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Key Drivers of PPPs in Electricity Generation in Developing Countries

Cross-Country Evidence of Switching between PPP Investment in Fossil Fuel and Renewable-Based Generation

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Abstract

This paper presents new global evidence on the key determinants of public-private partnership investment in electricity generated by fossil fuels and renewable energy based on a panel data analysis for 105 developing countries over a period of 16 years from 1993 to 2008. It aims to identify the key factors affecting private investors' decision to enter electricity generation, through probit analysis, and the amount of investment sunk in this market segment, based on Heckman's sample selection analysis. The paper shows some evidence of switching from investment in fossil fuels to investment in hydro and renewables and within fossil fuels from oil to natural gas. An interesting result of the econometric analysis is that the likelihood of switching toward renewable investment is driven by long-run environmental factors, such as the increases in the price of oil and the introduction of the Kyoto protocol. Another interesting result is that sector governance support schemes, provided by feed-in tariffs, affect only the entry in renewable based electricity generation and have no impact in reducing the amount of investment in fossil fuel based generation. Economy-wide governance factors, including control for corruption and degree of political competition, are factored in by private investors only in the initial stage of the game when the decision to enter into the generation market is taken and not the amount of investment. This confirms that the first generations of independent power producers have been developed on the basis of long-term power purchase agreements guaranteeing a fixed rate of return, through take-or-pay clauses and/or government guarantees.

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Key drivers of PPPs in electricity generation in developing countries*

Cross-country evidence of switching between PPP investment in fossil fuel and renewable-based generation

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Energy and Mining (EM) Sector Board

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1. Introduction

In 2008, according to UNEP (2010) for the first time, renewable energy including large hydro attracted globally more power sector investment than fossil fuel based technologies (UNEP, 2010). According to the IEA, the New Policies scenario, renewable sources of energy are expected to triple by 2035 (IEA, 2010). This growth followed from an alignment of global factors: rapid growth in energy demand from emerging economies such as China and India; increased competition for energy resources; geopolitical tension and energy security concerns; rising oil and gas prices; as well as the entry into force of the Kyoto Protocol in early 2005, and the rise of climate change up the political agenda more generally. Have the same trends occurred in developing countries?

Political concerns about fossil fuel energy security re-emerged in many countries. The Ukrainian gas supply crisis of 2006 and 2009 resulted in reduced supplies of Russian gas into the European Union due to a dispute between Ukraine and Russia, which saw the reduction of supplies to the gas transit country Ukraine leading to reduced onward flows of Russian gas to the EU gas market (Noel, 2009). This reduced the willingness of politicians to allow increases in the dependence of the power sector. In the UK for instance the energy regulator, conducted a significant review project into UK energy security (Project Discovery), which examined the need to encourage more LNG terminals, gas storage facilities and alternative sources of power and heat (see Ofgem, 2010).

More generally concerns about 'peak oil' heightened – the idea that the global output of oil and gas cannot continue to increase in line with growing demand (driven by Chinese and Indian industrialization) without substantial price rises (the factual basis for which is well discussed in Mills, 2008).[1] Peak oil is the point in time when the maximum rate of global petroleum extraction is reached and is applicable to the sum of a nation's domestic production rate, and is similarly applied to the global rate of petroleum production. This peak, also known as Hubbert's peak, was correctly predicted by Hubbert (1956).

A vast literature addresses whether global oil production has peaked or will soon peak; what consequences that could have for fossil fuel dependent societies; and what should be done about it. Most of the earlier literature was not based on economic insights. In his review of the peak oil literature, Porter (2006) states that "the standard Hotelling model offers little insight into the oil market." Notable exceptions are Pindyck (1978), who argued that there is an inverse relationship between marginal extraction costs and reserves, and Slade (1982), who assumes that costs decrease exogenously over time due to technological change.[2] In the economic models reviewed by Holland (2008), increasing demand, improvements in technology, additional reserves, and new site development tend to increase production while scarcity tends to decrease production.

The weaker and slower the responsiveness of policy makers to the challenges posed by climate change, the greater the risk of oil scarcity and the increase in crude oil prices. IEA (2010) projects

[1] Peak oil" refers to the peak in U.S. crude oil production in 1970. Hubbert predicted in 1974 that peak oil would occur in 1995. However, in the late 1970s and early 1980s, global oil consumption actually dropped (due to the shift to electricity and natural gas for heating, and other factors), then rebounded to a lower level of growth in the mid 1980s.

[2] However, the empirical evidence of a negative relationship between costs and reserves is not conclusive. Livernois & Uhler (1987) present empirical evidence arguing that aggregate reserves and cost are not negatively correlated and in fact are positively correlated.

the price needed to balance oil demand under three different scenarios. Assuming that the rate of increase in production capacity and in demand is relatively insensitive to price, the prices needed to balance oil supply and demand is almost entirely dependent on policies. The peak is almost entirely determined by policies. In the New Policies Scenario the average IEA crude oil import reaches US$ 113 per barrel in real terms in 2035, which compares very favorably to the current policies scenario where the crude oil price reaches US$ 135 per barrel in 2025.

This paper aims at addressing the questions below.

Has the introduction of the Kyoto protocol in combination with higher fossil fuel prices enhanced private investment in renewables? Has the degree of switching of private investment from fossil fuel to renewable based generation be enhanced by price oil shocks or by the introduction of support schemes provided to renewables? Have other governance factors played a role in enhancing private investment in renewable based generation and driving private investment in fossil fuel based generation down?

Within fossil fuels, has there been switching from private investment in oil and coal to natural gas? According to the IEA, fossil fuels will remain the dominant energy sources in 2035 under all policy scenarios. Within fossil fuels, natural gas is the only one that is expected to grow under all scenarios.

To what extent have private investors shared the risks with the public sector? The first generation of independent power producers (IPPs) for fossil fuel based generation were developed on the basis of long term power purchase agreements (PPAs) and guaranteeing a fixed rate of return, through take-or-pay clauses and/or government guarantees. Is this continuing to be the case? Have the current power sector reforms and unbundling effort separating transmission from generation increased the creditworthiness of power purchasers, leading to the reduction of demands from the private investors for very favorable and long-term PPAs?

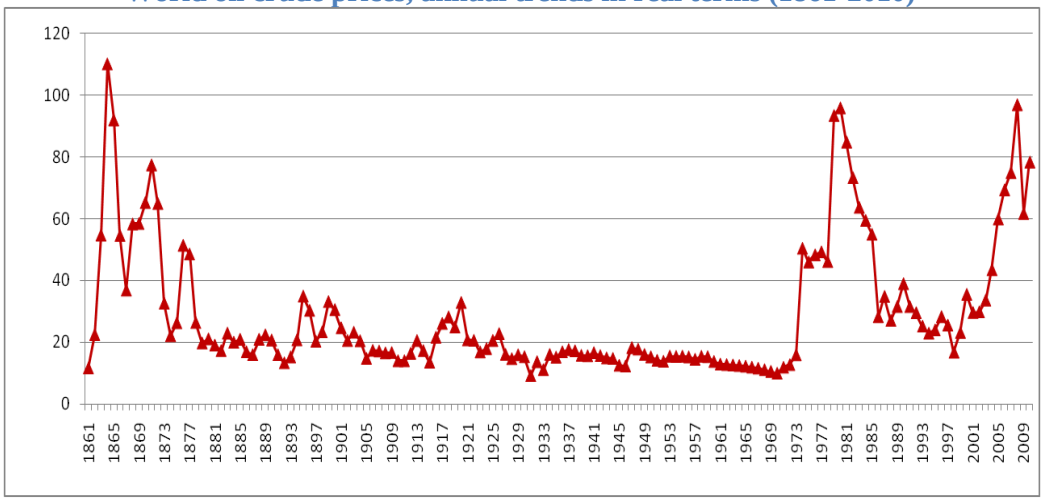
The rest of the paper is organized as follows. Section 2 will highlight the trends in oil price. Section 3 will draw the key objectives of the papers and the data that is used to carry out the analysis. Section 4 introduces the theoretical hypotheses that will guide the empirical analysis, whose results are reported in section 5. Section 6 concludes and presents new directions for future research.

