most cases increasing production costs. Figure 2 depicts the classification of the technologies in the electricity sector which the policy measures can be targeted at. The database is particularly detailed for renewable energy technologies. We categorize them into six main groups, two of which, i.e. Solar and Bioenergy, contain several subgroups.

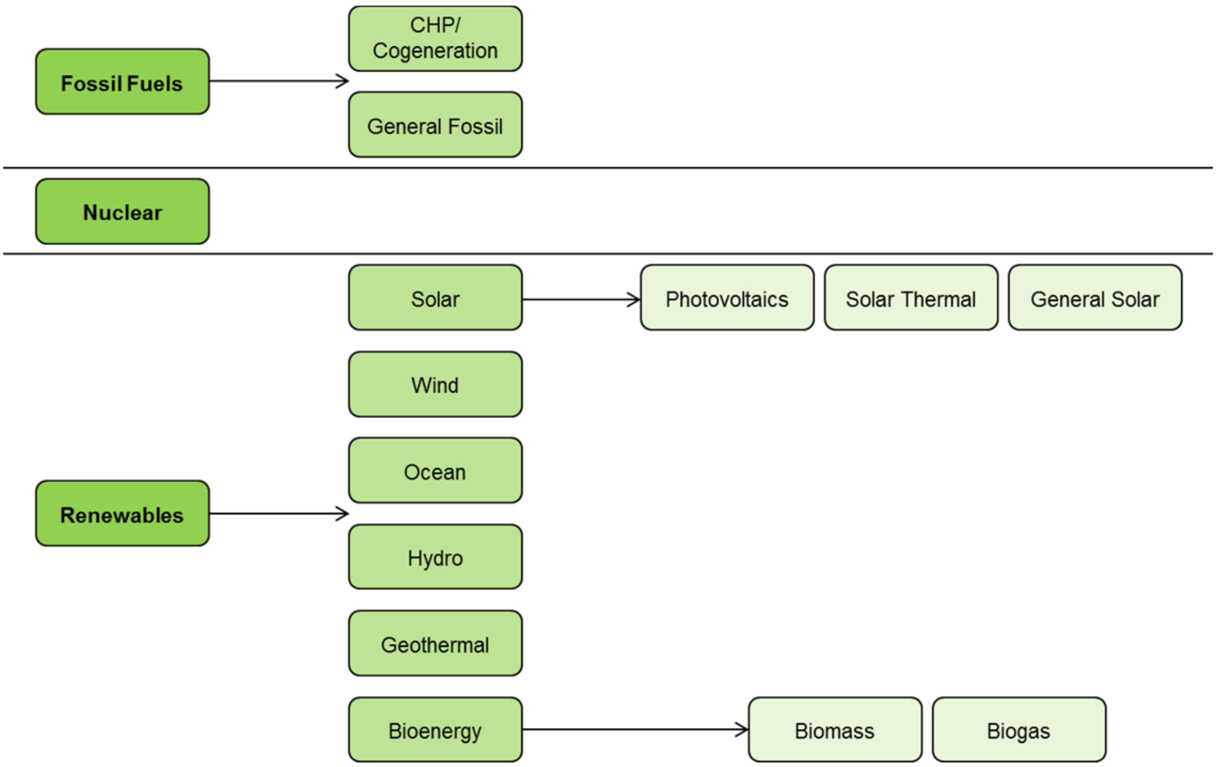
Figure 3 displays the regional distribution of the number of policy measures. As most of the policy interventions were implemented starting in the second half of the 1990s and because a complete coverage of policy measures in 2008 and 2009 in the database cannot be ensured, Figure 3 only includes policies between 1995 and 2007. Not surprisingly, most policies were introduced by the United States and Canada. Other notable countries include Australia, Japan, France and the United Kingdom among others. Among the BRIC countries China clearly implemented the highest quantity of policy measures. Despite the relatively small size of their economies, also countries such as the Netherlands, Finland and Denmark feature a large number of policy measures that were enacted. In the case of Belgium the high number of policy measures is due to the federal structure of the country – policies are often implemented separately in Flanders and in Wallonia. Those policies can thus be counted twice although they might be very similar regarding their content.

