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Abstract:
Many countries in Latin America and the Caribbean are interested in diversifying their energy sources for energy security and in contributing to the reduction of greenhouse gases. Non-traditional renewable energy (NTRE) sources, which include wind, solar, geothermal and small-scale hydropower, have received a lot of attention towards meeting these goals. To foster the expansion of NTRE, different countries have pursued different legal and regulatory approaches, but there remains very limited evidence regarding the effectiveness of different approaches. In this paper, we use a unique dataset that combines information on NTRE growth rates and information on the legal and regulatory framework, as well as other control variables, for 27 countries over the period 2001-2010. Legal and regulatory instruments include legally binding and non-binding quantity targets, contracts guaranteeing premium prices, fiscal incentives and import duty waivers, and guaranteed access to the grid. Using an information-theoretic Markov Chain analysis, results indicate that fiscal incentives and guaranteed access have relatively high impacts on transitions into high growth rates, whereas fiscal incentives and import duty waivers have relatively high impacts on transitions into moderate growth rates. Binding and non-binding agreements increase transitions out of negative and zero growth rates, but to relatively low positive growth rates. Contracts with premium subsidies also have limited impacts on transitions into high growth rates, though they are associated with transitions into the low growth category. These results provide additional evidence on which regulatory instruments have been most effective in aiding countries in expanding their NTRE.

KEYWORDS: renewable energy, regulatory framework

JEL Codes: H11, H23, H25, K32, Z18

1. Introduction:

In the past decade, many countries in Latin America and the Caribbean (LAC) have expanded renewable energy capacity. A number of reasons have been put forth to explain this development, including increased incentives for countries to secure energy independence and greater energy security through diversification of energy sources, to expand electricity access in rural areas, and to contribute to international efforts to curb growth in GHG emissions (Cherni, 2011; Dyner et al., 2011; REN21, 2011). While many countries in the region already had renewable energy sources before the past decade, these sources were overwhelmingly dominated by large hydropower. Non-traditional renewable energy (NTRE), which excludes large hydropower, contributed just 7.2 BKwh to electricity generation in 2000, but climbed to 23.2 BKwh by 2009 (US Energy Information Administration (EIA), nd)[1]. Even with a greater than three-fold increase in NTRE, these energy sources provide only a small fraction of energy used in electricity generation, less than ½ of 1 percent (EIA). Most experts agree that the contribution of NTRE is still well below potential in all Latin American countries and in many Caribbean countries (IDB, 2012).

As discussed in detail below, in order to reach NTRE goals that have been stated in legislation and policy documents, almost all countries have made changes to their respective legal and regulatory frameworks in the energy sector. These changes are meant to address a number of issues specifically related to expansion of NTRE. In most countries, NTRE is still not competitive with fossil fuels for electricity generation, particularly given that the price of fossil fuels does not take into account its full social costs (IDB, 2012; Luecke, 2011). Expansion of NTRE thus requires some type of subsidy on NTRE or a tax on fossil fuels. Second, given the high up-front financing costs for renewable energy generation facilities, firms face risks associated with the possibility that future profits will be insufficient to generate acceptable returns on investment (Lüthi and Wüstenhagen, 2009; Dyner et al., 2011; Luecke, 2011). These risks include market as well as political risks, since future returns will be affected by continued public support within the context of an ever-changing regulatory environment (IPCC, 2011; Cherni, 2011; Bjork et al., 2011; REN21, 2011). To induce expansion efficiently and effectively, governments need to determine an "optimal" subsidy level and then provide credible evidence that they intend to continue such support and/or ensure a market in the future. Thus, a key common principle with respect to effective renewable energy regulation is that a country select, and then commit to, one coherent support scheme (REN21, 2011; Bjork et al., 2011).

On the other hand, with limited experience with various policy and regulatory instruments designed to expand NTRE, it is difficult, *ex ante*, to design and credibly commit to specifics. For instance, it is often difficult to determine an optimal schedule of subsidies; if the subsidy is too high, too much NTRE investment will ensue at inefficiently high cost, if the subsidy is too low, no or limited investment will be

[1] Given the available data used below from EIA, we define non-traditional renewables electricity generation to include wind, solar, biomass, and geo-thermal electricity generation. Small hydropower is also generally included as non-traditional renewable; however, data on hydropower generation is not disaggregated by large and small hydropower so we could not include electricity generated from those sources.

forthcoming. Lack of experience with certain regulatory instruments means building flexibility into the instrument can be valuable, but at the same time, that flexibility cannot subvert a credible commitment to the overall scheme (Bjork et al., 2011). Thus, there is a potential tension in devising a legal and regulatory scheme that provides credible commitment to the broad goal of NTRE expansion, but that is flexible enough to adapt to a constantly changing external environment and the accumulation of information on the efficacy of specific regulatory instruments.

Given the multiple objectives and multiple NTRE sources identified above, a number of different of legal and regulatory instruments have been designed and implemented In LAC countries. These instruments can be broadly categorized as follows: 1) adoption of NTRE legislation, 2) establishment of NTRE quantity targets[2], 3) establishment of price premiums/guarantees, 4) adoption of fiscal incentives, and 5) investment in structural changes in the energy sector. In most countries, adoption of NTRE legislation, or adoption of energy sector legislation with sections on NTRE, is a first step, followed by the development and implementation of specific regulatory instruments.

There are relatively few papers using statistical methods to evaluate the impact of various government environmental policies and regulations in general, and fewer still that evaluate the impacts of such instruments on the expansion of renewable energy. Nesta et al. (2013) use an index of renewable energy policies to evaluate impacts on patents in "green" technologies in OECD, which is used as a proxy for innovation in the renewable energy sector; the index increases in the number of policies implemented. The analysis supports the hypothesis that such policies increase the number of "high-quality" green patents. Esty and Porter (2005) also use an index of the quality of the overall environmental regulatory regime in OECD countries to assess impact on energy usage and pollution concentrations. Their results also show support for the hypothesis that the environmental outcomes are improved with greater regulatory quality. They do not evaluate specific policies or regulations on outcome variables however. Johnstone et al. (2010) uses a statistical analysis to determine the impact of specific policy and regulatory instruments, in this case on patent applications for renewable energy technologies. The cross-country analysis, which includes mainly OECD countries, indicates that fiscal measures, quantity-based obligations and tradable certificates all have positive impacts on patents for all renewables. Price guarantees, such as feed-in tariffs, have no statistically significant impact for patents when aggregating across all renewables, but they do have a positive and significant impact on biomass patent applications.