2. Trends in crude oil prices

Boom/bust price shocks have been a feature of oil history ever since Edwin Drake drilled his first well in Pennsylvania (PA) in 1859. In those days, the products of crude oil competed mainly against ethanol, oil from lard or whale and turpentine from wood, for lighting, heating and as a lubricant. The run-up to the US Civil War had disrupted whaling, and whale oil used in lamps and stoves, was in short supply. In addition, supplies of turpentine from the South were cut off and the oil's main substitute, ethanol, was heavily taxed. This made crude oil an extremely valuable commodity and brought about a surge in prices and commodity demand more generally (see Fig. 1). Such price increases stimulated a substantial increase in production. By 1861, the Oil Creek commonwealth's wells were producing more than 2 million barrels annually, accounting for half the world's oil production. Later, the price quickly dropped, leading to the closure of many of the initial drilling operations (Derrick's Hand-Book of Petroleum, 1898).

The price shocks after World War II were generally associated with geopolitical events that significantly disrupted global production. The biggest geopolitical event for oil prices was the 1973 OPEC oil embargo, which was imposed on countries that had supported Israel after it had been attacked by Egypt and Syria (Hamilton, 2003). The promise of a negotiated settlement between Israel and Syria was sufficient to convince Arab oil producers to lift the embargo in March 1974. In 1979, the Iranian Revolution resulted in supply disruptions that were then made even worse by the outbreak of the Iran/Iraq War in 1980. Amid massive protests, the Shah of Iran, Mohammad Reza Pahlavi, fled his country in early 1979 and the Ayatollah Khomeini soon became the new leader of Iran. Protests severely disrupted the Iranian oil sector, with production being greatly curtailed and exports suspended. When oil exports were later resumed under the new regime, they were inconsistent and at a lower volume, which pushed prices up. Still, in the 1980s, global oil prices collapsed to US$ 12 per barrel.

Fig. 1
World oil crude prices, annual trends in real terms (1861-2010)



Source: 1861-1944 US Average, 1945-1983 Arabian Light posted at Ras Tanura, 1984-2009 Brent dated.

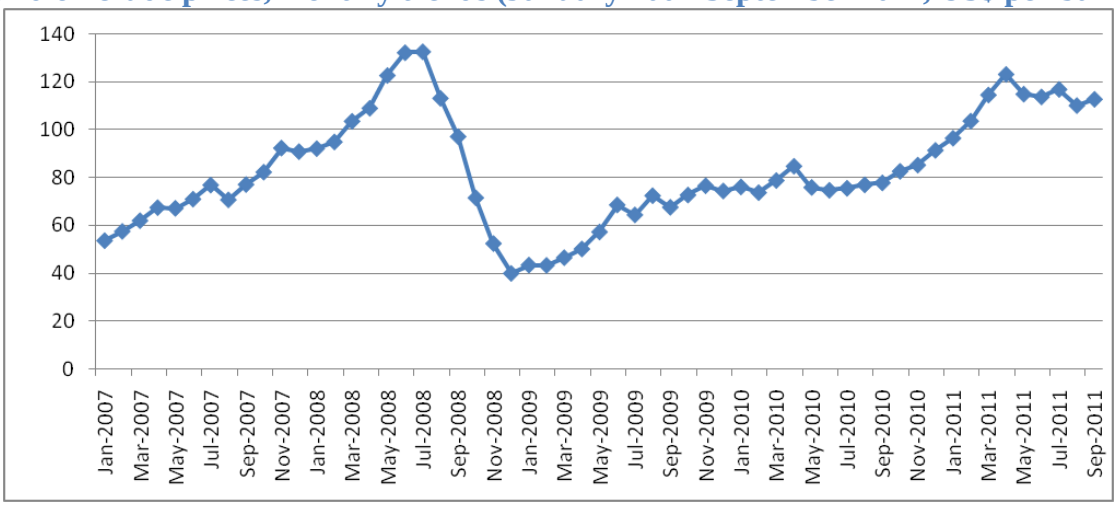
Whereas historical oil price shocks were primarily caused by physical disruptions of supply, the price run-up of 2007-08 was caused by strong demand confronting stagnating world production. China alone increased its consumption by 840,000 barrels a day between 2005 and 2007. With limited

increase in supply, the short run price elasticity of oil demand is small, and a very large price increase was necessary to contain demand (Hamilton, 2009). Other factors, including the return to negative ex post real interest rates in August 2007 and large flows of investment into commodity future markets contributed to introduce a speculative bubble in the price of oil (Kilian and Murphy, 2010).

The uprisings throughout the Middle East are in part responsible for the recent surge in oil prices in 2011. For example, the fighting in Libya has reduced global oil production by about one million barrels per day. On the other hand, members of the Organization of Petroleum Exporting Countries (OPEC) are boosting their output by a similar amount to make up for the shortfall. A new surge in March 2011 brought the world oil crude price close to $120 a barrel (see Fig. 2), though it is still below the July 2008 peak. These prices are comparable in real terms to those that caused the 1973 and 1979 energy crises.

Fig. 2

World oil crude prices, monthly trends (January 2007-September 2011, US$ per barrel)



Source: Brent dated

On the one hand, if the price of oil rises high enough, the use of alternative clean fuels could help control carbon emissions from fossil fuel use. High prices of oil are expected to encourage alternative energy development and energy efficiency. Getting prices more aligned to cost (including negative externalities) is critical as it influences the behavior of both firms and individuals. However, other public-policy interventions are needed as behavioral changes will often require complementary policy initiatives. For instance, the responsiveness of investors in renewable based energy to incentives provided support schemes including feed-in tariffs will also depend on whether transmission lines are built. Inertia in behavior and market failures are such that many energy efficiency measures that might pay for themselves are not taken. Recycling fossil fuel subsidies creates additional fiscal space to permit reduced taxation or subsidization of green public "goods" such as renewable energy (IEA et al., 2010 and Vagliasindi, 2012b)

On the other hand, substantial increases in the price of oil are expected to have negative implications for the world economy.. Throughout the first two quarters of 2008, there were signs that the late 200 recession was made worse by a series of record oil prices. Hamilton noted that nine of the last ten recessions in the United States were preceded by a substantial increase in the price of oil. Engemann *et al.* (2011) find that, for most countries, oil shocks do affect the likelihood of entering

a recession, estimating the turning points together with oil's effect in a Markov-switching model with time-varying transition probabilities.[3] Although the causes were different, the consequences for the US economy of the 2008 recession appear to have been very similar to those observed in earlier episodes, with significant effects on overall consumption spending and purchases of domestic cars in particular. In the absence of those declines, it is unlikely that the period of the 4th quarter of 2007 to the 3rd quarter of 2008 would have been characterized as one of economic recession for the US.

3. Data

This paper presents new global evidence on the key determinants of public-private partnership (**PPP) investment in electricity generated by fossil fuels (including oil, coal, and natural gas) and renewable energy (including hydro, wind, waste and geothermal)** based on a panel data analysis for 105 developing countries including 16 years from 1993 to 2008.

Our study aims to identify the key factors affecting the private investor's decision to enter electricity generation and the amount of investment sunk in this market segment.

The analysis of the key determinants of the private investor's decision to enter is done using the probit model, where the dependent variable is a dummy equal to 1 if PPPs were introduced in electricity generation and 0 if not.

The treatment of the modeling of the key factors affecting the private investor's amount of investment sunk in the renewable energy market is based on Heckman's approach to sample selection. This distinguishes between (1) the decision on whether to enter the generation segment of the electricity market (selection equation), and (2) the decision on how much investment to commit to (investment equation).[4] Unlike the Tobit model, the factors that affect the two decisions need not be identical and, where identical, could even be different in the sign of their effect on the decisions. The selection equation relates the choice of whether to attract PPPs (via a zero/one dummy variable) as a function of the governance variables and the price of oil is estimated over the complete set of countries using a probit model. The second-stage equation, relating PPP investment to the full set of short run and long run variables described in Table 1, is estimated over the sub-set of countries. Because the group has been selected by the first-stage equation, the possibility of selection bias would be introduced if a standard regression were used at the second stage. This bias is related to the magnitude of the correlation between the errors (that include the omitted variables) in the selection and investment equations. Where there is no correlation between these errors, there is no selection bias. The direction of the bias depends on the sign of the inter-equation error correlation.

