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HAS THE STRENTHENING OF PATENT RIGHTS SINCE 1990 FUELED ENERGY EFFICIENCY AND INNOVATION?

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INTELLECTUAL PROPERTY REFORM, INNOVATION AND ENERGY

Modern economies are highly dependent on ready availability of tremendous volumes of energy. Significant environmental impacts are associated with the current patterns of resource exploitation in the production of such amounts of energy, and for some countries constraints on energy availability appear to be slowing the pace of economic development. [3] In response to concerns with respect to economic development and climate change, scholars and policy makers are expending considerable effort exploring means of accelerating development and diffusion of more efficient and sustainable energy tech-

1. The views expressed are those of the authors and do not necessarily reflect those of the OECD, its member countries, COFEPRIS, or the Government of Mexico.

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3. E.g., with respect to electrical energy supply, *SAinfo reporter* notes that "[t]he biggest immediate threat to South Africa's continued economic growth is a capacity constraint that has arisen precisely because of the country's strong economic performance in recent years." See "South Africa: economy overview" on the web site SouthAfrica.info (accessed on 30 July 2011): http://www.southafrica.info/business/economy/econoverview.htm#ixzz1Tgg25aS9.

nologies.[4] With these concerns in mind, certain of these experts are generating a substantial and growing literature that considers means to improve the performance of the energy sector. A number of papers examine the potential for further reform in the protection of intellectual property rights (IPRs) – particularly patent reform – to accelerate innovation in energy technologies and promote technology transfer and diffusion (e.g., Barton, 2007; Maskus, 2010).

The present paper considers possible effects on energy efficiency of an earlier period of patent policy reform aimed at promotion of innovation, one that took place as part of the wave of strengthening of IPR provisions during the 1990s. This period covered the entry into effect of the World Trade Organisation's Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), expanded adherence to various accords of the World Intellectual Property Organisation (WIPO) and a variety of regional agreements and, in many countries, domestic reforms (Park and Lippoldt, 2008). Specifically, for a broad sample of countries, the present paper assesses empirically the relationship between the reform of patent protection rights since 1990 and the evolution of selected indicators for energy efficiency and innovation. Controlling for other factors, it considers whether the strengthening of patent rights was associated with technological achievement that may have influenced the energy intensity of economies around the world and the prevalence of energy production.

Technological achievement includes such dimensions as innovation, diffusion of innovation and technological adaptive capacity (World Bank, 2008). It is concerned not only with availability of technologies, but also institutions to develop and apply new technologies. Understanding the relationship of patent strengthening to technological achievement and, in turn, energy intensity and production matters because of the central role that energy plays in the economic and environmental situation of all nations. Moreover, it is reasonable to ask this question with respect to patent policy, since patents are by definition related to technological innovation and thus may be a factor capable of influencing technology with respect to energy efficiency. [5, 6]

4. E.g., see the discussion in United Nations (2011).

5. The conditions for issuing a patent require that the innovation be useful and novel, and that it embody an inventive step (i.e., it is non-obvious). For a more complete description, see WIPO (2004), *WIPO Intellectual Property Handbook: Policy, Law and Use*, chapter 2.

6. Despite the wave of international reforms in recent decades concerning patent rights, including establishment of minimum global standards of protection under the WTO TRIPS Agreement, there remains a substantial degree of variation in patent regimes. The various international accords governing IPRs permit some flexibility across a number of dimensions of patent protection, so there is room for use of patent policy as a lever for promotion of technological innovation and diffusion. E.g., the TRIPS Agreement provides for flexibility in the establishment of patent protection more stringent than the TRIPS minimum standards.

The paper is structured as follows. It begins with a statement on context, motivation and – briefly – perspectives from relevant literature, followed by an overview of the analytical approach and data employed. The results are then presented. A short conclusion highlights implications of the findings and provides an indication of potentially fertile areas for further research.

CONTEXT, MOTIVATION AND LITERATURE

Chart 1 provides an overview of selected world energy trends for the main study period covered by this article. The chart highlights improvements in certain indicators of energy efficiency, namely the energy required to produce a unit of GDP or volumes of carbon dioxide generated per unit of GDP. In addition, the chart highlights contrasting experience during the 1990s and 2000s with respect to energy production and consumption. During the 1990s oil prices moderated, as did overall per capita energy consumption. At the same time, alternative and nuclear energy grew to account for a larger portion of overall energy production. However, in the following decade, per capita energy consumption grew anew accompanied by rising oil prices and declining proportions of energy drawn from alternative and nuclear sources. In other words, despite the positive long-term trends in the two efficiency indicators shown here, overall consumption of energy has shown a renewed tendency to rise. The motivation for the present assessment is based on the economic and environmental importance of these developments and the potential to find evidence for their possible association with patent reform after controlling for other factors.