In this paper, we use a Markov chain analysis to evaluate how the NTRE sub-sector in LAC has changed over a 10-year time period, 2001-2010, and specifically to evaluate the impact of NTRE-relevant legal and regulatory changes on NTRE growth rates. This type of empirical model is particularly useful in analyzing transitions between growth rate regimes over time, identifying which factors are correlated with transitions, and providing insights into the likely future growth paths (Hyppolite and Trivedi, 2012; Tonini and Jongeneel, 2009; Henderson, 2014). In estimating the first-order Markov model, we use a semi-parametric, information-theoretic approach so as to introduce minimal distributional assumptions.

[2] Quantity targets are referred to under a number of different names, e.g. renewable portfolio standards (RPS), (REN21, 2012).

We apply the Markov chain analysis to a panel data set constructed using available secondary data on growth rates of NTRE in electricity generation, adoption of national-level legal and policy instruments, and other relevant control variables such as NTRE potential, availability of potential substitutes for NTRE such as fossil fuels and large hydro-power, and general economic conditions. Results indicate that countries tend to remain in the same growth rate category over time, and that most transitions occur into neighboring growth rate regimes. Of the legal and regulatory instruments, fiscal incentives and guaranteed access to the grid have relatively high impacts on transitions into moderate and high growth rate regimes. Public competitive bidding and feed-in tariffs have relatively high impacts on moving into the low-growth category, implying that such instruments can help start the NTRE growth process but not necessarily at high growth rates.

The analysis and results contribute to a relatively small body of literature using statistical techniques to evaluate the impact of legal and policy variables on environmental outcomes of interest more broadly, and in stimulating NTRE growth rates in Latin America and the Caribbean specifically. The dataset used in the analysis is unique, matching data from secondary sources such as EIA with data on the year the various legal and regulatory instruments were adopted, obtained from a comprehensive review of legislation in LAC countries. As noted above, all but one of the few papers evaluating the legal and regulatory framework in the renewable energy section have used composite indexes of legal and regulatory quality. Another contribution of this paper is the analysis of specific legal and regulatory instruments to generate evidence on relative effectiveness of the different instruments.

In the remainder of this paper, we first describe the legal and regulatory instruments in more detail and summarize the expected channel of impact on NTRE growth rates from the extant literature; we then provide a review of case-study evidence available for a subset of LAC countries. In the third section, we provide details and descriptive statistics from the dataset that combines information on the energy sector as well as NTRE-relevant laws and regulations for 27 Latin American countries over a 10-year period, 2001-2010. In the fourth section, we present our empirical strategy and estimation results. The fifth section concludes.

2. Legal and Regulatory Instruments and Selected Country Experiences

2.1: Legal and Regulatory Instruments

In LAC countries, NTRE quantity targets often take the form of legally binding targets for total renewable energy or the share of renewables in the overall energy mix, combined with mandatory purchase requirements of NTRE by electricity providers (Cherni, 2011). Quantity targets create an NTRE market, with electricity providers responsible for identifying lowest-cost NTRE suppliers. For quantity targets alone to work well, the energy sector needs to be mature and deep enough to integrate expanded NTRE capacity, and to have a sufficient number of NTRE suppliers to meet quantity targets and also to create real competition (Jaccard, 2004). Legally binding quantity targets provide a strong signal of credible commitment, but in and of themselves, provide only limited reduction in risks associated with future demand (Jaccard, 2004). They also provide flexibility in meeting targets through markets competition;

and, allowing trade in renewable energy certificates increases flexibility of such regulatory schemes (Wiser et al., 2010).

Some countries have adopted non-legally binding quantity targets. As detailed below, in LAC, non-legally binding targets are often not accompanied by any further regulatory instruments specifying how those targets might be met, so a market is not necessarily created (Dolezal, 2013). Non-legally binding targets thus provide a relatively weak signal of commitment, and do not address either risks or costs faced by potential investors (Dolezal, 2013; Garcia, 2013). On the other hand, non-binding targets by their very nature leave great scope for flexibility in implementation, and to react to changing external environment and the accumulation of new information over time.

Price premiums guarantee a certain price per unit of energy produced for some length of time to the NTRE supplier. Here the emphasis is on providing incentives directly to potential NTRE suppliers, mainly by ensuring that prices they will receive throughout some period will be sufficient to cover operation and financing costs (Haselip, 2011). Setting price premiums enables potential NTRE investors to calculate returns on investment, reducing investment risks associated with an uncertain stream of income. Government-backed guarantees can be quite important when financial markets are otherwise hesitant to fund such ventures. As with quantity targets, the energy sector needs to be sufficiently mature to integrate NTRE into the system (Garcia, 2013). Finally, these contracts leave limited room for flexibility to adjust to changing information and circumstances, as governments' are "locked in" to these relatively long-term agreements. Contract clauses can be drafted to increase flexibility such as inflation clauses, but at the cost of reducing firm risks.

There are a number of price premium schemes that have been developed. An option popular in Europe is the use of Feed-in Tariffs (FiTs),where electricity distributors or transmission companies are obligated to purchase energy at fixed tariff rates for a set contract duration (Bjork et al., 2011). Tariffs are set by the relevant energy sector authority, generally differentiating across renewable energy sources to account for cost differentials. Given that these rates are set to guarantee a sufficient rate of return to the NTRE supplier, such rates are above fossil fuel rates. FiTs are often coupled with mandatory purchase obligations stemming from legally binding quantity targets discussed above (Bjork et al., 2011). Feed-in tariffs are popular mainly because they are relatively simple to design and implement (Haselip, 2011; Mendonca et al., 2010). In reality, however, complexity arises in setting the schedule, which presupposes that the tariff-setting agent has good information on both the costs borne by the NTRE supplier. If rates are set too low, then sufficient investment will not be forthcoming. If rates are set too high, either consumers or the government via premium subsidies will be paying too much and innovation in NTRE supply will be stifled.