The condition for identification of the Heckman estimation procedure is that the selection equation contains a significant variable(s) not included in the investment equation. The significance of the Mills' ratio in the second stage indicates whether there would have been selection bias in its absence. If the Mills' ratio is insignificant, a simple regression of the quantity of investment on explanatory variables would be unbiased. The canonical Heckman model also assumes that the errors are jointly

[3] For a constant, zero term spread, an average-sized shock to WTI oil prices increases the probability of recession in the U.S. by nearly 50 percentage points after one year and nearly 90 percentage points after two years.

[4] The data on the dependent variable consist of observations related to the investment. This would be zero for countries that had not attracted PPPs, and positive for those countries that had decided to use it. This observation is split into two components: a zero or one variable indicating the lack of entry or entry of PPPs, and a variable measuring investment for the subset of countries that attracted PPPs.

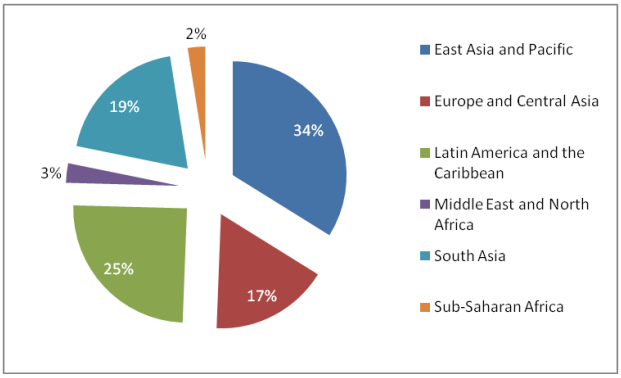
normal. If that assumption fails, the estimator is generally inconsistent and can provide misleading inference in small samples.

Data used in this paper is composed of both micro and macro level data. The micro, project-level data are from the Private Participation in Infrastructure (PPI)[5] database. The PPI database is managed by the World Bank and the Private-Public Infrastructure Advisory Facility (PPIAF). The data are collected at the project level. The following information of each project recorded in the database is used in this paper: 1) country and region[6] 2) year of financial closure and total life period of the project, 3) total investment (in both monetary value and physical capacity, 4) sector, subsector, segment, and technology (source of energy) of each project.[7]

The macro data are collected from other central databases, including i) the *World Development Indicators (WDI) 2009* for macroeconomic variable and the *World Governance Indicators* and Polity IV to select few indicators of governance ii) the *Energy Balances and Statistics 2009* of the International Energy Agency (IEA) to derive indicators of energy import dependence, price of oil and per capita CO_2 emissions and the electricity databases of the Energy Information Agency (EIA) of Department of Energy (DoE) of the US government (Annex 1) to countries' total installed capacity and their composition, total electricity generation, consumption, net import, and distribution losses. Finally, we also use REN21 to compile the list of countries adopting feed-in tariffs.

Figure 3 illustrates PPP investments were selective in developing countries with EAP and LAC leading with investments respectively 34% and above 25%. SAR and ECA are both below 20%. Very little investments have been recorded in the MNA and SSA regions.

Fig. 3
PPP investment in electricity generation, by region



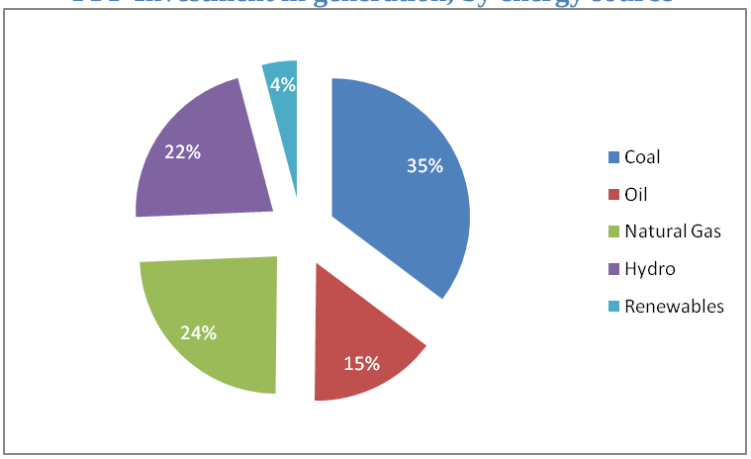
Source: World Bank/PPIAF PPI Database

As Figure 4 illustrates, fossil fuels account for the lion's share of the PPP investment in electricity generation. Coal and natural gas alone accounts for more than half of the total investment. Fuel oil accounts for another 15% bringing the total investment in fossil fuels to three thirds of the total.

[5] http://www.ppiaf.org/ppiaf/page/private-participation-infrastructure-database
[6] The six regions are East Asia Pacific (EAP), East Europe and Central Asia (ECA), Latin America (LAC), Middle East and North Africa (MNA), South Asia Region (SAR), and Sub-Sahara Africa (SSA).
[7] The primary sector is energy, and the subsectors are electricity, natural gas, and other (road, telecom, or treatment plant). For the electricity subsector, the segment information tells whether it is a project for power generation, transmission, or distribution, or a combination of these. For power generation project, the technology (fuel) indicates what fuel (coal, oil, or natural gas) or technology (hydro, wind, nuclear etc.) is used for the generation.

Excluding hydropower, which accounts for more than 20%, total investment in renewables represented a mere 4% of the total PPP investment.

Fig. 4
PPP Investment in generation, by energy source



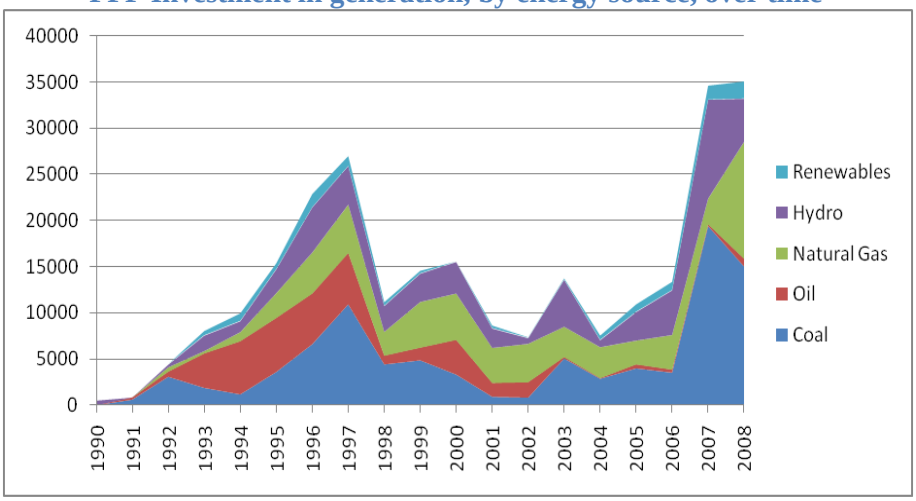
Source: World Bank/PPIAF PPI Database

The trends over time in PPP investment among developing countries has been affected by the financial crises. Past financial crises, notably the East Asian and Russian crisis in 1997-1998 as well as the most recent Latin American crisis in 2001, have negatively affected PPP investments. Investment in renewable based energy has been relatively more resilient to such short run shocks.

More importantly, the data show some evidence of switching of PPP investment from fossil fuels (and within fossil fuels towards from oil and coal to natural gas) to hydro and renewables (Fig. 5). Such a switching from fossil fuel to renewable based private investment affected negatively oil, which represented more than half of the total investment (amounting to about US$ 6 billion) at its peak in 1994 to drop to below 3% during the last few years covered in this study. The share of private investment in coal has declined sharply from above 70% to 10% in 2001, but since then it has increased, reaching above 40% of the total private investment in 2008. Natural gas is the only fossil fuel that has substantially increased its share of private investment from about 10% in the early 1990s to above half of the investment in 2002, to then decrease to below 40% of the total private investment in generation in 2008, its peak (with investment reaching above US$ 12,000).