Chart 2 provides an overview of the evolution of the stringency of patent protection during the same period. It does so for a broad sample of countries around the world, grouped by income level. The chart highlights, in effect, the results of the significant steps undertaken by international community towards the establishment of effective global minimum standards for protection of patent rights, particularly since the entry into force of the WTO TRIPS Agreement in 1995.[7] Moreover, many countries have undertaken further reforms in the context of regional or bilateral accords, or unilaterally. Nonetheless, the chart also highlights continued variation in patent protection across countries, both due to flexibility permitted under the emerging

7. Although the TRIPS Agreement was a major factor in strengthening IPR rights around the world during the 1990s, it was not the only one. Others include, for example, increased numbers of ratifications of agreements administered by the World Intellectual Property Organisation, increased numbers of regional trade agreements incorporating IPR provisions, and unilateral (domestic) IPR policy reform.

IPR framework and shortfalls in the implementation of the system. [8] As can be seen, there has been a positive long-term evolution of the average index scores for developed and developing countries, as well as a persistent gap between the levels of protection for patent rights across these three groups of countries. Thus, the chart provides an illustration of one dimension of the international strengthening of patent protection and the remaining diversity in this protection (see Park, 2008, and Park and Lippoldt, 2008).

The literature on intellectual property reform has highlighted the importance of empirical approaches in analyses of the strengthening of patent protection. As Maskus (2000) and others have noted, it is not clear *a priori* whether enhanced protection of innovation via strengthening of patent rights will have a positive or negative influence on specific innovations and their diffusion.

On the one hand, the strengthening of provisions for market exclusivity to be accorded to patent holders may offer them the prospect of increased financial (or other [9]) returns and thereby provide better incentives for innovation and technology diffusion. This may be important for example in developing countries, which may be seeking to catch up via technology transfer from abroad and which may need to reassure foreign rights holders of recourse in the event their innovations are abused. In other words, an appropriate degree of protection for patent rights can contribute to economic development and growth by helping to clarify ownership rights and by providing rights holders with a means to obtain benefits from their innovations; in turn, this establishes an incentive for innovation and diffusion of innovation (Maskus, 2000). Consequently, patent reform may have market expansion effects.

On the other hand, Maskus (2000) and others have pointed to the potential for patent reform to drive market power effects, whereby innovators granted reinforced market exclusivity could demand high prices for their innovations and unduly constrain access to their innovations. If this were to occur, technology diffusion could be slowed. Barton (2007) has highlighted the manner in which reinforced IPRs may induce limitations in diffusion of innovation and market failures related to imperfect information and high transaction costs (e.g., with respect to negotiating and licensing access to

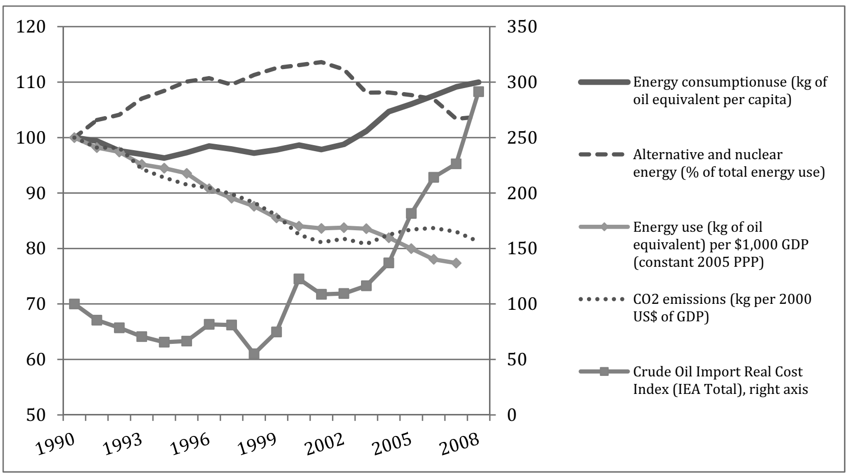
8. Based on objective criteria for scoring the relevant laws on the books, the Patent Rights Index provides an indication from 0 (low) to 5 (high) for the strength of patent rights in each country. For details on the construction of the index see Park (2008).

9. Non-financial returns may also play a role in patenting, such as benefits for career development and social status or through protection of an innovation for public use, among other motivations.

technologies). In another example, Correa (2005) challenged the legal and economic implications of strengthening IPRs, alleging that the system of international IPR rules is imposing an undue burden on developing countries by raising the cost of intellectual content in products they are acquiring.

Thus, the influence of patent reform on technological achievement can in principle have positive and negative effects and the net effect may be difficult to determine in advance. Consequently, this paper takes an empirical approach to assess the impacts of patent reform.

Chart 1 – Selected World Energy Indices, 1990 – 2005 (1990=100)



Source: International Energy Agency, 2011 (obtained on-line via World Bank, WDI, and OECD, iLibrary).