An alternative to the FiTS plus mandatory purchase agreement that also offers the stability of a guaranteed premium price is to hold public competitive bidding for NTRE suppliers, where the winners also then enter into long-term contracts to supply a certain amount of energy at the prices contained in the bid (Bjork et al., 2011). Most such schemes also include an obligation for electricity providers to purchase a certain amount of NTRE, either at a premium price (passed on to consumers) or with subsidies paid by the government to cover part or all of the premium. Public competitive bidding may be preferred to FiTs schemes where the regulator has limited information on NTRE suppliers' costs as well as social costs. All else equal, this system should be more cost-effective than a FiTs scheme, since firms "reveal" their costs, thereby ensuring that low-cost suppliers are those that end up providing the energy expansion. It is also easier to target certain NTRE sources and, given that a defined quantity will be produced, the government can more easily determine budget implications (Bjork et al., 2011). However, disadvantages include greater opportunities for corruption, including the incentives for bidders to make low cost offers that are unrealistic (and thus may be renegotiated at a higher rate in order to complete the project *ex post*, thereby negating the benefit of bidding versus other mechanisms), or that winning bidders then cut corners and construct inferior NTRE plants (Bjork et al., 2011; Dolezal et al., 2013). As with tariff setting, evaluating bids requires knowledge; in this case, the agency in charge of evaluating bids needs sufficient knowledge to weed out unrealistic bids. And, as with FiTs, these are generally long-term contracts leaving the government with relatively limited flexibility in the face of changing circumstances.

Fiscal incentives include such mechanisms as capital cost subsidies, loan guarantees, production tax credits, and reductions in sales tax, tax incentives or grants for R&E expenditures, and import duty waivers on renewables technologies (REN21, 2012; Bjork et al., 2011; Cherni, 2011). These instruments reduce costs for potential investors, but otherwise do not provide the same risk reduction role that the guaranteed price and mandatory purchase agreement schemes do. Setting such incentives does require some information in order to avoid under- or over-providing incentives given social goals, but they can also be more easily changed than the more elaborate price or quantity target schemes, thereby giving more flexibility to the regulatory authorities. Of course this flexibility means that adopting such mechanisms provide rather limited evidence of credible government commitment to NTRE expansion.

Finally, structural incentives include the basic legal right to provide NTRE to the grid and/or to distributed systems, as well as giving NTRE suppliers guaranteed or priority access to the grid. Implementing guaranteed or priority access to the grid for renewables expands the scope for renewables to reach grid-connected users, but often requires somewhat complex regulatory changes and investments in grid infrastructure (Bjork et al., 2011; Garcia, 2013). While some political risk remains that regulations that guarantee or give priority access may be repealed, significant investments in infrastructure that enable such access reduce the riskiness of investing in NTRE capacity.

To summarize, each of the different regulatory mechanisms have different costs and benefits to potential investors, and in terms of regulatory credibility and flexibility. Quantity targets rely more heavily on market mechanisms to induce expansion of NTRE via mandatory demand on the part of electricity providers; however, in and of themselves, they do not reduce price risk. Price guarantees set by a regulator do reduce price risks for the investor, but in the absence of very good information, such price schemes can lead to either lower-than optimal expansion or to relatively high-cost NTRE investments. Such schemes also provide limited incentives to innovate and reduce costs. Public bidding, for long-term contracts that provide price certainty and often guaranteed sale quantities, can induce lower costs, but also require sufficient knowledge to weed out poorly structured bids and possibly corrupt practices. Long-term contracts provide reduced long-term risks for NTRE investor, but this means that they are less flexible in responding to either new information or unanticipated future shocks. Fiscal incentives are more flexible and generally require less information, but of course, do not reduce long-term risks. Finally, structural changes that expand access to either the grid or to distributed systems expand potential demand; but do not directly reduce risks for investors. They also often entail large-scale investments up-front on the part of the government so that they afford less flexibility. Of course, countries can, and often do, implement more than one of the incentive mechanisms as discussed above. For instance, most countries with legally binding energy targets also have some type of premium pricing scheme, as well as fiscal incentives as detailed below.

2.2 Selected Country Experiences

Cherni (2011) reviews the experience of Argentina, Brazil and Peru. In Argentina, one of the main goals of the government since the late 1990's has been to expand access to electricity in rural areas, large World Bank loans supported renewable energy development in rural areas. On the other hand, Argentina also has both large hydropower and natural gas reserves, which are cheap and relatively "clean" alternatives to NTRE, so that subsidies need to be relatively high for NTRE to be competitive vis-à-vis countries with limited natural gas reserves. In terms of policy, Argentina was one of the first countries to establish a voluntary target and to introduce feed-in tariffs for wind power in 1998. FiTs were then subsequently faded out, and replaced by public competitive bidding 2006. The feed-in tariff program guaranteed a price premium for wind and solar energy for 15 years, and also provided other tax incentives. In hindsight, it became clear that two factors impeded the growth in NTRE from this program, the first being the limited focus on just wind and solar (thereby excluding small-scale hydro, biomass and biogas, for instance). The second was currency devaluation experienced in the early to mid-2000's, since the FiTs were paid in local currency. With respect to public competitive bidding, the return on investment targeted was 14%, which is far more generous than the FiTs program. While investment has been uneven in the last decade, Argentina has the second largest growth rate in renewables investment[3] in the period 2005-2010, at 115%; and the sector expanded 568% in 2009-2010 alone (PEW, 2011). The largest share of this investment went to biofuels development in order to displace oil, though wind investments have also garnered a large share of investment, particularly more recently (PEW, 2011).

Brazil has adopted many policies to promote renewables, including FiTs and guaranteed sale, public competitive bidding, and state financing and subsidies (Cherni, 2011). At the same time, Brazil is one of the world's largest hydropower producers, and also has substantial natural gas and oil reserves (PEW, 2011). Brazil also set a legally binding target of 10% NTRE in 2002, to be met in 20 years; NTRE stood at about 3% in 2002, and had increased to about 6% in 2010 indicating they are on track (Cherni, 2011). As with Argentina, Brazil relies on public competitive bidding to identify low-cost suppliers with whom they then enter into 20-year contracts with set prices (including a premium that adjusts to a market index), and has also experimented with feed-in tariff programs tied to guaranteed sale, such as Proinfa

[3] Investment figures provided in the PEW report are based on the following renewable energy projects: wind generation of more than 1MW, hydro projects between .5 and 50MW, solar projects of .3MW or greater, and all biofuel projects with capacity of 1M liters per year or more.