Examining the trends of private investment in renewables, those in hydro increased from a very low starting point to 40% in 2003 and 30% in 2007 (their peak in US$ terms) and finally to 15% in 2008. Other renewable sources (mainly wind) reached 7% in 2005 (the year of adoption of the Kyoto Protocol) to decline to 5% in 2008 (when they however reached their peak in monetary terms). 2008 represented the peak of investment for wind among the renewable-based generation (with investment reaching US$ 2,000).

Fig. 5
PPP Investment in generation, by energy source, over time



Source: World Bank/PPIAF PPI Database

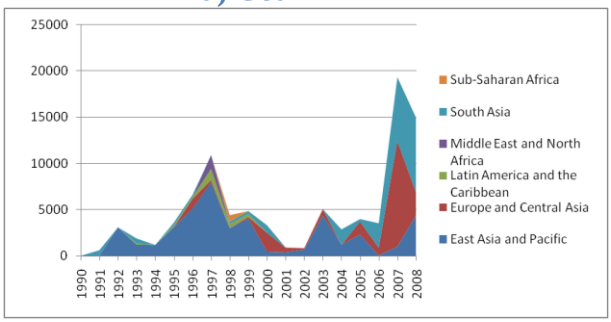
Each region has attracted investment based on their energy endowment and untapped potential. East Asia followed closely by South Asia has attracted more than 40% of the global PPP investment in oil and coal. Latin America is by far the region which has attracted the highest share of investment in renewables, accounting for about half of the total investment, as well as in natural gas with a share of total investment in this fuel equal to 35%. ECA follows closely LAC lead in natural gas (accounting for about 30% the total investment to about 30%). These trends over time by each energy source and by regions are shown in Fig. 6.

Coal Investment in coal based generation reached its first peak of US$ 10,000 billion in 1997 to decline sharply after the East Asian crisis, to then reach the global peak of US$ 20,000 billion in 2007. EAP accounts for the largest share of cumulated private investment in coal, equal to about half of the total investment in this fuel, reaching its peak of investment in 1995 and 2003 accounting for almost 90% of annual total investment in coal. SAR and ECA each accounts for almost one quarter of the total cumulated investment, with their respective peaks reached in 2000 and 2006 respectively. The other three regions each account for a very small percentage of total investment in coal.

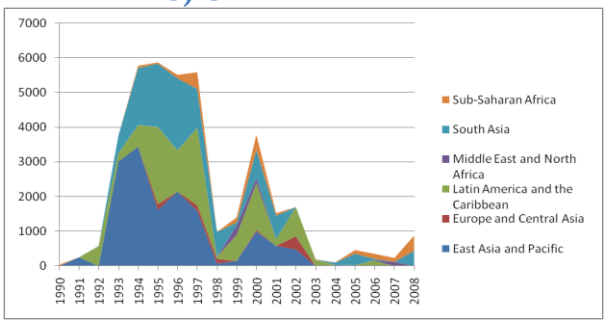
Oil. As noted earlier, PPP investment in oil based generation declined sharply from the peak of US$ 6,000 million in 1995 to US$ 100 in 2004. Investment has increased again in the past few years, reaching almost US$ 900 in 2008 triggered by the emergency rental of diesel mobile plants to face power outages (see Box 1). EAP accounts for the largest share of total cumulated PPP investment in oil, a share that has declined sharply from 80% in 1993 to 5% in 2005 to become zero since 2006. LAC share of total cumulated investment in oil based generation also declined sharply from almost 100% in 1992 to 40% in 2006 to then stop. SAR on the other hand increased its share from an insignificant percentage in the early 1990s to more than 70% in 1998 to then decrease, and to increase again to 50% in 2008. SSA is the region for which oil based generation has increased the most, being the region most affected by severe power outages requiring emergency intervention (see Box 1).

Fig. 6
Investment in renewable by energy source and region, 1990-2008

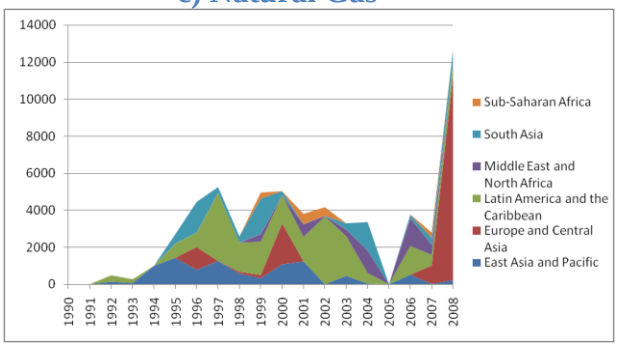
a) Coal



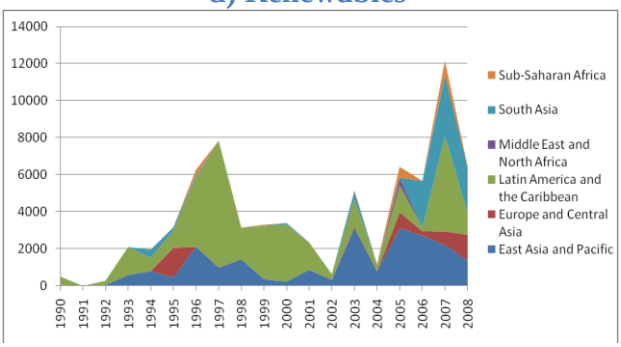
b) Oil



c) Natural Gas



d) Renewables



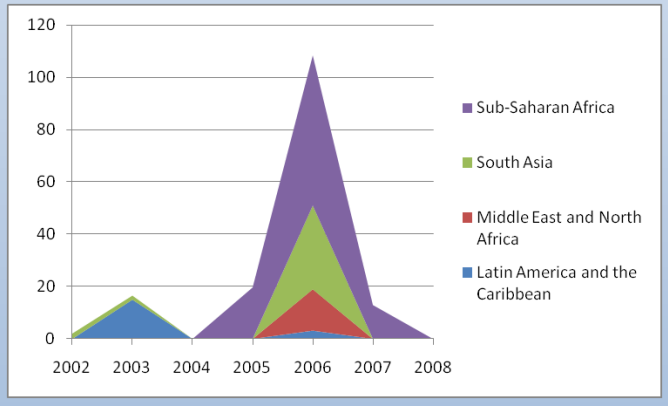
Source: World Bank/PPIAF PPI Database

Natural Gas. Investment in natural gas based generation reached its first peak of a level above US$ 5,000 billion in 1997 to decline sharply after the East Asian crisis and stabilize at levels above US$ 4,000 to then reach the global peak of US$ 12,000 billion in 2008. The boom of investment in natural gas based generation in 2008 was driven by investment in ECA, which accounted for almost 90% of the total annual investment in natural gas. LAC accounts for the largest share of total cumulated private investment in natural gas, a share that has declined sharply from 80% in 1993 to 40% in 2006 to become 5% in 2008. EAP is the second region in terms of share of cumulated investment that mostly took place up to 2001 and then declined sharply. Investment in SAR that accounts for about 15% of the cumulated investment in natural gas, sharply increased to become 45% of the annual investment in 2004. Similar increasing trends in investment were recorded in MENA that account for about 10% of the cumulated investment in natural gas, seeing a sharp increase to reach 40% of the annual investment in 2006.

Box 1 Emergency solutions to power sector crises

In around 30 countries in Sub-Saharan Africa, and in South Asia (Bangladesh and Pakistan), but also in some countries in Middle East and Latin Amercia, the chronic problems of the electricity sector have escalated in recent years into crises, taking a heavy toll on economic growth and productivity. Under investment in a context of rapid demand growth has been a major cause of the power crisis. In some countries, supply shocks have exacerbated the situation. Supply shock include droughts in East Africa; oil price inflation which made it difficult for many West African countries to afford diesel import; gas shortage due to growing domestic demand and declining domestic production have reduced gas for power generation and led to greater dependency on imported oil in Bangladesh and Pakistan; and conflicts that destroyed the power infrastructure in some fragile African states. In some countries, subsidies to the electricity sector have become a heavy burden for public finances. Electricity and petroleum subsidies represented 3% of GDP in Pakistan in 2008.