Figure 1: Fields of policy types



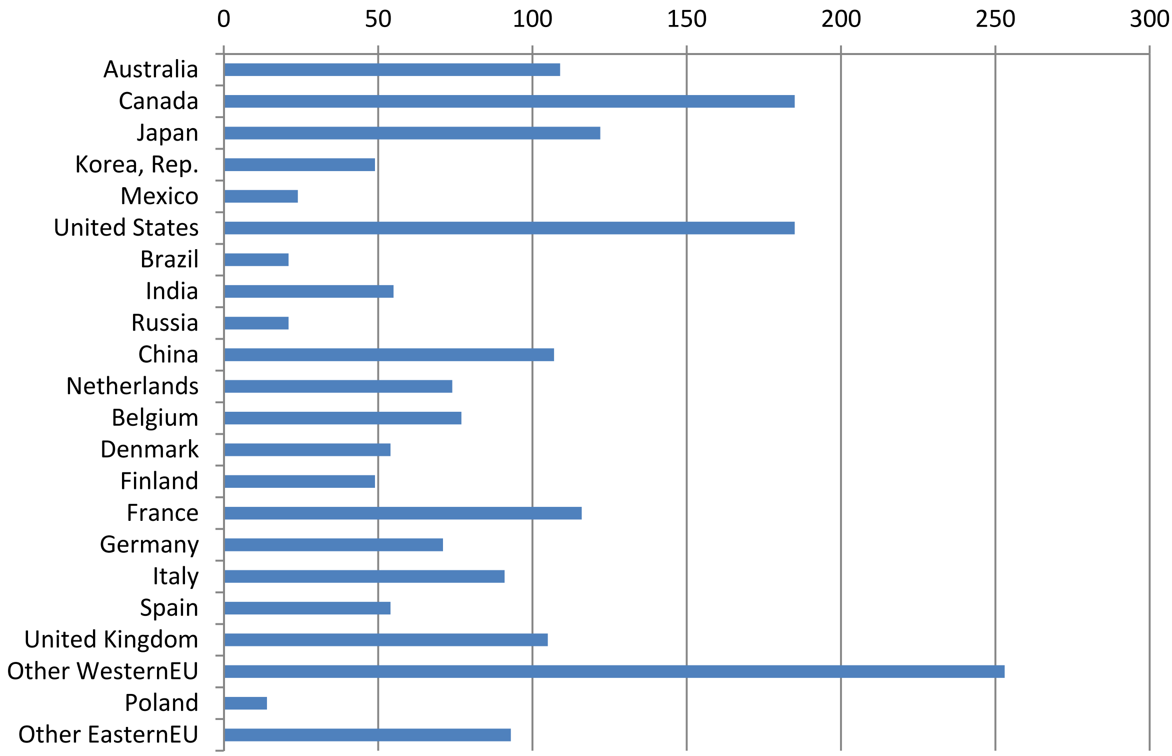
Source: own representation

Figure 2: Technologies within the electricity sector



Source: own representation

Figure 3: Regional distribution of policies from 1995 to 2007

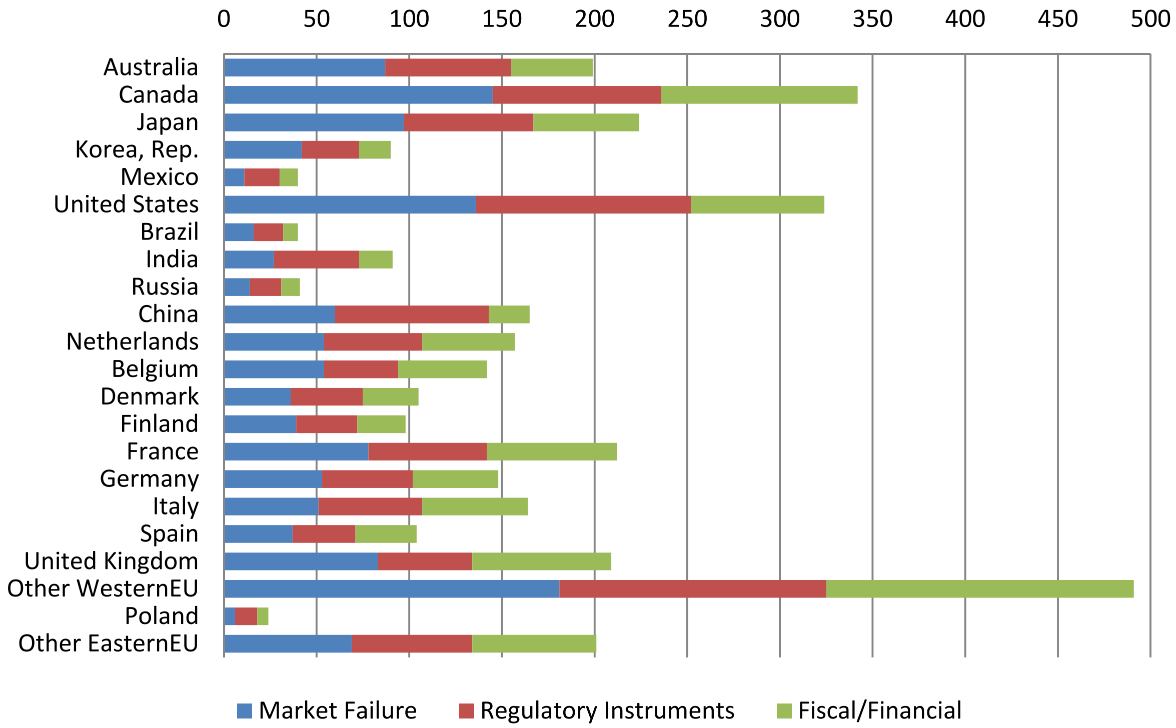


Source: IEA (2011), own calculations

Figure 4 depicts the distribution of policy interventions for the three groups of policy types laid out above whereas Figure 5 presents the distribution of the technologies. It is important to point out that one policy measure can comprise several policy types, e.g. it might be a combination of educational programs, feed-in tariffs and subsidies. This policy measure would then be counted as three policy interventions in Figure 4 and Figure 5 since we are interested in the occurrence and distribution of all the policy types within our sample. Therefore, the numbers in Figure 4 and in Figure 5 differ from those in Figure 3 where only the policy measures as a whole are counted.