(Bloomberg New Energy Finance, 2011). However, as with Argentina, Brazil appears to be favoring a move towards public competitive bidding; Proinfa was replaced with a public tendering system in 2010 (Bloomberg New Energy Finance, 2011). Since 2004, Brazil has also implemented import duty waivers on select NTRE technologies and has put in place fiscal incentives to spur investment (Cherni, 2011). In terms of expansion over the 5-year period 2005-2010, Brazil was sixth in the world, posting a 5-year growth rate of 81%; 40% was invested in biofuels, 31% in wind, and 28% in "other" (PEW, 2011).

Peru has also enacted policies to promote renewable energy, particularly in programs aiming to increase rural electrification since 2002. Instruments include preferential premiums through a feed-in tariff scheme since 2008, along with guaranteed sale to the grid and fiscal incentives (Cherni, 2011). In 2008, the government adopted a new RE law that includes a binding target of 5% by 2013, with a target of expanding capacity by 500 MW per year (Cherni, 2011). Nonetheless, according to EIA, the share of NTRE in electricity generation was just 1.54% in 2010, up only 4% from the 1.48% in 2008. Peru has s moderate level of installed capacity for hydro-electric, as well as moderately high potential to expand large hydro, and also has relatively large natural gas reserves relative to domestic demand that may reduce incentives to vigorously pursue NTRE (Cherni, 2011). Finally, Peru has recently engaged in public competitive bidding via an auction in 2009-2010, resulting in licenses for 300 MW of solar, wind and biomass provision (PEW, 2011). Twenty-year contracts are written with independent power producers, which include a price premium that differs by type of energy. Cherni (2011), citing Global Feed-in Tariffs, notes that these premiums are quite a bit below the current premiums in Argentina, though the auctions were still successful. A second round of auctions – targeting biomasss and solar – were not as successful, and low premiums are cited as being a major factor (Cherni, 2011).

Mexico has also been very active in promoting NTRE, through both energy sector policies and regulations and under the rubric of cross-sectoral climate-change initiatives. Mexico has installed nearly 1GW in wind energy capacity, and provides price premiums to wind, biomass and geothermal energy generators (PEW, 2011). Mexico also provides a 50-70% discount on power transmission for RE plants with capacity of 500 KW or more (PEW, 2011). Mexico also has a very rich legal and regulatory framework for promoting renewable energy, including import duty waivers, fiscal incentives, guaranteed access to the grid, and public competitive bidding; they have also created transmission contracts that aim to stabilize incomes given fluctuating wind energy produced (Climatescope, 2012; Dyson et al., 2011).

Finally, Colombia also adopted a renewable energy policy framework and implementing legislation in 2002 and 2003[4]. However, the only specific incentive for potential NTRE electricity suppliers is a fifteen-year tax exemption for wind energy. To obtain this tax benefit, suppliers must obtain carbon emission certificates from the Clean Development Mechanism, and then invest at least 50% of income from the carbon certificates into social benefit programs (Vergara et al., 2010). Observers have argued that such limited incentives are the main reason for limited investment, with just one wind farm currently in operation (Dyner et al., 2011; Vergara et al., 2010).

[4] Details are provided in Law 697, 2001; Law 788, 2002; and Decree 3683, 2003.

Looking at the country-case studies presented above, it remains quite difficult to determine which policies – or policy mix – are the most effective at spurring NTRE at least cost. As noted above, an over-riding concern of many potential private investors is long-term government commitment to support expansion. Signing long-term contracts is one mechanism to provide assurances of return on investment, as is enacting legally binding targets. Non-binding targets may provide some assurances, but likely only when undertaken with other more substantial measures such as long-term contracting with price guarantees, guaranteeing access to the grid, etc. Competing domestic sources of fossil fuels and large hydropower can also hinder the development of NTRE via increased opportunity costs; additionally, large domestic conventional energy interests can also influence NTRE regulation development and implementation (PEW, 2011).

3. Data and Descriptive Statistics

3.1 Data Sources

Our dependent variables, NTRE growth rate, was constructed using historical information on non-hydropower renewable electricity generation obtained from the US Energy Information Administration (EIA) website (http://www.eia.gov/countries). As noted above, small hydropower is often considered a non-traditional renewable energy source, but no database includes this disaggregated information consistently for all countries in our sample.

Our starting point for compiling the policy and regulatory variables for the database was the Renewable Energy & Energy Efficiency Partnership (REEEP) database, which provides summaries of the legal and regulatory framework for renewable energy. The REEEP database had at least some information available for all countries included in this study[5]. We then consulted the REN21 database on renewable energy support policies, which also provides information on a number of regulations, as well as a report on renewable energy regulations prepared for the World Bank (Andres et al., 2007). Information from these three sources was used as a starting point for further research, since these databases were not necessarily up to date, not always consistent, and critically, often did not provide dates on which the laws and regulations were enacted. To get information on dates that laws were enacted, we then turned to the internet, and used the Google search engine to search for specific laws and regulations in each of the 27 countries, in order to verify information in the REEEP and REN21 databases and to determine the dates various laws were enacted and regulations implemented[6]. This resulted in a database of information on the years in which a country had adopted a specific renewable energy law, legally binding quantity targets, non-legally binding quantity targets, feed-in tariff schemes, public competitive bidding, guaranteed or priority access to the grid, domestic fiscal incentives, and import duty concessions on renewable energy equipment.

[5] For instance, summaries for some countries have far more detail than others, but absence of information in the summary did not necessarily mean that a country did not have some specific type of regulation.
[6] In Appendix 1, we document the laws that were reviewed to create the database. Additionally, the database itself is available in an excel spreadsheet which cites to the relevant source of information for each cell.

In addition to NTRE-specific instruments, we also collected information on broader energy-sector policy regulations, including whether the country has an independent energy sector regulator[7] and whether or not regulations allowed for independent power producers. Many countries in Latin America underwent significant energy sector reforms in the 1990's, so that by 2000, 18 countries had independent regulators and allowed for independent power producers (Cherni, 2011). Both policy variables are expected to have a positive impact on NTRE growth rates by limiting political risks associated with non-independent regulators, and fostering competition by expanding the number of potential power producers. Information on whether and when such policies were adopted was obtained from the same sources as for the NTRE-specific policy variables, including REEEP, REN21, Andres et al. (2007) and country-level laws and regulations.