A common response to the immediate crisis is to tender short-term leases for energy power, ranging from six months to three years. Unlike conventional electricity generation projects, rental projects can be put in place in a few weeks or months, providing a rapid response to pressuring shortages. However, these plants can become an important burden for fiscal finances. Due to the preponderance of small diesel units, the cost has typically been US$0.20-US$0.30 per kilowatt-hour, exceeding by many times the cost of electricity from longer term sources. Developing countries, primarily those with power crisis, implemented almost 2,000 MW of rental power plant capacity in 2005–09 (see Fig. below).



More rental capacity is expected to be commissioned in the coming year or so to reduce electricity shortages, primarily in Bangladesh and Pakistan. For some countries, the price tag of emergency power generation can be high. Some studies estimate to be 4% of GDP in Sierra Leone and almost 3.3% of GDP in Uganda (see Table below).

Overview of Emergency Power Generation in SSA

Country	Date	Contract	Capacity	% total installed capacity	Estimated annual cost as % GDP
Kenya	2006	1 year	100	8.3	1.45
Uganda	2006	2 years	100	41.7	3.29
Sierra Leone	2007	1 year	20	133.3	4.25

Sources: AICD 2008 for data on SSA

.*Source:* Vivien Foster and Cecilia Briceño-Garmendia, (2010) Africa Infrastructure: A time for transformation; Asia Pulse, 24 December 2009, 5 Rental Power Plants in Private Sector Okayed in Bangladesh; Reuters, September 17, 2009, Will Rental Power Solve Pakistan's Energy Woes?

Renewables. Investment in renewable based generation reached its first local peak of a level just below US$ 8,000 billion in 1997 to decline sharply after the East Asian crisis, to then reach the global peak of a level above US$ 12,000 billion in 2007. The boom of investment in renewable based generation in 2007 was driven by investment in LAC, which accounted for above 40% of the total annual investment in renewables. LAC accounts also for the largest share of total cumulated private investment in renewables, a share that has halved from 90% in 1990 to 40% in 2007. EAP is the second region in terms of share of cumulated a share that has increased sharply from 15% in 1993 to two thirds in 2007. Investment in SAR a region that accounts for about 15% of the cumulated investment in renewables, sharply increased from 5% in 1992 to become 40% of the annual investment in 2008.

Table 1
Explanatory Variables Influencing Private Investment in Renewables
(Expected Relationship)

Variables	Definition	Exp. Sign
SECTORAL GOVERNANCE VARIABLES		
Introduction of feed-in tariffs *FIT*	= 1 since the year of establishment of a feed-in tariff system = 0 otherwise	?
ECONOMY WIDE GOVERNANCE VARIABLES		
Control of Corruption *wgi_cc*	= measures the perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests. (Kaufmann and Kray World Governance Indicator)	+
Political Competition ***Polity2***	= Revised Combined Polity Score: This variable is a modified version of the POLITY variable to facilitate the use of the POLITY regime measure in time-series analyses. It ranges from +10 (strongly democratic) to -10 (strongly autocratic), based on 6 indicators.	+
LONG RUN ENVIRONMENTAL SUSTAINABILITY FACTORS		
Price of oil	= value of the international price of oil	?
Kyoto Protocol	= 1 for the years after 2005 = 0 otherwise	+
Transmission Investment	= commitment of private investment in transmission (US million dollars)	+
LONG RUN ECONOMIC FUNDAMENTALS		
GDP *ln_GDP*	= GDP, PPP (constant 2005 international $)	+
Population *ln_Pop*	= total population	+
REGIONAL CONTROL		
Region *d_region1, 2, 3,4,5,6*	Dummies , 1=EAP, 2=ECA, 3=LAC, 4=MNA, 5=SAR, 6=SSA	

We divide the determinants of PPPs into three channels, reported in Table 1. These include long run environmental sustainability factors (including the price of oil, the entry in force of the Kyoto protocol and behavior by high emitter countries), (sectoral and economy-wide) governance variables and short and long run drivers, represented respectively by financial crises and economic fundamentals. We also control for sectoral and regional variables.

4. Theoretical hypotheses

The hypotheses that we are going to test are reported below. Each of the hypothesis is divided in two parts (part A and B), taking into account respectively the key factors affecting the private investor's decision to enter the renewable energy market and the amount of investment sunk in renewable energy, because of the different modeling that will be used (as described in Section 2).

Long run Environmental Sustainability Drivers

Hypothesis 1A The likelihood of developing countries to attract private sector investment if the price of oil is increasing depends on the degree of switching between investment in fossil fuel and renewable based electricity generation.

Hypothesis 1B The likelihood of developing countries to retain private sector investment if the price of oil is increasing depends on the degree of switching between investment in fossil fuel and renewable based electricity generation.

Hypothesis 2A Developing countries are more likely to attract more investment in renewable based generation in the years following the entry into force of the Kyoto Protocol due to the rise of climate change up in the political agenda.

Hypothesis 2B Developing countries are more likely to retain more investment in renewable based generation in the years following the entry into force of the Kyoto Protocol due to the rise of climate change up in the political agenda.

The impact between the increase in the price of oil and the likelihood and the amount of investment in electricity generation is uncertain, depending on the degree of switching between investment in fossil fuel and renewable based electricity generation. Depending on which of the countervailing effects (increase in investment in renewable based generation and decline in investment in fossil fuel based generation) dominates it can be either positive or negative.

To get an initial indication of whether the data confirm these hypotheses we can calculate the two means between different groups (e.g. the proportion of investment or the volume of investment for the observations where the price of oil have been increased above average and those below average) and compare them to see if one is greater than the other, and by how much. The significance of differences between two sample means can be assessed using the t-statistic calculated as part of the t-test. The t-statistic may be thought of as a scaled difference between the two means, where the absolute difference between means is rescaled using and estimate of the variability of the means. Such tests will be performed for each of the following hypotheses.

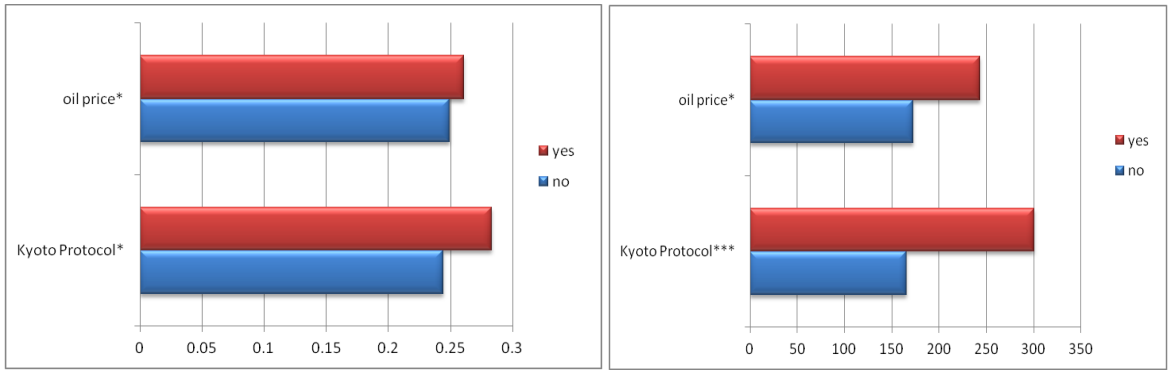
Fig. 7 shows that developing countries have been 40% more likely to attract PPPs in generation in periods characterized by above average price of oil. They also attracted 5% more investment in

generation when the price of oil increased above the average.

Developing countries have been 80% more likely to attract PPPs in generation after the entry into force of the Kyoto Protocol. They also attracted 16% more investment in generation (a small percentage compared to the doubling of investment in renewable-based generation).