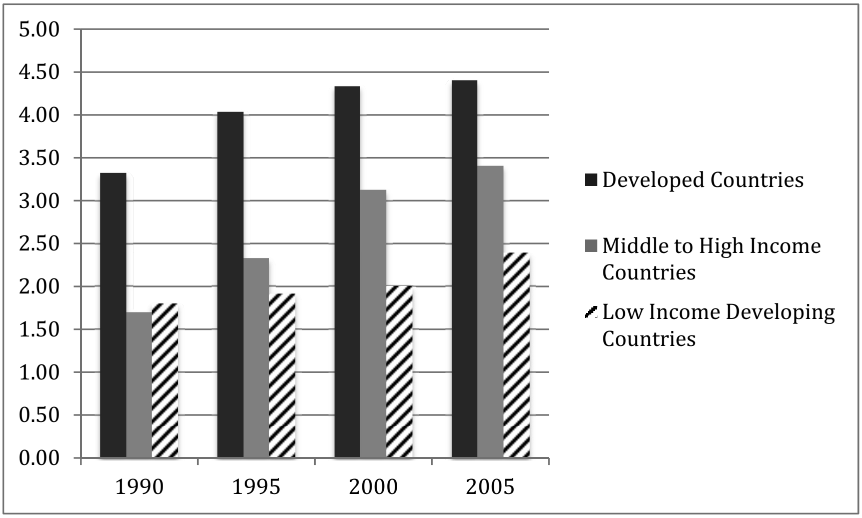
The theoretical and legal literature on patents and the specific case of energy-related technology contains varied assessments that sometimes diverge in their conclusions. A number of scholars have expressed concerns that the increased stringency of protection for intellectual property rights in recent decades, notably with respect to patent rights, may impede development or diffusion of energy-related technologies that are important for economic development, sustainability and climate change mitigation. Sovacool (2008), for example, highlights a variety of problems with the US patent system (e.g., alleged use of anti-competitive patent techniques) that can prevent the innovation and diffusion of clean energy technologies. Barton (2007), on the other hand, provides an assessment of intellectual property and access to clean technologies in developing countries. Taking into account market structure and patent status of core elements of the respective means of power generation, he considers the photo-voltaic, bio-mass and wind energy sectors. He notes that in these areas there is considerable competition amongst firms and between alternate energy generation technologies. IPR protection does not appear to interfere with access to the basic technologies and patenting is mostly focused on specific improvements or features. He highlights the possibility that in the context of promoting technology transfer with respect to energy, the more scientifically advanced developing countries may benefit from strengthening IPR protection. In a similar vein, Maskus (2010) notes that with respect to the policy objective of international transfer of climate change-relate technology, there is little evidence of value from placing limitations on use of IPRs. Some adjustments to the international rules governing patent regimes could be made to permit increased differentiation and tailoring to local conditions, but – more importantly – improved approaches to climate change policy demand broader policy strategies such as establishment of appropriate pricing for carbon-based energy resources and sound investment environments.

Turning to the empirical literature on IPR reform and technological development, the emerging tendency is relatively positive. IPR reform in recent decades appears to be broadly consistent with a story whereby steps to address significant shortfalls in protection tended to benefit the reforming countries. Changes in IPR protection have been shown to be associated with change in general indicators for innovation, technology transfer, trade and foreign direct investment (e.g., Park, Lippoldt, 2008; Cavazos *et al.*, 2010; Branstetter *et al.*, 2006). Where positive steps are taken, such developments can facilitate the gradual accumulation of knowledge capital in firms, sectors and economies. [10]

Cavazos and Lippoldt (2011) considered empirically the relationship between change in the protection of IPRs between 1990 and 2000 and the evolution of technological achievement, as well as the relationship of such achievement to change in labour productivity. They note the potential influence of IPRs on the ability of innovators (and subsequent rights holders) to appropriate benefits from their innovations. They viewed this as potentially affecting economic incentives for the application of improved technologies in the economy (e.g., from domestic innovation and technology transfer from abroad, including via trade and foreign direct investment), with potential implications for productivity and, ultimately, comparative advantage. Their core assessment proceeded via regression analysis using a two-stage approach and national level data. The results pointed to a positive and statistically

10. For a detailed explanation about knowledge capital, see Romer (1986) and Grossman and Helpman (1990a, 1990b).

Chart 2 – Index of Patent Rights Based on Laws on the Books (0 = weak, 5 = Strong)



Notes:
1. Country coverage -- *Developed Countries*: Australia, Austria, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Malta, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, United Kingdom, United States. *Middle and High Income Countries*: Algeria, Argentina, Bolivia, Botswana, Brazil, Cameroon, Chile, China, Colombia, Congo, Costa Rica, Egypt, Ghana, Honduras, Hong Kong-China, India, Iran, Jordan, Kenya, Korea, Malaysia, Mexico, Morocco, Pakistan, Panama, Paraguay, Philippines, Singapore, South Africa, Sri Lanka, Syria, Thailand, Trinidad and Tobago, Tunisia, Turkey, Uruguay, Venezuela. *Low Income Countries*: Bangladesh, Congo (Democratic Republic), Nepal, Senegal, Sudan, Togo and Zambia.
2. The chart presents the average score for the Patent Rights Index for OECD and developing countries. Using objective criteria, the Patent Rights Index scores the strength of patent rights based on laws on the books. Scores can range from 0 to 5.
Source: Park and Lippoldt (2008)

significant relationship between indicators for protection of patent and trademark rights and technological achievement (the coefficient for copyrights was not statistically significant). The relationship between such technological achievement and labour productivity was positive and significant in certain specifications.