We then collected data on other control variables associated with NTRE expansion, including NTRE potential, extent of fossil fuel reserves, national wealth, and previous investments in the sector by multilateral institutions. With respect to NTRE potential, we obtained data on wind and solar potential from the Solar and Wind Energy Resource Assessment (SWERA), data on geo-thermal potential from the Geothermal Energy Associate website, and, to proxy biomass potential, data on arable land per capita from the World Bank[8]. We expect greater NTRE potential to be associated with lower generation costs, and thus to lead to higher NTRE growth rates (Burke, 2012). There is also some evidence of economies of scale in NTRE generation and distribution, which would reinforce the positive impact of NTRE potential on growth rates (Wiser et al, 2010; Hearps & McConnell, 2011). Data on fossil fuel reserves was obtained from the US Energy Information Administration (EIA), and included data on petroleum, natural gas, and coal reserves. Fossil fuel reserves can dampen incentives for governments to vigorously pursue investments in NTRE (Cherni, 2011; Burke, 2012). On the other hand, countries with a long history of fossil fuel-based electricity generation often have the regulatory experience and infrastructure to more easily accommodate expansion into NTRE (Burke, 2012). Thus, the hypothesized impact of fossil fuel reserves is ambiguous. Finally, we obtained historical information on GDP per capita, in real 2000 US dollars from the World Bank, to account for different wealth levels on growth rates. Following the logic from the environmental Kuznets curve, once economies are sufficiently large per capita, we would expect greater investments in clean technologies (Andreoni & Levinson, 2001; Tahvonen & Salo, 2001). However, such economies also need more energy, and governments may rather pursue cheaper fossil fuel alternatives. Kijima et al. (2010) do find some experimental support in favor of the Kuznets' inverted-U hypothesis, though noting inherent empirical difficulties in determining the relationship. We thus include both GDP per capita as well as its square to test the impact on NTRE growth rates.

Finally, many multilateral investment banks and institutions such as the Global Environmental Fund have made loans for countries to expand renewable energy generation, either as direct renewable energy

[7] Determining whether or not the energy regulator is "independent" requires some interpretation. As documented in the dataset, we used information from the World Bank's assessment of energy sector regulations (Andres et al., 2007), which differed from the Renewable Energy and Energy Efficiency Partnership database on determining whether a regulator was deemed independent. In particular, the World Bank assessment considers that both Honduran and Costa Rican regulatory agencies are independent, whereas the REEEP does not.

[8] See appendix 2 for exact definitions, and source information.

investment loans or for “policy-based loans” that are focused on aiding governments in establishing the legal and regulatory framework necessary to promote NTRE expansion. We obtained historical information from the World Bank, Inter-American Development bank and the Clean Development Mechanism on investments in renewable energy, and from the Global Environmental Facility and the Inter-American Development bank on policy based loans. Many of these projects were operational for more than one year but with limited information on the amount disbursed per year; in these cases, we assigned proportional disbursements across the number of years of project operation. Using a one-period lag, we hypothesize that multi-lateral funded investments have an indirect impact on NTRE growth rates by either helping to create the an enabling policy framework for NTRE expansion and by investments that establish “proof of concept” (Griffiths-Jones et al., 2012). Both of these indirect impacts are expected to help mobilize funds from private-sector investors (Griffiths-Jones et al., 2012). Similarly, the policy-based loans should also have a direct positive impact on growth rates through an improved legal and regulatory framework; again, we use a one-period lag to capture these potential impacts.

3.2 Descriptive Statistics

NTRE and Energy Sector Laws and Regulations

As shown in Table 1, of the 27 countries in the database, 15 have specific renewable energy laws and regulations. Four countries have legally binding targets for renewable energy as a share in the overall energy mix; Brazil has a target of 10% by 2029, the Dominican Republic has a target of 10% by 2015, and 25% by 2025. Chile has a binding target of 5% by 2010, and also a non-binding target of 20% by 2020. Peru is a somewhat difficult case to classify in terms of binding vs. non-binding targets; legislation in 2008 provides for increasing NTRE up to 5% per year, giving the Ministry of Energy and Mines the authority to set the exact percentage; and also provides for setting up and auction system and price guarantees (Decreto Legislativo No. 1002). In the analysis below, we have chosen to code Peru as having binding legislation from 2008. Non-binding targets are considered to be a considerably weaker signal than legally binding ones. In addition to Chile, 9 countries have non-binding targets, including Argentina, Colombia, Ecuador, Honduras, Jamaica, Mexico, and Uruguay. Feed-in-tariffs were adopted in Argentina, Brazil, the Dominican Republic and Peru by 2008; more recently both Nicaragua and Jamaica have also adopted FiTs. Nine countries have adopted public competitive bidding, including Argentina, Brazil, Costa Rica, Guatemala, Honduras, Jamaica, Mexico, Peru and Uruguay. By 2010, 12 countries had guaranteed or priority access to the grid, 15 countries had import duty reductions or waivers on renewable energy – related imports, and 13 countries had tax incentives. This is in contrast with 2000, where just 3 countries had guaranteed access to the grid, and just 4 countries had import duty reductions/waivers and tax incentives for businesses.

Table 1: NTRE Legal and Regulatory Instruments, by Country, 2010

	NTRE Specific Legislation	Legally Binding Targets	Non-Legally Binding Targets	Import Waivers	Fiscal Incentives	Public Competitive Bidding	Feed-In Tariffs	Guaranteed Grid Access
Antigua and Barbuda	0	0	0	0	0	0	0	0
Argentina	1	0	1	0	1	1	1	1
Bahamas	0	0	0	0	0	0	0	0
Barbados	0	0	0	1	0	0	0	0
Belize	0	0	0	1	0	0	0	0
Bolivia	0	0	0	0	0	0	0	0
Brazil	1	1	0	1	1	1	0	1
Chile	1	1	1	1	0	0	0	1
Colombia	1	0	1	1	0	0	0	0
Costa Rica	1	0	0	1	1	1	0	1
Dominican Republic	1	1	0	1	1	0	1	1
Ecuador	1	0	1	0	0	0	0	1
El Salvador	1	0	0	1	1	0	0	0
Grenada	0	0	0	0	0	0	0	0
Guatemala	1	0	0	1	1	1	0	0
Guyana	0	0	0	0	0	0	0	0
Honduras	1	0	1	1	1	1	1	1
Jamaica	0	0	1	1	0	1	1	1
Mexico	1	0	1	1	1	1	0	1
Nicaragua	1	0	0	1	1	0	1	1
Panama	1	0	1	1	1	0	0	0
Paraguay	0	0	0	0	0	0	0	0
Peru	1	1	0	0	1	1	1	1
Suriname	0	0	0	0	0	0	0	0
Trinidad and Tobago	0	0	0	1	1	0	0	0
Uruguay	1	0	1	1	1	1	0	1
Venezuela	0	0	0	0	0	0	0	0