Fig. 7
Links between Investment in Generation and long run Environmental Factors

a) Likelihood of attracting PPPs in generation *b) Investment in PPP generation (US$ million)*



Source: World Bank/PPIAF PPI Database
Note: *, **, *** indicate significance of the t test of the difference between the average respectively at 10%, 5% and 1% confidence level.

Sectoral and Economy-Wide Governance

Hypothesis 3A The likelihood to attract private investors to provide electricity generation is higher in countries where support mechanisms, including feed-in tariff, have been put in place.

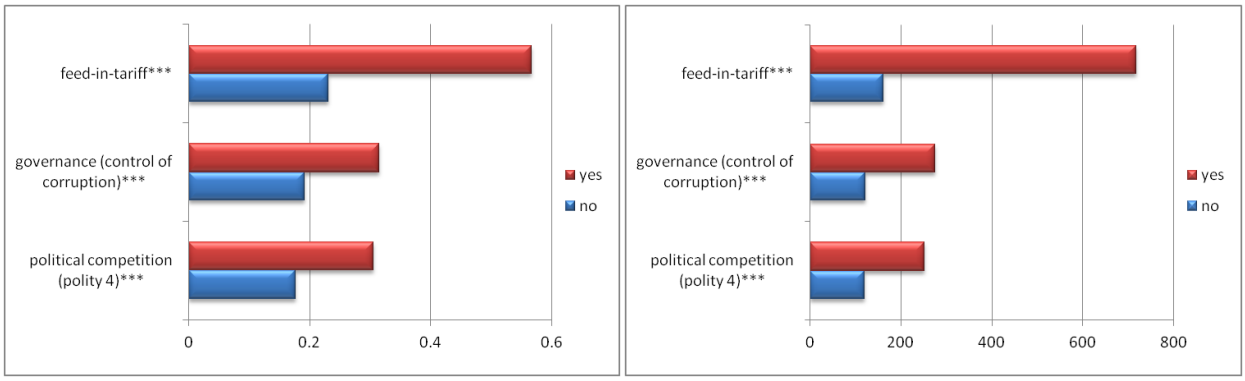
Hypothesis 3B The link between the incentives for renewable based generation and the level of generation investment is uncertain and depends on several factors, including the relative magnitude of investment as well as the degree of switching between investment in fossil fuels and renewable-based generation.

Private investors are more likely to choose to invest in renewable energy if the country offers sufficient incentives from the regulatory side. This is because most renewable sources of energy cost more than conventional ones and it also typically entail higher upfront capital costs, hence higher investment (compared to fossil fuels). After recouping upfront capital cost, private investor can enjoy lower operational costs. Private investment in fossil fuel based generation can be reduced if support schemes for renewables are high enough.

Fig. 8 illustrates the underlying trends in the data. Countries that have introduced feed-in tariff are almost twice times more likely to attract private investment in generation and about 4 times more investment than countries where such support mechanisms have not been introduced. Looking only at renewable based generation the likelihood to attract investment as well as the amount of investment is twice as high.

Fig. 8
Links between Investment in Generation and Governance

a) Likelihood of attracting PPPs in generation *b) Investment in PPP generation (US$ million)*



Source: World Bank/PPIAF PPI Database *Note:* *, **, *** indicate significance of the t test of the difference between the average respectively at 10%, 5% and 1% confidence level.

Hypothesis 4A The livelihood to attract private investors to provide electricity generation is higher in countries characterized by higher standards of economy-wide governance and a more democratic political system.

Hypothesis 4B The private sector investment in electricity generation is higher in countries characterized by higher standards of economy-wide governance and a more democratic political system.

Countries with above average economy wide indicators in terms of control of corruption and political competition are twice as likely to attract private investment and to get about twice the volume of investments. Similar results hold for the fossil fuel and renewable based generation.

Short run crises and economic fundamentals

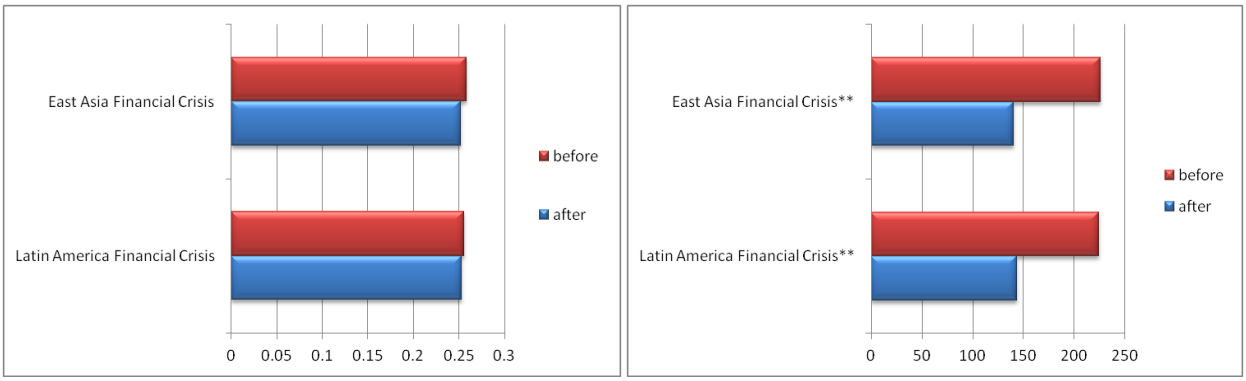
Hypothesis 5A Countries facing severe financial crises are more likely not to attract new PPPs in the few years following the crises.

Hypothesis 5B Countries facing severe financial crises are more likely to receive less PPP investment from existing PPPs in the few years following the crises.

The likelihood to attract investment declined by less than 2% after the East Asian and Latin American financial crises, a not significant decline. Investment dropped by 40 percent after the East Asian and Latin American financial crises. Not surprisingly the impact of the both financial crises was significant in terms of reduction of investment. Among the different fuels, renewable-based generation was the most resilient to the financial crises.

Fig. 9
Links between Investment in Electricity Generation and Financial Crises

a) Likelihood of attracting PPPs in generation *b) Investment in PPP generation (US$ million)*



Source: World Bank/PPIAF PPI Database
Note: *, **, *** indicate significance of the t test of the difference between the average respectively at 10%, 5% and 1% confidence level.

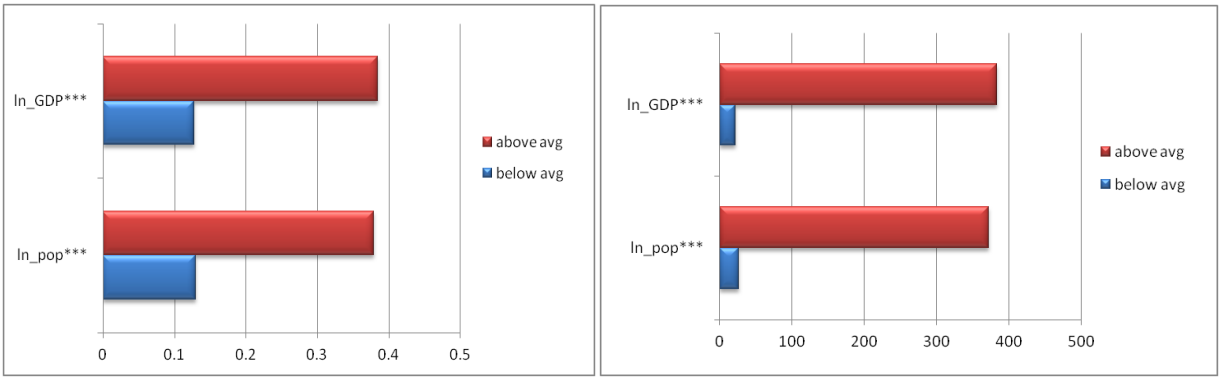
Hypothesis 6A Countries characterized by higher income and size of the market are more likely to attract PPPs in electricity generation.

Hypothesis 6B Countries characterized by higher income and size of the market are more likely to attract a higher volume of PPP investment in electricity generation.