In sum, the theoretical and legal literature reflects some divergence in views with respect to the relationship of IPR protection to economic performance. This highlights the importance of empirical assessment of policy reforms. For the period from 1990 to 2005, a time of substantial IPR reform, the empirical literature cited above points to a tendency for IPR reform – including patent reform – to be associated with positive technological developments. For a broad sample of developed countries, this progress was also positively associated with improvements in labour productivity. Taken together with the observed progress in energy efficiency indicators presented in Chart 1, such findings can be seen as supporting a hypothesis that patent reform during the same period may have influenced technological innovation and its diffusion such that energy efficiency tended to improve in association with the patent reform, controlling for other factors. The next section of the paper will consider this possibility.

ANALYTICAL APPROACH AND DATA

The analytical approach employed in this paper is empirical, based on a set of regression equations designed to test the relationship of the strength of patent rights to key developments in technological progress and energy efficiency, controlling for other factors. [11] The analysis proceeds first to establish the relationship of patent reform to economy-wide technological achievement. The analysis is similar to the first stage employed in Cavazos and Lippoldt (2011), but takes into account the present sample of countries. It then turns to consider the relationship of such technological achievement to energy efficiency. The next exercise considers more directly the relationship of patent reform to change in energy efficiency. In a similar manner, the analysis then considers the relationship of patent reform to environmental performance and intensity of alternative technology energy supply (i.e., energy sources not driven by fossil fuel). Finally, the paper considers the relationship of strengthened patent protection to intensity of alternative energy sources in total energy supply.

Across the various analyses, a number of control variables were included in order to better isolate the effects of patent protection or technological achievement. In each phase of the analysis, the selection of control variables was adjusted to take into account probable concomitant influences on the dependent variable. These menu of controls included GDP per capita, FDI (aggregate or per capita inward stock), service sector share in GDP, the government budget for research and development (R&D), the mean weighted tariff on manufactured products, and price or cost of energy (imported oil). The regression runs were conducted with country fixed effects. The regression analysis was implemented using an ordinary least squares (OLS) approach and, with the exception of regression runs conducted to consider

11. The regression analyses were implemented using the E-Views and Stat-plus statistical packages.

first differences, the variables were introduced as natural logarithms. [12] The logarithmic transformation was performed to obtain elasticities that indicate the sensitivity of changes in the dependent when the explanatory variables change by one percent. Moreover, the monotonic transformation allows us to comply with the OLS assumptions in which the regression error term is distributed normally.

The target time period for the assessment was 1990 to 2005, a period of substantial reform of patent regimes. The Patent Rights Index is available in 5 yearly increments, meaning that for assessments covering this full time period, four observations were available. The sample was structured as a balanced panel and in each instance countries were only included where full data were available for the covered time period (i.e., for the dependent variables and for the controls). In the analyses involving the Technology Achievement Index, the time frame included just two observations, 1990 and 2000. In the analysis involving first differences, the period was expanded to include five-yearly observations from 1985 to 2005, thereby leaving 4 observations for each country included in the regression runs.

The hypothesis underlying this analysis is that in view of initial weaknesses in patent protection (relative to current standards) for the countries concerned as of 1990, the strengthening of patent protection during the subsequent decade would be associated with stronger incentives to innovate and diffuse innovation, and consequently more efficient utilisation of energy *ceteris paribus*. While the empirical literature related to energy efficiency has pointed out a relationship between energy use and development we do not present structural models in this paper. By employing OLS, the parameter estimates obtained from the regression models represent correlations between the variables of interest and should be interpreted as such. There is no attempt to uncover a causal relationship with the econometric specifications presented.

The regression models as estimated are presented below:

(1) $\ln TAI_{it} = \alpha_1 + \beta_1 \ln X_{it} + \eta_1 \ln T_{it} + \eta_2 \ln U_{it} + \Theta_i + \varepsilon_{it}$

(2) $\ln E_{it} = \alpha_1 + \beta_1 \ln TAI_{it} + \eta_1 \ln U_{it} + \eta_2 \ln V_{it} + \eta_3 \,LN\, W_{it} + \Theta_i + \varepsilon_{it}$

(3*) $\ln E_{it} = \alpha_1 + \beta_1 \ln X_{it} + \eta_1 \ln T_{it} + \eta_2 \ln U_{it} + \eta_3 \ln V_{it} + \eta_4 \ln R_{it} + \Theta_i + \varepsilon_{it}$

(4) $\ln CO_{2it} = \alpha_1 + \beta_1 \ln X_{it} + \eta_1 \ln T_{it} + \eta_2 \ln U_{it} + \eta_3 \ln V_{it} + \Theta_i + \varepsilon_{it}$

12. In the case of first differences assessments, in a number of cases there was no change and with a change of zero it was not possible to determine the natural logarithm. Therefore, in order to maximise the number of observations, natural logarithms were not employed.

(5) $\ln PA_{it} = \alpha_1 + \beta_1 \ln X_{it} + \eta_1 \ln T_{it} + \eta_2 \ln U_{it} + \eta_3 \ln V_{it} + \eta_4 \ln R_{it} + \Theta_i + \varepsilon_{it}$

(6) $\ln A_{it} = \alpha_1 + \beta_1 \ln X_{it} + \eta_1 \ln T_{it} + \eta_2 \ln U_{it} + \eta_3 \ln V_{it} + \Theta_i + \varepsilon_{it}$

(* In certain runs of equation 3 estimated using first differences, variables were not introduced as natural logarithms.)