NTRE Potential

The countries with the greatest potential for wind include Brazil, Peru, Argentina, Ecuador and Chile; countries with limited wind potential include The Bahamas, Barbados, Grenada, Guyana, Jamaica, Panama, Suriname and Trinidad and Tobago. With respect to solar, again the small Caribbean countries have limited total solar potential with the exception of Grenada, as does El Salvador, Costa Rica and the Dominican Republic, though the Caribbean countries do have relatively high solar potential relative to their size. Brazil, Argentina, Mexico and Peru have relatively high solar potential, whereas Guyana and Suriname have relatively moderate solar potential. A similar pattern holds for arable land per capita. In fact, the correlation coefficients between wind, solar and arable land are all above .9. Geothermal potential is less correlated with other NTRE potential sources. Mexico has the greatest potential followed by Nicaragua, Guatemala and Peru, whereas most Caribbean countries, Uruguay and Paraguay have no geo-thermal potential. The correlation coefficients for total NTRE electricity generation with respect to wind, solar, arable land and geothermal are .78, .84, .87 and .29, respectively.

NTRE Substitutes

Having other domestic energy sources, including oil, gas and large hydropower, may either foster or dampen incentives to expand NTRE capacity. The correlation coefficients between potential NTRE sources and oil and gas reserves are all positive, .17 and .01, respectively. The correlation coefficients between actual NTRE and oil and gas reserves are similar, .11 and .01, respectively. While Brazil, Argentina and Mexico have significant fossil fuel reserves as well as actual and potential NTRE, other countries with large hydropower and/or fossil fuel production have limited actual NTRE levels, including Bolivia, Trinidad & Tobago, Uruguay and Venezuela.

The above trends can be seen by looking at tables that segment countries according to high and low NTRE in 2010, and: 1) high and low wind and solar potential, and 2) high and low fossil fuels. We considered "low" actual NTRE in 2010 to be those values below the median value for countries with any NTRE, and at or above the median value to characterize "high" actual NTRE. Given that wind, solar and biomass potential are all highly correlated, we use above and below median wind potential to create categories for high and low potential in table 2. Gas and oil reserves are also highly correlated (.92), so we used values above and below median oil reserves to create categories for table 3.

Table 2: Actual and Potential NTRE

	High Actual NTRE, 2010		Low Actual NTRE, 2010	
High NTRE Potential	Argentina Brazil Chile Columbia	Nicaragua Mexico Peru	Bolivia Ecuador Venezuela	
Low NTRE Potential	Costa Rica El Salvador Guatemala		Antigua & Barbuda Bahamas Barbados Belize Dominican Republic Grenada Guyana	Honduras Jamaica Panama Suriname Trinidad & Tobago Uruguay

Table 2 captures highlights the positive correlation between potential and existing NTRE generation in 2010, since most countries with high potential have high actual NTRE, and particularly because those with low NTRE potential have low actual levels of NTRE in electricity generation. Even so, of countries with high potential, only Brazil, Chile and Mexico have really begun to exploit that power. Bolivia, Ecuador and Venezuela look particularly attractive for future investment given high potential but limited actual installed capacity for electricity generation.

Table 3: Actual NTRE and Oil Reserves

	High Actual NTRE	Low Actual NTRE	
High Oil Reserves	Argentina	Ecuador	
	Brazil	Trinidad & Tobago	
	Columbia	Venezuela	
	Mexico		
Low Oil Reserves	Chile	Antigua & Barbuda	Guyana
	Costa Rica	Bahamas	Honduras
	El Salvador	Barbados	Jamaica
	Guatemala	Belize	Panama
	Peru	Bolivia	Suriname
	Nicaragua	Dominican Republic	Uruguay
		Grenada	

As noted above, many countries that have high NTRE potential are also those with high oil and gas reserves, and for many, high potential for expanding large hydro-power as well. Table 3 looks at the categorization of countries by actual NTRE levels in electricity generation and by oil reserves. There is a great deal of overlap of the placement of countries according to both high and low NTRE Potential and according to high and low oil reserves. All of the countries with high actual NTRE but relatively low potential all have low oil reserves as well, namely Costa Rica, El Salvador and Guatemala. There are some notable exceptions, highlighted in Table 3 by underlined countries. Chile, Peru and Nicaragua have limited oil reserves but high NTRE potential, and all three have high actual NTRE. On the other hand, Trinidad and Tobago has high oil reserves, but low NTRE potential, and low actual NTRE. Bolivia has limited oil reserves and limited actual and potential NTRE, though Bolivia also relies heavily on large hydropower and has significant potential to develop large hydropower even further.

4. Empirical Analysis:

4.1 Methodology

We conceptualize NTRE growth as a first-order Markov process and, in what follows, outline a semi-parametric, information-theoretic approach to estimating a first-order Markov model. A first-order Markov process consists of three principal quantities: (1) a finite and mutually exclusive set of states of nature; (2) the distribution of entities among those states of nature; and (3) a transition probability matrix (TPM) whose elements are the probabilities of moving among the states of nature. In our specific case, the states of nature represent NTRE growth regimes, the entities are countries, and the TPM captures the probabilities of countries transitioning among growth regimes.

Following Golan (2008), consider the following stationary first-order Markov model:

$$y_{itj} = \sum_{k=1}^{K} p_{kj} y_{i,t-1,k} \qquad (1)$$

where for country *i* at time *t* the binary variable $y_{itj}=1$ if state *j* is observed and zero otherwise. Further, p_{kj} represents elements of the TPM *P,* which is a $K \times K$ matrix of unknowns where $\sum_j p_{kj}=1$. Accounting for noise in the data, we can write the above moment condition as follows:

$$y_{itj}=\sum_{k=1}^{K} p_{kj} y_{i,t-1,k}+\varepsilon_{itj} \tag{2}$$

or

$$y_{itj}=\sum_{k=1}^{K} p_{kj} y_{i,t-1,k}+\sum_{m=1}^{M} w_{itjm} v_{jm} \tag{3}$$

where the zero mean disturbance $\varepsilon \in [-1,1]$, *v* is an $M \geq 2$ dimensional support vector for state *j*, and *W* is the set of probability distributions defined on the support vector such that their expected value is ε_{itj} .