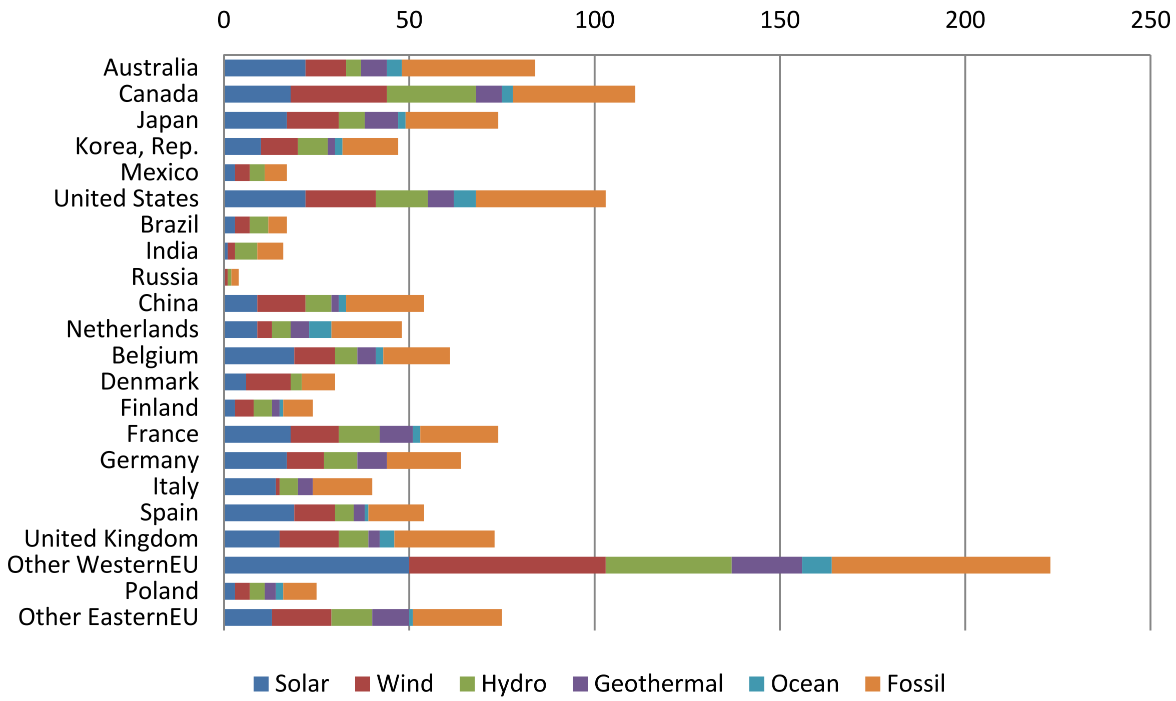
When looking at the policy types, we observe that fiscal and financial instruments play a larger role in developed regions than in developing countries. Whereas in the former approximately one third of policy interventions consists of measures such as tariffs, taxes or permits, policy interventions especially in the BRIC countries make up only a small part. Developing and emerging economies instead seem to focus either on instruments involving voluntary, educational or investment actions or on measures such as measures, standards and quotas. The reason for this might lie in the fact that developing countries aim at generating specific environmental standards before applying purely market-based mechanisms such as taxes or permit systems. Furthermore, the introduction of such mechanisms might impair the international competitiveness of firms in developing countries.

Figure 4: Distribution of policy interventions by policy type from 1995 to 2007



Source: IEA (2011), own calculations

Figure 5: Distribution of policy interventions by technology targeted from 1995 to 2007



Source: IEA (2011), own calculations

Figure 5 shows that a high number of policies target fossil fuels. In most regions at least 30% of the policy interventions are devoted to these energy carriers with the highest shares – more than 40% – in Australia, India and Russia. This is not surprising since the energy supply in these countries depends notably on fossil fuels. On the other hand, Southern European countries such as Italy and Spain have a high fraction of policy interventions devoted to solar technologies – both countries with more than 30%. Policy interventions dedicated to wind power are particularly present in Denmark (about 40%) and policies targeting hydropower receive special attention in India and Brazil (more than 30% in both countries). Policy measures concerning technologies related to geothermal and ocean power play a minor role in all regions.

3. Intellectual Property Rights

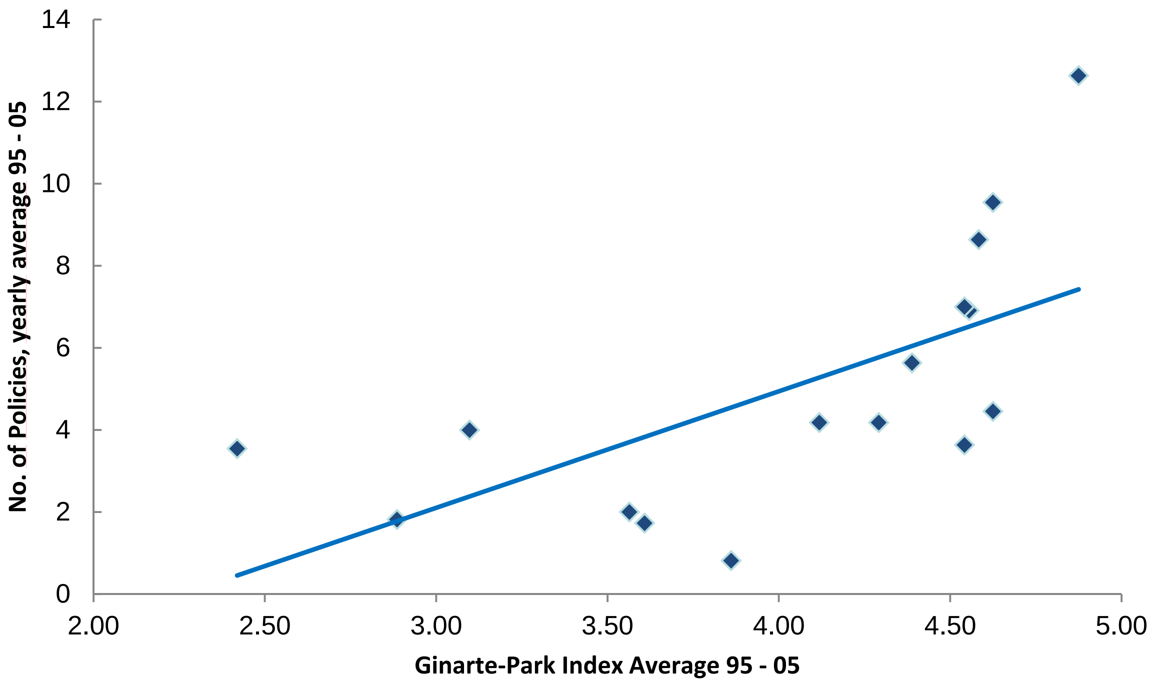
There are various indexes to measure the strength of Intellectual Property Right (IPR) systems. The most established is the Patent Rights Index (Ginarte-Park-Index) by Juan Ginarte and Walter Park (Ginarte & Park 1997). This index represents mainly the strength of the legal environment for patenting in five year-time steps from 1960 to 1990. It was further developed to include the period from 1995 to 2005 by Park (2008). The index contains the impacts of five categories: the coverage of research fields in which inventions can be patented, the membership in international agreements, criteria regarding the loss of patent protection, the enforcement rules, and the duration of patent protection. In each category a value between 0 and 1 is assigned, leading to a value between 0 and 5 for the overall index, where a higher value indicates a stronger patent system. For details we refer the reader to Ginarte & Park (1997).