Where

TAI=Technology Achievement Index (discussed below)

E = Energy Intensity, an indicator of GDP produced per unit of energy

CO_2= CO_2 emissions per unit of GDP

PA= Patent Co-operation Treaty patent applications tagged in the International Patent Classification as being related to energy production and efficiency technologies

A= Alternative and nuclear energy as a share of total energy use

i = *country*

t = *year* (1990, 1995, 2000, 2005)

α_1 = *constant.*

β_1 = coefficients for the independent variables of prime interest in the present analysis, namely those concerning protection of patent rights (equations 1, 3, 4, 5 and 6) and technological achievement (equation 2), respectively.

X = a measure of the strength of *patent rights* (Park *et al* index for patent protection),

R = a control variable, namely, government research and development budget

T = a control variable, namely GDP per capita

U = a control variable, namely inward FDI

V= a control variable, namely share of the service sector in GDP

W=a control variable, namely mean weighted tariff (manufactured products)

Θ = *country fixed effects*

ε = the *error term.*

ln denotes the *natural logarithm.*

The data for the analysis were drawn from several sources:

– The data on energy efficiency (units of energy per unit of GDP), energy consumption per capita, CO2 per unit of GDP, crude oil import cost and prices, and alternate plus nuclear energy share in total energy supply, were drawn from International Energy Agency data series, as of July 2011 (obtained online via World Bank, *World Development Indicators*, and OECD, *iLibrary*).

– The *Technology Achievement Index* (TAI) was presented in the World Bank's *Global Economic Prospects, 2008* (World Bank, 2008). It is based on a broad range of indicators concerning innovation, technological adaptive capacity, channels of technology diffusion, diffusion of recent technologies and penetration of old technologies. [13] All together, there are 34 separate variables underlying the TAI. Aggregation is accomplished using weights calculated by principle components analysis.

– The *Patent Rights Index* measures the strength of patent protection based on laws on the books assessed using objective criteria concerning such dimensions as membership in relevant international treaties, statutory laws and legislation, and case law (for details see Park, 2008, and Park and Lippoldt, 2008).

– The selection of patent rights and technological achievement as variables of interest lies in their potential to incentivise and enable innovation and diffusion of innovation, including potentially with respect to energy production, distribution and use. Moreover, the availability of technology is a key contributor to productivity, and differences in productivity are especially important in that they explain the large variation in incomes across countries (Hall, Jones, 1999; Keller, 2009). Internationally, patent protection may contribute to an environment conducive to economically important technology transfer from abroad. Keller (2009) finds that in a majority of countries, foreign sources of technology are estimated to account for up to 90% of domestic productivity growth (Keller, 2009). Similar mechanisms may operate in the specific case of patents and energy-related technologies.

– Control variables for GDP and FDI were drawn from the dataset underlying Park and Lippoldt (2008). GDP was included as a control for level of development, while FDI was included as a control for openness and the extent of availability of this important channel for international technology transfer. [14]

– Data for mean applied tariffs for manufactured goods were drawn from the World Bank's World Integrated Trade Solution system. [15] These were

13. The data from the TAI for the present analysis cover two time periods, 1990 and 2000.

14. Maskus (2004) points to five main market mediated channels for such technology transfer including trade, FDI (foreign direct investment), licensing, joint ventures and cross boarder movement of personnel. Park and Lippoldt (2005, 2008) have considered the first four of these channels and found a significant association of strengthened patent rights to these flows into developing countries. The association is particularly strong for FDI.

15. The tariff data are estimated based on data from United Nations Conference on Trade and Development's Trade Analysis and Information System (TRAINS) database and the World Trade Organization's (WTO) Integrated Data Base (IDB) and Consolidated Tariff Schedules (CTS) database.

included as a further control for openness and another channel for technology transfer.

– Data on the share of services in the economy were drawn from World Bank national accounts data, and OECD National Accounts data files, as reported via the World Bank WDI on-line data site. This indicator was included as a control for the structural aspects of energy demand; the services sector is generally much less energy intensive than other sectors in terms of the value of output per unit of energy consumed. [16]

– IEA data on Government R&D budgets were drawn from the OECD, *iLibrary*, and were included as a control on innovation processes not directly driven by market incentives.

– All data were accessed during July 2011.

– The combined dataset from these sources covered a maximum of 65 countries. Economically, the sample included countries from three groupings: developed, middle-to-high income developing and low income developing). Geographically, the sample included countries from each continent. Data availability was the key factor in the selection of individual countries for inclusion in the sample.

RESULTS

The analysis found a very mixed picture with respect to the strengthening of patent rights during the period from 1990 to 2005 for the countries covered by the sample.

Table 1 points to a positive relationship between the strengthening of patent rights and technological achievement, in a manner somewhat similar to the analysis of Cavazos and Lippoldt (2011). For the whole sample and for the developed countries, the results indicate a statistically significant and positive relationship of the patent rights index and technological achievement. For the developing countries, the indicator for patent rights is not statistically significant but the indicator for inward FDI is highly significant, possibly indicating the importance of FDI as a particular channel for technology transfer for this country group.