Countries with above average GDP are three times more likely to attract investment in electricity generation and about 20 times more investment than countries whose population is increasing below the average. Countries with above average population growth are three times more likely to attract private investment and fourteen times more investment than countries whose population is increasing below the average (Fig 10).

Fig. 10
Links between PPP in Generation and GDP per capita

a) Likelihood of attracting PPPs in generation *b) Investment in PPP generation (US$ million)*



Source: World Bank/PPIAF PPI Database
Note: *, **, *** indicate significance of the t test of the difference between the average respectively at 10%, 5% and 1% confidence level.

The result of the regressions will allow us to test the robustness of these preliminary findings, controlling for other factors.

5. Regression results

In this section the hypotheses that we put forward in the previous section are tested. Table 2 reports the parameter estimates using in the probit model as a dependent variable a dummy variable equal to 1 if PPP occurred for electricity generation and 0 if not.

Table 2 Key Determinants of the Introduction of PPP in Electricity Generation

	(1)	(2)	(3)
GOVERNANCE VARIABLES			
SECTORAL GOVERNANCE VARIABLES			
Introduction of feed-in tariffs *FIT*	0.703*** (0.143)	0.434*** (0.158)	0.461** (0.179)
ECONOMY WIDE GOVERNANCE VARIABLES			
Control of Corruption *wgi_cc*	0.437*** (0.082)	0.379*** (0.094)	0.361*** (0.094)
Degree of democracy *Polity2*	0.037*** (0.009)	0.024** (0.010)	0.024** (0.010)
LONG RUN ENVIRONMENTAL SUSTAINABILITY FACTORS			
Price of oil			-0.018** (0.007)
Price of oil*Kyoto Protocol			0.010** (0.005)
Transmission investment			0.002* (0.001)
MACROECONOMIC CONTROL			
GDP *ln_GDP*		0.170*** (0.064)	0.165** (0.065)
Population *ln_Pop*		0.187*** (0.073)	0.183** (0.074)
REGIONAL CONTROL			
Regional dummies	Yes	Yes	Yes
Constant	0.631*** (0.080)	-0.736*** (0.197)	-7.355*** (0.198)
N	1185	1143	1143
Log likelihood	-611.63	-524.77	-518.8
χ^2	167.04***	307.6***	319.64***
Pseudo R^2	12.01	22.67	23.55

Note: *, **, *** indicate significance of the coefficient respectively at 10%, 5% and 1% confidence level.

Regression (1) reported in Table 2 represents the basic probit model introducing as explanatory variables the key sectoral and economy wide governance variables to test Hypotheses 3A and 4A. Regressions 2-3 then extend the analysis to analyze the role of long run environmental variables (to test Hypotheses 1A and 2A), controlling for short run financial crises (Hypotheses 5A), macroeconomic fundamental variables (Hypothesis 6A) and regional control.

In what follows the key results are highlighted, focusing on the specific hypotheses tested in each of the regressions.

Regression 1 provides support to Hypothesis 3A with the introduction of feed-in tariff positively and highly significantly associated to the introduction of PPPs in electricity generation. Hypothesis 4A is also confirmed with higher standard of economy wide governance making more likely to attract PPPs in electricity generation.

Regression 2 confirms Hypothesis 6A related to economic fundamentals. Countries characterized by higher income significantly increase the probability of attracting PPPs, but no significantly so. The size of the market instead has both a positive and highly significant relationship with the introduction of PPPs. Short run crises are consistently not significant (so that the results have not been included. Regression 3 confirms the robustness of the previous results controlling for regional dummies.

Regression 3 shows that higher international prices of oil determine a lower overall likelihood to attract PPPs. This seems to imply that among the two countervailing effects, the reduction of PPP in fossil fuel based generation dominates the increase of PPPs in renewable-based generation. Regression 3 shows that controlling for the interaction between the price of oil and the Kyoto protocol, climate change consideration affects the choice of introducing PPPs in generation, resolving the uncertainty of the predictions by Hypothesis 1A. The positive sign of the interacted terms however implies that after the introduction of the Kyoto protocol countries became more likely to introduce PPPs in renewable based generation, also driven by the higher price of oil. Regression 3 introduces as additional variable the level of committed private investment in transmission. Countries with higher investment in transmission are positively and significantly associated to the introduction of investment in generation. This confirms the importance of including considerations related to access to the grid and development of the network, particularly as renewables have been introduced in the power system. Because of the potential concerns with endogeneity due to the fact that private investment in both segment of the power sector can be driven by similar factors, we also used instrumental variables, including the lagged variable of the transmission variables. The results are robust to the introduction of instrumental variables.

We can now move to determine which of the previous factors affect the private investor's decision to enter the market of generation and the amount of investment sunk in the sector. The treatment of the modeling is based on Heckman's approach to sample selection. This distinguishes between (1) the decision on whether to enter the market (selection equation), and (2) the decision on how much investment to commit to (investment equation).[8]

[8] The data on the dependent variable consist of observations related to the investment. This would be zero for countries that had not attracted PPPs, and positive for those countries that had decided to use it. This observation is split into two

Table 3 Key Determinants of PPP Investment in Electricity Generation

	Two step (1)	Two step (2)	(3)
SECTORAL GOVERNANCE VARIABLES			
Introduction of feed-in tariffs *FIT* *First step in red*	0.719*** (0.141)	0.819*** (0.150)	
ECONOMY WIDE GOVERNANCE VARIABLES			
Control of Corruption *wgi_cc* *First step in red*	0.369*** (0.078)	0.360*** (0.079)	
Degree of democracy *Polity2* *First step in red*	0.034*** (0.007)	0.036*** (0.007)	
LONG RUN ENVIRONMENTAL SUSTAINABILITY FACTORS			
Price of oil *First step in red*		-0.016** (0.007)	
Price of oil*Kyoto Protocol *First step in red*		0.009* (0.005)	
MACROECONOMIC CONTROL			
GDP *ln_GDP*	0.686*** (0.114)	0.681*** (0.112)	0.664*** (0.153)
Population *ln_Pop*	0.581*** (0.051)	0.581*** (0.052)	0.469*** 0.080
Constant	-10.744*** (1.613)	-10.666*** (0.575)	-8.310*** (1.890)
N	1182	1182	331
Censored N	861	861	
Wald χ^2	140.39***	141.36***	50.86***
Within R^2			1.00
Between R^2			40.59
Overall R^2			31.03

Note: *, **, *** indicate significance of the coefficient respectively at 10%, 5% and 1% confidence level.

Regressions (1) and (2) in Table 3 report the results of the two step Heckman model, introducing in the first stage as a dependent variable (reported in red) the likelihood to attract private investment in generation and as explanatory variables the key sectoral and economy wide governance variables. The second step of the model uses the logarithm of amount of private investment in generation as the dependent variable, conditional on the decision to enter the generation market, and as explanatory variables the broader model. The final regression report the GLS model using as a

components: a zero or one variable indicating the lack of entry or entry of PPPs, and a variable measuring investment for the subset of countries that attracted PPPs.

dependent variable the logarithm of amount of private investment in generation, which restrict the number of observations only to countries with a non-negative level of private investment.

Some interesting results are worth highlighting. We will first focus on the different factors that affect the entry and the level of investment in electricity generation.

First, increases in the price of oil affect negatively only the entry of PPPs in generation but not the level of investment in generation. Higher price of oil, which is also highly correlated to higher price of natural gas and coal, determines a lower likelihood to attract PPPs, by reducing investment in fossil fuel based generation which represents the bulk of investment in generation. The positive sign of the interacted terms however seems to imply that after the introduction of the Kyoto protocol countries became more likely to introduce investment in renewable based generation, and add additional investment in generation, also driven by the higher price of oil. There is no evidence on the impact of increases in the price of oil on the level of investment in generation (and the variable is not reported). In other words, the reduction in the level of investment in fossil fuel based generation is not significant.