Another interesting index is constructed by De Saint-Georges & van Pottelsberghe (2011). Whereas the Ginarte-Park-Index mainly concentrates on the strength of patent protection, the latter puts more emphasis on the quality of the patent system. Therefore, the components of these indexes differ immensely and evaluate certain items in a different way. The quality index for patent systems established by De Saint-Georges & van Pottelsberghe (2011) consists of nine components of which seven are structural and two are managerial. The authors measure quality by the novelty and the inventiveness conditions and emphasize the transparency and certainty of the patent system. Also for this index each component is given a value between 0 and 1.

The two indicators concentrate on different aspects of the patent system. The clear advantage of the Ginarte-Park-Index is its availability as time series from 1960 to 2005, whereas the quality index is only available for 2008. In addition, the former contains 122 countries in contrast to 32 patent systems covered in the latter. Therefore, we will use the Ginarte-Park-Index throughout the remainder of the paper. However, an additional, more comprehensive index is worth mentioning. It was constructed by the IPRI (International Property Rights Index) project (Chandima Dedigama 2008). This index emphasizes, in addition to patent protection, the legal and political environment, physical property rights, and other aspects of intellectual property rights. The Ginarte-Park-Index is one component of the IPRI.

However, as in the case of the quality index by De Saint-Georges & van Pottelsberghe (2011) no time series are available for this indicator.

Figure 6: Relationship between patent protection and environmental and climate policy interventions, 1995-2005