We can further let this Markov process be conditional on individual country characteristics. Accordingly, we model p_{kj} as a function of explanatory variables z_{its} where *s* denotes a given explanatory variable for country *i* at time *t*. Such country covariates can be introduced via the cross moments as follows:

$$\sum_{t=2}^{T}\sum_{i=1}^{N} y_{itj} z_{its}=\sum_{t=1}^{T-1}\sum_{i=1}^{N}\sum_{k=1}^{K} p_{kj} y_{itk} z_{its}+\sum_{t=1}^{T-1}\sum_{i=1}^{N}\sum_{m=1}^{M} z_{its} w_{itjm} v_{jm}, \tag{4}$$

which then yields a system of *KS* equations. In examining Eq. (4), it is evident that in most applications the number of unknown quantities will exceed the number of known quantities. In an attempt to introduce minimal *a priori* assumptions, we thus estimate Eq. (4) via a semi-parametric, information-theoretic estimation technique that is based on Shannon's (1948) entropy or uncertainty measure.

Consider first estimating *P* within a pure inverse framework (i.e. Eq. [1]). Jaynes (1957a, b) proposed a constrained optimization problem that maximizes Shannon's entropy measure

$$H(\mathbf{p})=-\sum_{k=1}^{K}\sum_{j=1}^{K} p_{kj} \ln p_{kj} \tag{5}$$

subject to the appropriate moment consistency (i.e. Eq. [1]) and proper probability constraints. The entropy measure $H(\mathbf{p})$ is defined on a set of proper probabilities and reaches a maximum when $p_{k1}=p_{k2}=\cdots=p_{kK}=1/K$ for all *k*.[9] Simply stated, maximum entropy (ME) formalism amounts to selecting the most uniformly distributed *P* (i.e. the most conservative estimates) among those values of *P* that satisfy the specified constraints.

Termed generalized maximum entropy (GME), the above is readily generalized to incorporate noise as follows:

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[9] Note also that $p_{kj} \ln p_{kj}=0$ for $p_{kj} \to 0$.

$$H(\mathbf{p},\mathbf{w}) = -\sum_{k=1}^{K}\sum_{j=1}^{K} p_{kj} \ln p_{kj} - \sum_{i=1}^{N}\sum_{t=1}^{T-1}\sum_{j=1}^{K}\sum_{m=1}^{M} w_{itjm} \ln w_{itjm} \tag{6}$$

where *P* and *W* remain as defined above and the intuition regarding the solution is identical to that of the pure inverse problem. To estimate the conditional Markov model, we thus maximize Eq. (6) subject to Eq. (4) and the appropriate proper probability constraints. The reader is referred to Golan (2008) for the solutions, discussion of efficient computation via the unconstrained dual formulation, and issues of inference.

Another methodological consideration pertains to examining the effects of the explanatory variables on the number of entities in each Markov state. Following Karantininis (2002) as well as Tonini and Jongeneel (2009), the following elasticity is calculated:

$$E_{js}^{y} = \left(\sum_{k=1}^{K} \frac{\partial \hat{p}_{kj}}{\partial \bar{z}_s} \cdot \bar{y}_k \right) \frac{\bar{z}_s}{\bar{y}_j} = \frac{\partial \bar{y}_j}{\partial \bar{z}_s} \frac{\bar{z}_s}{\bar{y}_j} = \frac{\bar{z}_s}{\bar{y}_j} \left[N(T-1) \sum_{k=1}^{K} \hat{p}_{kj} \bar{y}_k^2 \left(\hat{\lambda}_{sj} - \sum_{j=1}^{K} \hat{p}_{kj} \hat{\lambda}_{sj} \right) \right] \tag{7}$$

where bar notation denotes sample means. In brief, the above elasticity captures the percentage change in the proportion of entities in state *j* for a given percentage change in explanatory variable *s.*

Finally, to determine the mutually exclusive growth rate regime states, we employed a k-means analysis to determine both the appropriate number of clusters and the ranges of each cluster. Noting that the k-means clustering technique does not handle extremes well (Hautamaki et al. 2005), we performed the analysis dropping the observations in the lowest and highest 10% of the sample (Bahr, 2010. We chose the number of bins by examining the within-group sum of squares, which resulted in the choice of 5 bins. The first bin contains negative growth rates, the range of the second bin is -.08 to .045, the range of the third is .0451 to .15, the fourth is .151 to .35, and the fifth contains all higher growth rates. For simplicity, we will refer to these as negative, zero, low, moderate and high growth rate regimes.

4.2 Results

Tables 4 and 5 present the transition probability matrix and state elasticities, respectively. Regarding Table 4, each entry of the matrix provides the probability of transitioning from the corresponding row state to the corresponding column state. First we note that the probability of staying in the same growth rate regime from one period to the next is greater than 75% across all regimes, and is particularly high for those with zero growth (95%) and for those with negative growth rates (90%). From both negative and zero growth regimes, the next highest transition probability is to the low growth regime. For the three positive growth regimes, the next highest transition probabilities are into neighboring positive growth regimes. For instance, the probability of transitioning to a moderate rate from a low rate is .125, whereas the probability of transitioning from a moderate to low rate .146. To summarize, there are higher transition probabilities within the positive growth rate regimes, and lower probabilities of moving out of negative and zero growth rates.

Table 4: Transition Probability Matrix

Growth Regimes	Negative	Zero	Low	Moderate	High
Negative	0.903	0.006	0.089	0	0.001
Zero	0.002	0.946	0.029	0	0.023
Low	0.016	0	0.858	0.125	0
Moderate	0.027	0.037	0.146	0.752	0.037
High	0.021	0.021	0.017	0.191	0.757

As can be seen in table 5 below, of the policy variables, import duty waivers and fiscal incentives have relatively high elasticities with respect to the moderate and high growth rate regimes, whereas guaranteed access to the grid has a particularly high elasticity with respect to high growth rates. Specifically, a one percent increase in the proportion of countries with import duty waivers (fiscal incentives) is associated with a one percent increase in the proportion of countries in the high growth state. The two types of contracts, public competitive bidding and feed-in tariffs generally have negative elasticities with respect to moderate and high growth, though they both have relatively high and positive elasticities with respect to low growth. Elasticities for binding agreements are similar to those for public competitive bidding and feed-in tariffs. Non-binding agreements have much more muted impacts, though they do lead to movements into all three positive growth regimes. Taken together, these results suggest that both financial incentives and reducing risk via guaranteed access to the grid are important in fostering higher NTRE growth rates. Quantitiy target agreements alone generally have relatively muted impacts. More striking is the negative impacts of the two contract variables on high and moderate growth rates. Such contracts generally provide financial incentives via subsidized rates and they also guarantee sales, which reduce risks to the producer over the lifetime of the contract. Nonetheless, implementing these (more) market-based mechanisms appears to slow down growth rates, at least over the time period covered here. It may simply be that more time is needed for the governments to efficiently administer such mechanisms and perhaps to gain trust of the industry that such contracts will continue to be honored throughout their duration.