The economy wide governance factors affect only the first step of the Heckman model, confirming the results of the probit model analyzed before. In other words, better control of corruption and higher degree of political competition are crucial in attracting the entry of private investors, but they do not affect the extent of investment in generation. This suggests that the first generations of IPPs have been developed on the basis of long term PPAs guaranteeing a fixed rate of return, through take-or-pay clauses and/or government guarantees. This has been the results of challenges in reforms and the adoption of sub-optimal sequencing of reforms. For example, postponing tariff adjustments and delaying unbundling effort separation of transmission from generation reduced the creditworthiness of power purchasers, leading to demands from the private investors for very favorable and long-term PPAs. In this case, other governance indicators may play a less relevant role in determining the extent of investment.

Sectoral support schemes, provided by feed-in tariffs, affect only the entry and not the level of investment in electricity generation. The result is easy to be explained, as PPP investment in renewable based generation are crucially dependent on the existence of support mechanisms, but still account for a relatively small share of investment in overall electricity generation.

Other differences in results are more a question of nuances. In terms of economic fundamentals, whereas the level of entry was mainly affected by the market size (in terms of population) both income and population size affect the level of investment, highlighting the importance of consideration related to affordability and sustainability of the support for generation, particularly for renewable-based generation.

We can now move to determine which of the previous factors affect the private investor's decision to the amount of investment in the separate fossil fuel and renewable sub-segments of the generation market. Regressions (1) in Table 4 (and 5) report the results of the two step Heckman model (reported in red), introducing in the first stage as a dependent variable the likelihood to attract private investment in renewable (fossil fuel) based generation and as explanatory variables the key sectoral and economy wide governance variables. The second step of the model uses the logarithm of amount of private investment in renewables (fossil fuel) as the dependent variable, conditional on the decision to enter the generation market, and as explanatory variables the broader

model including the short run and long run variables described above. The final two regressions report the GLS model using as a dependent variable the logarithm of amount of private investment in renewable based generation, which restrict the number of observations only to countries with a non-negative level of private investment.

Table 4 Key Determinants of PPP Investment in Renewables

	Two step (1)	Two step (2)	(3)	(4)
SECTORAL GOVERNANCE VARIABLES				
Introduction of feed-in tariffs *FIT* *First step in red*	0.803*** (0.143)	0.681*** (0.150)		0.509* (0.318)
ECONOMY WIDE GOVERNANCE VARIABLES				
Control of Corruption *wgi_cc* *First step in red*	0.386*** (0.088)	0.372*** (0.088)		
Degree of democracy ***Polity2*** *First step in red*	0.023*** (0.008)	0.020** (0.009)		
ENVIRONMENTAL SUSTAINABILITY FACTORS				
Price of oil			0.011* (0.006)	
Kyoto Protocol		0.003*** (0.001)		
MACROECONOMIC CONTROL				
GDP *ln_GDP*	0.627*** (0.173)	0.541*** (0.174)	0.586*** (0.197)	0.628*** (0.192)
Population *ln_Pop*	0.345*** (0.171)	0.196 (0.170)	0.312 (0.213)	0.373* (0.209)
Constant	-6.998*** (2.412)	-5.466** (2.397)	-5.370** (2.345)	-5.109** (2.378)
N	1184	1184	189	189
Censored N	1002	1002		
Wald χ^2	32.85***	27.32***	23.80***	22.87***
Within R^2			7.88	7.20
Between R^2			17.92	20.29
Overall R^2			16.72	15.85

Note: *, **, *** indicate significance of the coefficient respectively at 10%, 5% and 1% confidence level.

Table 5 Key Determinants of PPP Investment in Fossil Fuels

	Two step (1)	(2)	(3)
SECTORAL GOVERNANCE VARIABLES			
Introduction of feed-in tariffs *FIT* *First step in red*	0.828*** (0.116)		
ECONOMY WIDE GOVERNANCE VARIABLES			
Control of Corruption *wgi_cc* *First step in red*	0.239*** (0.082)		
Degree of democracy *Polity2* *First step in red*	0.028*** (0.008)		
LONG RUN ENVIRONMENTAL SUSTAINABILITY FACTORS			
Price of oil	-0.008*** (0.003)	-0.001 (0.005)	
Kyoto Protocol *d_Kyoto*			-0.291 (0.199)
Constant	-0.650*** (0.091)		
MACROECONOMIC CONTROL			
GDP *ln_GDP*	0.828*** (0.116)	0.801*** (0.167)	0.824*** (0.162)
Population *ln_Pop*	0.586*** (0.058)	0.525*** (0.087)	0.538*** (0.085)
Constant	-11.898*** (1.749)	-10.420*** (2.116)	-10.794*** (2.531)
N	1183	242	242
Censored N	946		
Wald χ^2	127.52***	54.82***	60.00***
Within R^2		0.39	0.34
Between R^2		51.51	52.06
Overall R^2		37.91	38.35

Note: *, **, *** indicate significance of the coefficient respectively at 10%, 5% and 1% confidence level.

Some interesting results are worth highlighting. In what follows we focus on the different factors that affect the level of investment in renewable and fossil fuel based generation.

First and most importantly, increases in the price of oil (which is highly correlated to the price of other fossil fuels) make the likelihood of investment in renewables higher and those in fossil fuels lower. As seen before the likelihood of a reduction of investment in fossil fuel based generation is larger than the increase of investment in renewable based generation, so that the overall impact of the increase in the price of oil on the likelihood of electricity generation is negative.

Second, the sectoral support scheme, provided by feed-in tariffs, affect only the entry in renewable based generation, and their link is much less significant when it comes to enhance the amount of investment in renewable based generation and becomes insignificant in driving the amount of investment in fossil fuels down. The result implies that investment in renewable-based generation are crucially dependent on the existence of support mechanisms, though their incentive power has not be so strong as to affect the volume of investment, nor to reduce the investment in fossil fuels.

6. Conclusions

This paper shows some evidence of switching from investment in fossil fuels to investment in hydro and renewables and within fossil fuels from oil to natural gas. Such a switching from fossil fuel to renewable based private investment negatively affected oil, which represented more than half of the total investment (amounting to about US$ 6 billion) at its peak in 1994 to drop to below 3% during the last few years covered in this study. Natural gas is the only fossil fuel that has substantially increased its share of private investment from about 10% in the early 1990s to below 40% of the total private investment in generation in 2008.

The key results of the empirical analysis are summarized below:

- **Increases in the price of oil (which is highly correlated to the price of other fossil fuels) increase the likelihood of investment in renewables and decrease the one of investment in fossil fuels.** The likelihood of a reduction of investment in fossil fuel subsidies is larger than the one of an increase of investment in renewables, so that the overall impact of the increase in the price of oil on the likelihood of investment in electricity generation is negative.

- **The introduction of the Kyoto protocol in combination to higher fossil fuel prices enhances the probability to invest in renewables, enhancing overall PPP investment in generation.**

- **Short run financial crises do not affect either the decision to enter the generation market or the level of investment in generation.** This proves the resilience of investment to such shocks.

- **Sectoral governance support schemes, provided by feed-in tariffs, affect only the entry in renewable based electricity generation. Their link is much less significant when it comes to enhance the amount of investment in renewables and becomes insignificant in driving the amount of investment in fossil fuel based generation down.** The result implies that investment in renewable based generation are crucially dependent on the existence of support mechanisms, though their incentive power has not be so strong as to affect the volume of investment, nor to reduce the investment in fossil fuels and drive any significant switching from fossil fuels to renewables.

- **Economy-wide governance factors, including control for corruption and degree of political competition are factored in by private investors only in the initial stage of the game when the decision to enter into the generation market is taken.** This suggests that the first generations of IPPs have been developed on the basis of long term PPAs guaranteeing a fixed

rate of return, through take-or-pay clauses and/or government guarantees. This has been the results of challenges in reforms and the adoption of sub-optimal sequencing of reforms. For example, postponing tariff adjustments and delaying unbundling effort separation of transmission from generation reduced the creditworthiness of power purchasers, leading to demands from the private investors for very favorable and long-term PPAs. In this case, other governance indicators may play a less relevant role in determining the extent of investment.

- **Private investors entering the market looks more at the size of the market rather than the income level, whereas when determining the level of investment in generation they assess both the size and "affordability" level of consumers**.

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