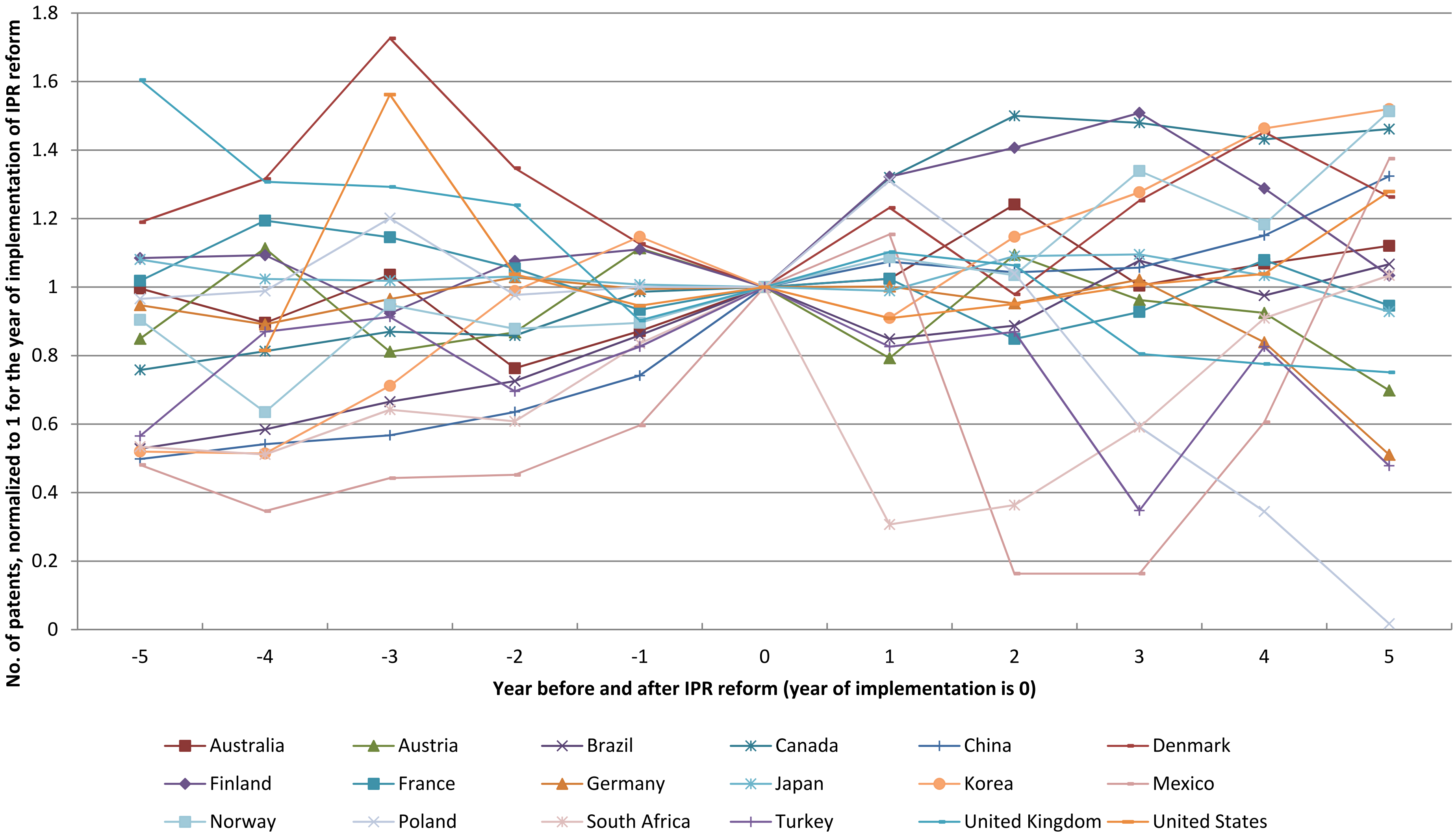


Source: IEA (2011), Ginarte & Park (1997), Park (2008), own calculations

Figure 6 presents the correlation of IPR protection according to the Ginarte-Park-Index and the number of environmental and climate policy interventions for the period from 1995 to 2005. We observe a clear positive relationship between these factors. Although the figure describes a merely descriptive relationship, we can gain some significant insights. First, countries with a high degree of IPR protection also pursue stricter policies. It seems that a certain level of IPR protection is required in order to be able to implement stringent environmental and climate policies. The second insight concerns methodological issues. In empirical analyses that include IPR protection and policy stringency as explanatory variables one has to be aware of possible endogeneity problems between both variables.

A very substantial issue when examining the significance of IPRs is the existence and the timing of reforms of the IPR systems. In order to obtain the dates of major patent reforms in the countries of our sample, we performed an extensive data collection based on Maskus (2000), Branstetter et al. (2006), Qian (2010), Qiu & Yu (2010) and various legal texts provided by WIPO Lex (WIPO 2012).

Figure 7: Patenting before and after IPR reform



Source: PATSTAT (2011), Maskus (2010), Branstetter et al. (2006), Qian (2010), WIPO (2012), Qiu & Yu (2010), own calculations

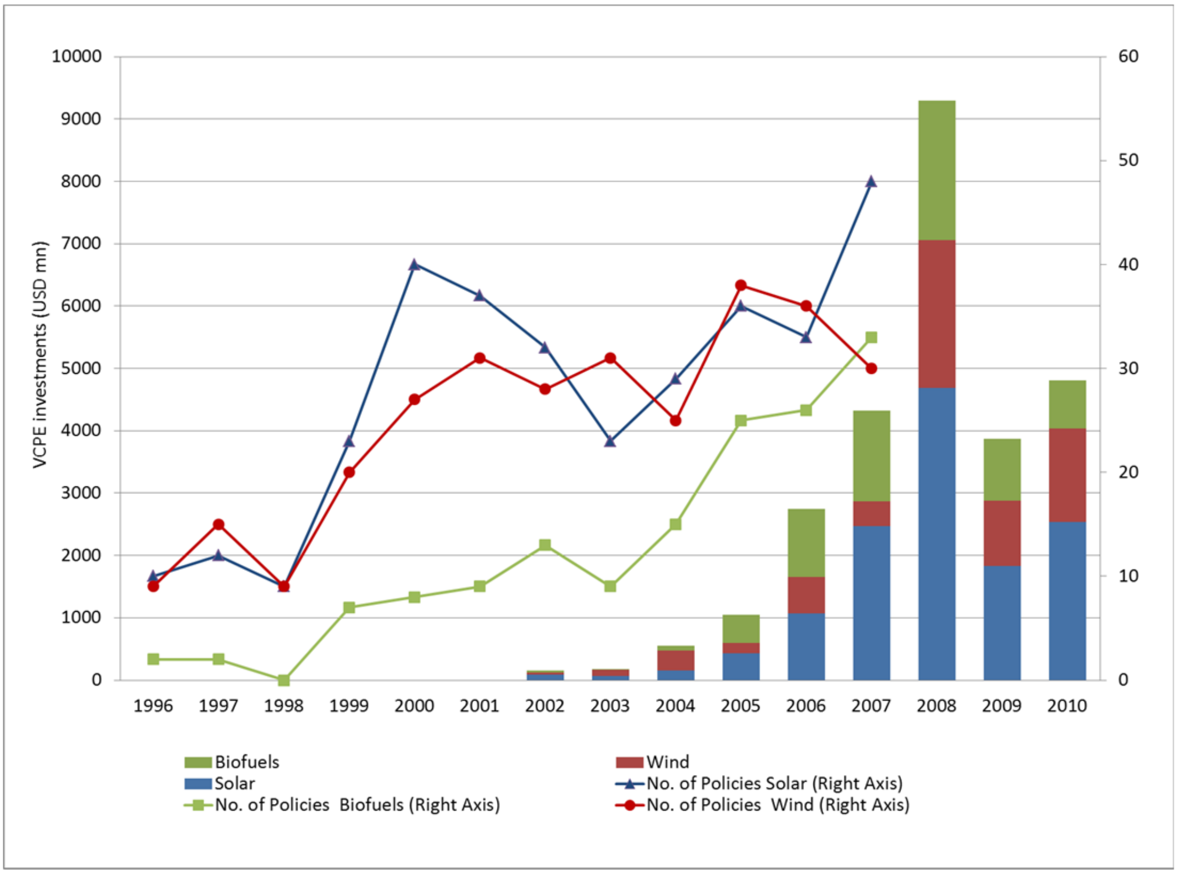
To analyze the impact of these reforms, Figure 7 shows the behavior of patenting activities before and after the reforms of the IPR systems in the respective countries. The number of patent applications is normalized to 1 for the year of implementation of the reform. We observe ambiguous impacts of the reforms. In many countries, e.g. Canada, China, South Korea or Australia, the reform led to higher patenting activities, sometimes with a lag of up to three years. On the other hand, countries such as South Africa, Mexico or Poland show increasing patenting activities up to the reform year or the following year and declining activities afterwards. Obviously, the propensity to patent depends on the specific character of the reform. For instance, for inventors in particular research fields the reform may set adverse incentives since a reform does not necessarily imply an improvement for all potential applicants. Nevertheless, the behavior of rising patent applications up to the reform year and decreasing activity thereafter occurs for quite a lot of countries. It can also indicate that applicants anticipate the reform, retain their application until that date and apply relatively quickly after the reform was implemented. Therefore, potential applications might accumulate until the implementation and hence patenting activities decline in the aftermath of the reform. Altogether, Figure 7 shows that an IPR reform does not necessarily induce higher patenting activities in each country.