These positive economy-wide relationships are not echoed in the relationship of technological achievement to energy efficiency as measured in units of GDP produced per unit of energy consumed. As shown in Table 2, GDP per capita appears to be the only statistically significant factor conside-

16. For example, see this study of energy intensity by sector in Australia: http://www.abare.gov.au/interactive/09_ResearchReports/EnergyIntensity/htm/chapter_4.htm

red in this regression run. Controlling for other factors, overall technological achievement does not tend to translate into improved energy efficiency by this measure. [17]

Table 3 considers the direct role that strength of patent rights may play in incentivising innovation and diffusion of innovation with an impact on energy efficiency as measured in units of GDP produced per unit of energy consumed. The results for patent rights as shown in the table run counter to the hypothesised relationship. Other factors appear to have a much stronger influence on energy efficiency by this measure. These include, in particular, GDP per capita and share of services in GDP. [18] The level of development and the structure of the economy matter more than patent rights in this context. Moreover, the sign of the coefficient for patent rights is negative, meaning that the direction of the relationship appears to be associating stronger patent rights with lower GDP per unit of energy used. Shifting to consider first differences yields a similar result, whereby GDP per capita remains a significant influence on change in energy efficiency, but patent rights remain a negative influence albeit no longer statistically significant.

This negative finding is somewhat surprising in that we know from the earlier exercise that patent rights are positively related to technological achievement (Table 1) and from Cavazos and Lippoldt (2011) that this in turn is related to overall labour productivity. There are several possible explanations for these results. First, it may be the aggregate findings mask a relatively strong positive influence of stronger patent rights on sectors of the economy that are more energy intensive (e.g., chemicals). Earlier work by Park and Lippoldt (2005 and 2008) found some evidence of such a relationship. It may be that this structural effect dominates over the efficiency effects of IPR incentivised technological progress with respect to energy.

Second, it is unlikely that the result reflects a market power effect whereby stronger patent rights result in negative developments in energy efficiency. The reason is that even if patent rights constrained follow-on innovation or diffusion of innovation, the result would probably be to limit further *progress* in energy efficiency rather than to deliver a negative evolution in energy efficiency. However, as technological innovation diffuses, relative prices are

17. This finding with respect to the general level of technological achievement is in contrast to references in the literature on the linkages between updating of specific energy technologies and improvements in energy efficiency (e.g., Geller et al, 2006) and in the forward-looking literature on progress in energy technology and mitigation of climate change (e.g., Wilbanks, 2011; Nordhaus, 2011).

18. The controls for FDI inward stock, the price of oil imports and government R&D budget were not significant, where they were included.

modified allowing consumers to adopt new technologies and may create a rebound effect whereby energy consumption increases having a net negative effect on the overall economy.

Finally, the results could be pointing out the physical relationship present in nature. Specifically, to generate output an amount of resources (labour, capital and information), needs to be expended. Therefore, while the energy embedded in GDP is being accounted for in the empirical specifications, the energy embedded in the resources required to generate the output is not. In this case, the amount of energy required to generate the output could be greater and be driving the negative relationship shown in the results (Stern, 2011).

Table 4 considers the potential influence of patent rights strengthening on environmental performance as measured by CO_2 emissions per unit of GDP and innovation as measured by energy-related and environmentally-relevant patent applications. Once again the patent rights indicator has a negative relationship to the hypothesized outcome, in this case being associated with higher CO_2 emissions. This may also be related to the structural effects of patents dominating over the innovation effects with respect to energy. On the other hand, level of development (GDP per capita) and structure of the economy (share of services in GDP) appear to have much stronger influence in contributing to improved outcomes in this measure, with FDI contributing in a significant manner as well. Patent rights are positively associated with energy innovation as measured by corresponding patent applications, but the association is not statistically significant. GDP per capita and the share of services in the economy are much stronger and statistically significant positive influences on this measure.

Table 5 presents an assessment of the influence of patent rights on the share of alternative and nuclear energy in total energy use, controlling for other factors. Here, the influence of patent rights appears to be fairly strong and positive, though not statistically significant in the case of developed countries. Once again, level of development appears to be a strong influence, with statistically significant coefficients across the board. Inward FDI appears to have a negative influence, but here again there may be a sectoral dimension whereby these investments are concentrated in sectors and countries where traditional fossil fuels drive energy production.

Table 1 – Relationship of Patent Rights to Technological Achievement, 1990-2000

	Technological Achievement Index		
Patent Rights Index	0.3643**	0.8541**	0.4283***
	(0.1433)	(0.3652)	(0.1074)
GDP per capita	0.3475	-0.4727	0.3539
	(0.3886)	(0.6049)	(0.3501)
FDI Inward Stock (Real USD)	0.1767**	0.5042***	0.0183
	(0.0867)	(0.1252)	(0.0753)
Intercept	-2.9895**	-1.4729	-2.366**
	(1.1488)	(2.3456)	(1.0253)
Country Fixed Effects	Yes	Yes	Yes
N	84	34	50
Country Cases	42	17	25
Adjusted R2	0.6620	0.7333	0.7259
Country Group	All	Developed	Developing

Notes:

1) Here and subsequent tables, statistical significance is shown as follows:
*** p<0.01, ** p<0.05, * p<0.1.