4. Investments in Venture Capital and Private Equity and Indicators of Environmental Performance

This section analyzes the impact of environmental and climate policy interventions on several indicators concerning investments and environmental performance. With respect to the former indicators we consider in particular investments in venture capital and private equity (VC/PE). Venture capital is particularly interesting because it represents early stage investments for technology development provided to high risk startup companies. Private equity, on the other hand, characterizes late stage investments for technology expansion and the commercialization of products. Hence, these types of investments represent important stages for clean energy technologies which still have to assert their position in the market. The data we use for this analysis stems from the Bloomberg New Energy and Finance database (BNEF 2011). The database reveals insights on private investments in clean energy technologies. It has particular significance since it is the first database that provides information on energy R&D with a global coverage which was not available previously.

Figure 8 presents policy interventions and VC/PE investments, both broken down by three technologies, i.e. biofuels, wind and solar. The figure suggests a relationship between both indicators which is lagged by approximately one to three years. The most obvious interrelation exists for the case of wind. In the case of solar energy technologies the figure suggests a relatively short time lag of approximately one year in the later years of the covered period. In the early years, however, the relationship is not very apparent.

Figure 8: Relationship between policy interventions and VC/PE investments

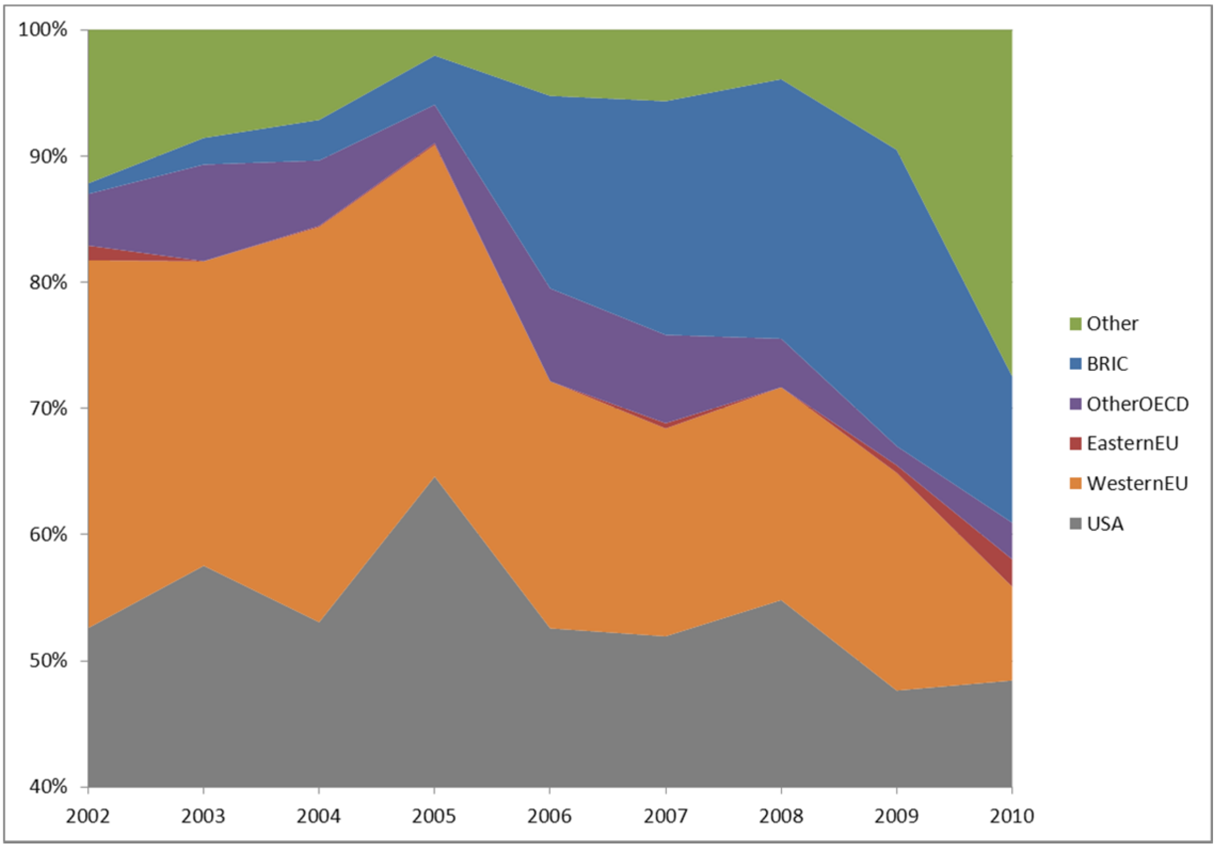


Source: IEA (2011), BNEF (2011), own calculations

Figure 9 shows the distribution of host regions of VC/PE investments between 2002 and 2010. Since the United States (the bottom region in the figure) is the main host of these investments, note that the share is scaled such that the figure only presents 60% of the whole scope of VC/PE investments. Whereas the share of the US has more or less remained constant over the past ten years, in the second half of the period investors shifted their investments increasingly to emerging economies such as the BRIC countries. The region other countries which features a rapid increase in the past years includes fast growing countries such as Singapore, Taiwan and South Korea. In contrast, the share of Western Europe and other OECD countries declined. This shows the importance of this type of investments with respect to technology transfer from developed to emerging economies.

As our main objective is to examine the joint effect of environmental and climate policies and IPRs on the environmental performance of energy-intensive industries, we develop performance indicators by decomposing carbon intensity of output into carbon intensity of energy (measured in ton per TJ) and energy intensity of output (measured in TJ per US$). These indicators can be generated with the help of the WIOD database (WIOD 2012), a consistent and comprehensive KLEM dataset enhanced with satellite environmental data. A specific strength of WIOD is the inclusion of emerging and developing countries, so that it is possible to include the BRIC countries as major emerging economies into our analysis.

Figure 9: Share of VC/PE investments by aggregate regions

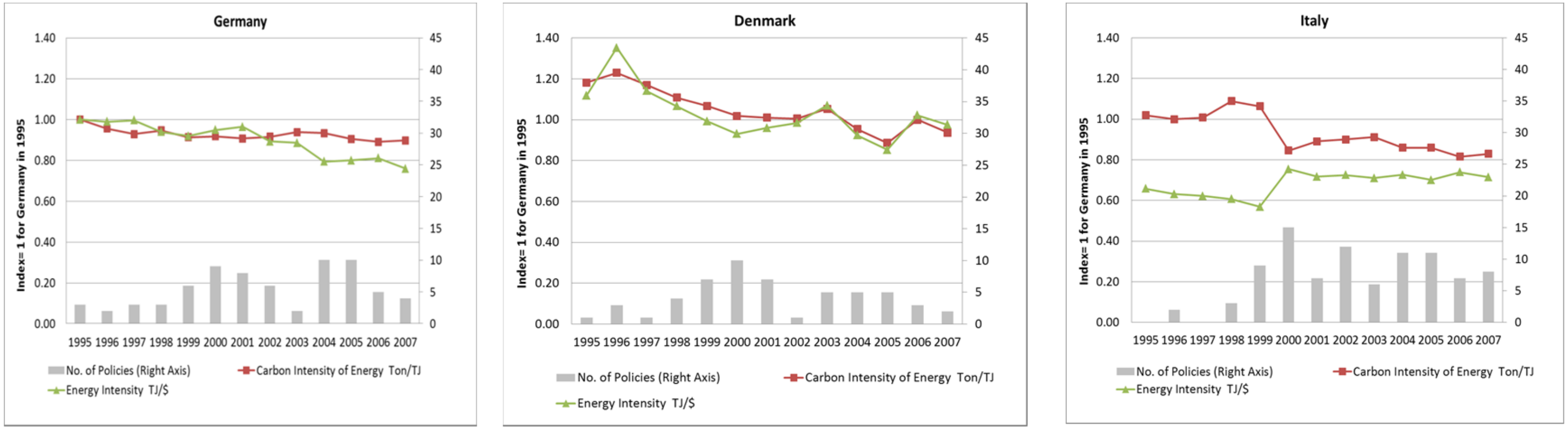


Source: BNEF (2011), own calculations

Figure 10 presents the carbon intensity of energy and the energy intensity of output of the sector "Electricity, gas and water distribution" as well as the number of policy measures for Germany, Denmark and Italy. To ensure better comparability of the single graphs, the former two indicators are normalized so that for the 1995 values of carbon intensity of energy and energy intensity of output in Germany we assign the value 1.