2) Country Coverage:
Developed: Australia, Austria, Canada, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain and Sweden.
Developing: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Egypt, India, Iran, Kenya, Malaysia, Mexico, Pakistan, Panama, Paraguay, Philippines, Senegal, Singapore, Sudan, Syria, Thailand, Togo, Trinidad and Tobago, Tunisia and Turkey

3) All variables entered were entered in the regression as natural logarithms.

Source: Authors' calculations.

Table 2 – Relationship of Technological Achievement to Energy Efficiency, 1990-2000

GDP Per Unit of Energy Used (constant 2005 PPP USD per kg of oil equivalent, IEA indicator: EG.GDP.PUSE.KO.PP.KD)	
Method:	OLS, variables entered as LN
Technological Achievement Index	-0.0719 (0.0765)
GDP per capita	0.4364** (0.1802)
FDI Inward Stock per capita	0.0133 (0.0606)
Services as %GDP	0.1515 (0.3032)
Mean weighted tariff (manufactured products)	0.0017 (0.0014)
Intercept	-0.9497 (0.8998)
Country Fixed Effects	Yes
N	56
Country Cases	28
Adjusted R2	0.9156

Notes:

1) *Country coverage*: Argentina, Australia, Austria, Bolivia, Brazil, Colombia, Finland, France, Germany, Greece, India, Ireland, Italy, Japan, Malaysia, Mexico, Netherlands, New Zealand, Paraguay, Philippines, Portugal, Spain, Sweden, Thailand, Trinidad and Tobago, Tunisia and Turkey.

2) To test the robustness of these results, the regression was rerun substituting an indicator for level of legal effectiveness in place of GDP per capita (Index of Legal Effectiveness, Source: Economic Freedom Network, 2006 Dataset: http://www.freetheworld.com/release.html). The results did not materially alter the general results (i.e., signs, significance or order of magnitude of the coefficients).

Source: Authors' calculations.

Table 3 – Energy Efficiency of GDP Production

	GDP Per Unit of Energy Used (constant 2005 PPP USD per kg of oil equivalent, IEA indicator: EG.GDP.PUSE.KO.PP.KD)				
Method=>	OLS, variables entered as LN, 1990-2005				OLS First Differences, variables not LN, 1985-2005
Patent Rights Index	-0.0901***	-0.0861***	-0.3305***		-0.0968
	(0.0290)	(0.0259)	(0.0702)		(-0.0824)
GDP per capita	0.4840***	0.4918***	0.7194***	0.6185***	0.0002***
	(0.0.519)	(0.0454)	(0.1616)	(0.1706)	(0.00005)
FDI Inward Stock (Real USD)	0.0041			-0.0039	0.0000002
			0.0447		
	(0.0131)		(0.0292)	(0.0346)	(0.0000009)
Services as a % GDP	0.1644**	0.1636**	-0.0271	-0.0033	0.0009
	(0.0683)	(0.0681)	(0.2169)	(0.2736)	(0.0080)
Oil Import Price Per Barrel			-0.0315 (-0.0355)		
Government Energy R&D Budget				0.0384 (0.0233)	
Intercept	-1.2372***	-1.2431***	-2.5168***	-2.2240**	0.0209
	(0.1468)	(0.1453)	(0.7533)	(0.8956)	(0.2635)
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes
N	260	260	64	64	228
Country Cases	65	65	16	16	57
Adjusted R2	0.9676	0.9678	0.9664	0.9525	0.2186
Country Group	All	All	Selected Developed[1]	Selected Developed[1]	All (except [2])

Notes: Country Coverage - Algeria[2], Argentina, Australia, Austria[1], Bangladesh, Bolivia, Botswana[2], Brazil, Cameroon, Canada[1], Chile, China, Colombia, Congo, Congo (Zaire), Costa Rica, Denmark[1], Egypt, Finland[1], France[1], Germany[1], Ghana, Greece, Honduras, Hong Kong-China[2], Iceland, India, Iran, Ireland, Italy[1], Japan[1], Jordan[2], Kenya, Korea, Malaysia, Malta[2], Mexico, Morocco, Nepal, Netherlands[1], New Zealand[1], Norway[1], Pakistan, Panama, Paraguay, Philippines, Portugal[1], Senegal[2], Singapore[2], South Africa, Spain[1], Sri Lanka, Sudan, Sweden[1], Syria, Thailand, Togo, Trinidad & Tobago[2], Tunisia, Turkey, United Kingdom[1], United States[1], Uruguay, Venezuela and Zambia. Source: Authors' calculations.

Table 4 – Patent Rights and Environmental Performance, 1990 - 2005

	CO2 Emissions Per Unit of GDP[1]	**Patent Applications Tagged in IPC Energy Production and Efficiency Technology Categories**[2]
Patent Rights Index	0.1757***	1.6242
	(0.0375)	(1.0662)
GDP per capita	-0.3115***	2.8646*
	(0.0713)	(1.5853)
FDI Inward Stock (Real USD)	-0.0546***	0.4665
	(0.0203)	(0.3216)
Services as a % GDP	-0.4465***	5.5188**
	(0.1302)	(2.4907)
Government Energy R&D Budget		0.3607
		(0.2151)
Intercept	2.0685***	-25.5759
	(0.3140)	(7.7292)
Country Fixed Effects	Yes	Yes
N	188	64
Country Cases	47	16
Adjusted R2	0.9806	0.9080
Country Group	Developed and Middle-to-High Income Developing	Developed (subject to data availability)[3]

Notes:

1) This ratio is expressed in kilogrammes of CO_2 per 2000 US dollar. IEA has computed this indicator using the Sectoral Approach CO_2 emissions and the GDP calculated using exchange rates.