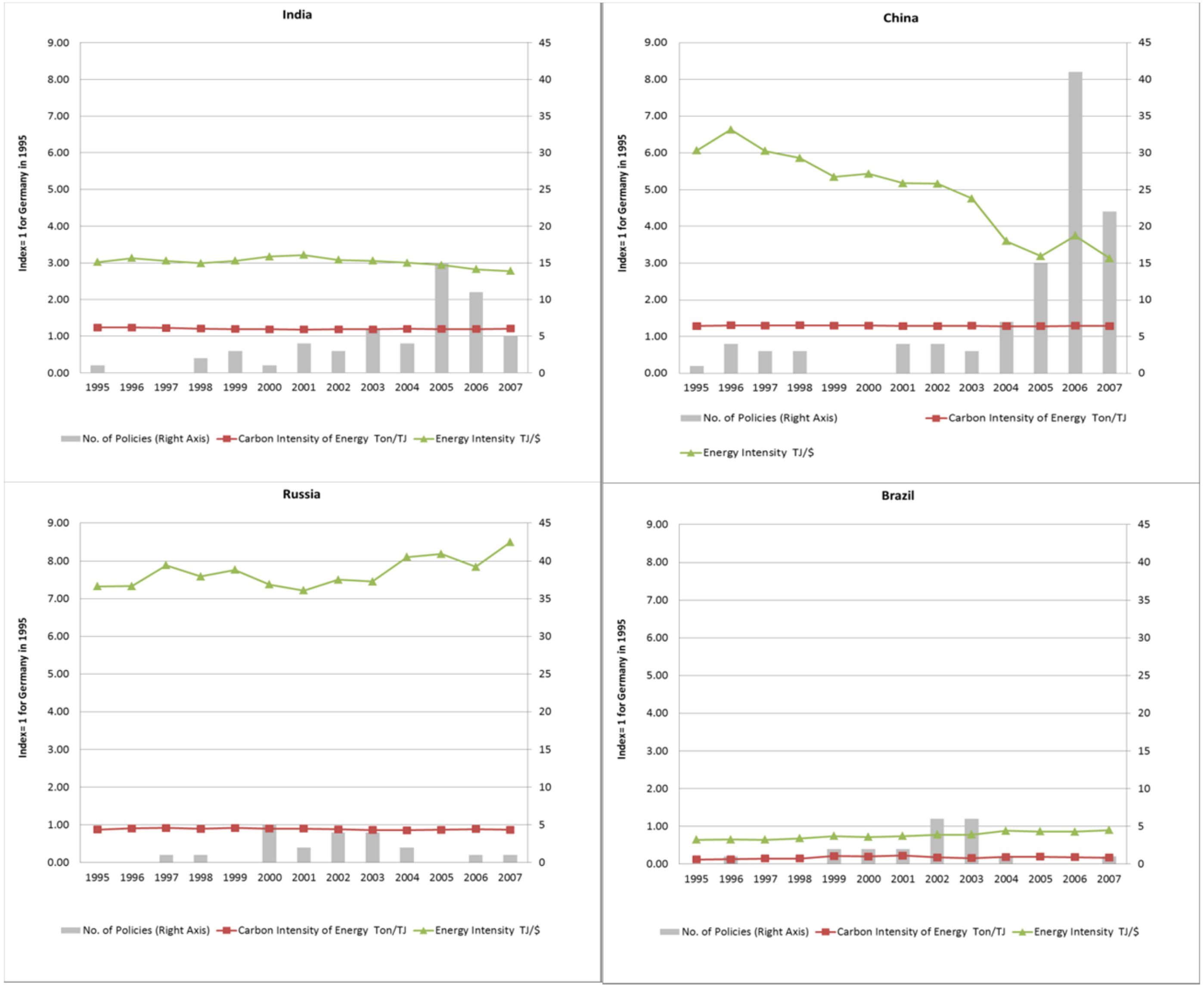
In general, a decline in both carbon and energy intensity over the given period can be found which also leads to a decrease in overall carbon intensity of output (ton per US$). Furthermore, we can observe a relationship between the number of policy actions and the two performance indicators. However, different regional patterns occur. Whereas in Germany energy intensity decreased over time, carbon intensity of energy remained more or less stable. In Denmark, on the other hand, we detect diminishing carbon and energy intensities until the beginning of the 21st century but a higher fluctuation afterwards. Both indicators are at a higher level than in Germany which is unexpected as a high share of electricity generation stems from wind power. Surprisingly, among the countries considered here Italy shows the lowest level in both indicators. However, after a strong antipodal shift of both factors in 2000, they have since remained relatively constant.

Figure 10: Policy interventions, carbon intensity of energy and energy intensity of output for electricity, gas and water distribution in selected developed countries



Source: WIOD (2012), IEA (2011), own calculations

Figure 11: Policy interventions, carbon intensity of energy and energy intensity of output for electricity, gas and water distribution in the BRIC countries



Source: WIOD (2012), IEA (2011), own calculations

The case of the BRIC countries for these indicators is presented in Figure 11 with the same normalization. The results are ambiguous. In China, the energy intensity of output decreased tremendously, by approximately 50% within 12 years. This is accompanied by a strong rise in environmental and climate policies. The carbon intensity of energy barely changed in this period. Hence, the carbon intensity of output has also declined but this is mostly due to the lower energy intensity and there still is reduction potential with respect to the emissions per unit of output. In India, despite a relatively high number of policy actions and despite low energy and carbon intensity values compared to China in the beginning of the period, no substantial change in both indicators can be identified so that India's energy intensity is at the same level as China's energy intensity although the values of the latter country were twice as high in 1995. Industries in Russia have the highest energy intensity of output. The value even increased during the period presented here, particularly between 2003 and 2007. This shows a growing dependence of the Russian electricity supply of fossil fuels such as coal and natural gas. In comparison to the other BRIC countries, energy and carbon intensity are small for the Brazilian electricity sector. The surprisingly low values for carbon intensity of energy are due to a high share of hydropower (more than 60%) in the Brazilian energy mix. Nevertheless, the energy intensity of output increased throughout the period considered in Figure 11 and the number of policy interventions is the lowest among the BRIC countries. However, we can observe a slight interrelation between policy interventions and carbon intensity of energy after 2001.

5. Conclusions

This paper provides a first preliminary analysis of sectoral economic and environmental performance for selected countries between the years 1995 and 2007. Preliminary empirical results show that the higher the stringency of policy (both environmental and technology), the lower is the carbon intensity of energy and of output in a given sector. The relationship between energy intensity and policy is on the other hand less straightforward. In our contribution, we control for confounding factors and show that IPR protection and stringent environmental policy are associated with lower energy and carbon intensity in the economy. While this is a general conclusion, developing countries show very different trends from developed countries. These country-sector specificities need to be accounted for when drafting successful and efficient energy and environmental policies.

Further research shall concentrate on the following issues. In an empirical framework we will explore the link between climate and environmental policies and environmental performance and we will examine the effectiveness of environmental policy, i.e. do econometric analyses confirm the assumption that policy stringency has an impact on carbon intensity of energy as implied by the descriptive analyses of this paper? In addition, since we have concentrated on the electricity sector so far, we will extend the analysis to several energy-intensive sectors because the policies considered here also affect these industries as well as renewable energy sectors.

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