2) This includes applications under the Patent Co-operation Treaty tagged under the International Patent Classification as falling under the following environmentally-relevant patent classes: Energy generation from renewable and non-fossil sources, Combustion technologies with mitigation potential (e.g. using fossil fuels, biomass, waste, etc.), Technologies with potential or indirect contribution to emissions mitigation, Emissions abatement and fuel efficiency in transportation, and Energy efficiency in buildings and lighting

3) *Country Coverage*: Algeria, Argentina, Australia, Austria[3], Brazil, Canada[3], Chile, China, Colombia, Costa Rica, Denmark[3], Egypt, Finland[3], France[3], Germany[3], Greece, Hong Kong-China, India, Iran, Ireland, Italy[3], Japan[3], Jordan, Kenya, Korea, Malaysia, Mexico, Morocco, Netherlands[3], New Zealand[3], Norway[3], Pakistan, Panama, Philippines, Portugal[3], Singapore, South Africa, Spain[3], Sweden[3], Thailand, Trinidad & Tobago, Tunisia, Turkey, United Kingdom[3], United States[3], Uruguay and Venezuela.

Source: Authors' calculations.

Table 5 – Factors Associated with Alternative Energy Intensity, 1990-2005

	Alternative and nuclear energy[1] (% of total energy use)		
Patent Rights Index	0.4649*	0.1324	0.6708*
	(0.2670)	(0.2826)	(0.3807)
GDP per capita	0.4145***	0.8864***	0.2872**
	(0.0892)	(0.1205)	(0.1151)
FDI Inward Stock (Real USD)	-0.2426***	-0.3711***	-0.1924**
	(0.0624)	(0.0789)	(0.0799)
Services as a % GDP	-0.9195	1.3225	1.0258
	(0.6324)	(1.2108)	(0.7610)
Intercept	2.1971**	-3.2972	2.4764**
	(1.0291)	(2.2546)	(1.2332)
Country Fixed Effects	Yes	Yes	Yes
N	192	68	124
Country Count	48	17	31
Adjusted R2	0.6746	0.9118	0.5407
Country Group	All	Developed[2]	Developing

Notes:

1) Alternative and nuclear energy is non-carbohydrate energy that does not produce carbon dioxide when generated. It includes hydropower, nuclear, geothermal and solar power, among others.

2) Country Coverage: Argentina, Australia[2], Austria[2], Bangladesh, Bolivia, Brazil, Cameroon, Canada[2], Chile, China, Colombia, Congo (Rep.), Congo (Dem Rep.), Egypt, Finland[2], France[2], Germany[2], Ghana, Greece[2], Honduras, Iceland[2], India, Iran, Japan[2], Kenya, Korea, Malaysia, Mexico, Morocco, Nepal, Netherlands[2], New Zealand[2], Norway[2], Pakistan, Portugal[2], South Africa, Spain[2], Sri Lanka, Sudan, Sweden[2], Syria, Tunisia, Turkey, United Kingdom[2], United States[2], Uruguay, Venezuela and Zambia.

Source: Authors' calculations.

CONCLUSIONS

For a sample of developed and developing economies during the period from 1990 to 2005, this paper has considered the relationship of the protection of patent rights to indicators of energy efficiency and innovation. The result is a mixed picture, whereby the strengthening of patent rights appears to be one factor driving overall technological achievement, as well as some innovation related aspects of energy production and utilisation. However, based on the present dataset, there does not appear to be a tendency for a positive relationship to energy efficiency. Unfortunately, the present dataset does not permit a more detailed sectoral analysis. This issue merits further exploration as new or alternative datasets become available. The present empirical analysis was conducted for a particular set of countries, during a specific period of time, with patent protection being strengthened over a particular range of stringency. Thus, any generalisation should be approached with caution.

However, the results in this paper do indicate the potential importance of further work in this area. The relationship between innovation and energy efficiency is not as straightforward as it might seem. There are a number of issues suggesting effects going in opposite directions and the final outcome has to be evaluated from an empirical point of view. New products, specifically designed to be more efficient, may shift relative prices and change signals to both consumers and producers, thereby affecting their behaviour. The gains from reassigning resources to more productive uses could be offset by demand effects whereby a considerable growth in use of an innovation could increase demand for resources. In addition, heterogeneity related to resource intensity required by industry and consumer preferences could be usefully studied in order to determine adoption time of new products. Therefore, while this paper might be viewed as contributing a marginal step towards establishing the direction and magnitude of strengthening of patent rights on energy efficiency, it also points to areas for further exploration.[19]

19. For example, one cannot extrapolate these results to assume that strengthening of patent protection beyond the range considered here would yield further positive or negative results of similar magnitudes.

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