The energy sector regulatory variables have distinct impacts; neither has a high elasticity with respect to the high growth regime, but an independent regulator appears to pull some of the low growth countries into the moderate growth regime whereas independent power producers appears to pull countries to the low growth regime, from both moderate and zero growth rate regimes. The varying signs of the elasticities point to the ambiguous impact of these variables discussed above; they are both generally associated with countries that have a more sophisticated energy sector but that also have fossil fuels and large hydropower.

With respect to other variables of interest, we note that NTRE generation potential, in terms of wind power potential and arable land per capita, have high positive elasticities with respect to moderate growth, and to a lesser extent, with high growth rates. Hydropower potential has both positive and negative elasticities with respect to the positive growth regimes, and also has positive, though small, elasticities with respect to negative and zero growth. As with the energy sector regulations, hydropower has an ambiguous hypothesized relationship to NTRE expansion, and that is reflected in the elasticities presented here. Finally, external donor-based investments have relatively small elasticities, except for the case of World Bank investments, which have a relatively high positive elasticity with respect to moderate growth. The lagged policy-based loans both have negative elasticities with respect to the high growth rate regime. GEF-based loans do have a positive elasticity with respect to moderate growth rates, and IDB-based loans to low growth rates. The latter results imply that there is room to improve the performance of these loans so that their impact is more strongly related to helping countries transition out of negative or zero growth rates and into moderate and high growth rate regimes.

Table 5: Elasticities with respect to Explanatory Variables

Explanatory Variables / Growth Regimes	Negative	Zero	Low	Moderate	High
Legally Binding Agreement	-0.387	-0.367	1.734	-0.156	-0.679
Non-Legally Binding Agreement	0.076	-0.284	0.414	0.306	0.592
Import Waivers	-0.292	-0.301	-0.097	1.325	0.938
Fiscal Incentives	-0.042	0.367	-2.442	0.853	1.841
Feed-in-Tariffs	-0.051	-0.401	3.858	-2.225	-3.012
Public Competitive Bidding	-0.114	-0.243	1.630	-1.350	-0.064
Guaranteed Access to Grid	0.093	-0.944	0.747	-1.840	7.336
Independent Regulator	-0.632	1.742	-6.390	2.278	-0.211
Independent Power Producers	1.039	-1.458	5.915	-3.016	-0.015
Post-Copenhagen Dummy	0.155	0.310	-0.883	-0.043	-0.323
Wind Potential	-0.153	0.140	-4.064	4.801	2.058
Hydro Potential	0.805	0.070	1.882	-6.052	2.316
Land Potential	-0.932	0.461	-2.991	3.592	-0.202
Oil Reserves	-0.066	0.081	-0.482	0.747	-0.396
Gas Reserves	0.011	0.036	0.143	0.059	-0.670
GDP per capita	-0.028	-0.550	3.046	-2.650	0.534
World Bank Investments, t-1	-0.434	-0.195	-0.880	3.765	-1.094
CDM Investments, t-1	0.124	-0.046	0.190	-1.254	1.412
IDB Investments, t-1	-0.001	0.006	-0.026	0.048	-0.047
GEF RE Policy Loan, t-1	0.464	0.697	-1.624	1.441	-3.683
IDB RE Policy Loan, t-1	-0.051	-0.054	1.242	-0.964	-1.169
NTRE Levels, t-1	0.291	0.809	-0.153	-0.037	-5.676

4.3 Using the Analysis to Rank Countries in Terms of Attractive NTRE Expansion Characteristics

Finally, we draw from the results presented above in order to evaluate which countries currently have the most favorable environment for NTRE expansion. Specifically, we run a principal component factor analysis to recover weights to assign to Import Waivers, Fiscal Incentives, Guaranteed Access to the Grid and Wind and Land Potential[10,11], since these factors are associated with high elasticities with respect to the moderate and high growth categories. Brazil, Argentina and Mexico are at the top of the list in that order; even though capacity is already relatively high in those countries, there is still great potential for expansion and the policy environment is particularly favorable in Brazil and Mexico. Peru, Uruguay and Nicaragua also score high on the factor analysis, having both a relatively favorable policy environment as well as high NTRE potential in Peru and Nicaragua, and moderate NTRE potential in Uruguay. The Dominican Republic and Costa Rica have relatively low potential, but the policy environment is favorable in both countries. On the other hand, a number of countries with significant potential do not have favorable policy environments, including Bolivia, Columbia, and Paraguay and Venezuela.

These results can be compared to the country rankings developed in the Climatescope 2012 report, which based its rankings on an aggregated index of 30 indicators, which captured numerical data as well as expert assessments of the policy enabling framework, financing capacity, supply value changes and participation in CDM activities. A direct comparison is difficult, mainly due to the fact that the Climatescope index considered the environment for all renewables, including large hydropower as well as biofuels, whereas the above analysis focuses on NTRE electricity generation only. The rankings from the factor analysis and the Climatescope report are presented in Table 5. First we note that there is more agreement in the rankings for those at the bottom of the rankings. Differences between the top and middle of the rankings is in part due to the broader renewable energy sector focus in the Climatescope mentioned previously. Another reason may be that potential to develop renewable energy sources was not considered separately in the Climatescope report, though it seems to have implicitly affected some of the rankings. Our rankings are explicitly based on underlying potential, which appears to be a particularly important variable in explaining transitions into higher NTRE growth regimes. For instance, in our analysis, Argentina and Uruguay are ranked very high in part due to their relatively large potential, but fall in the middle of the Climatescope rankings. On the other hand, Nicaragua and Panama are ranked in the middle using the factor analysis, largely because they have relatively low total potential, though with moderately and highly favorable policies, respectively. They are ranked 2nd and 3rd in the Climatescope report. Colombia is ranked seventh on Climatescope, but is ranked 15th using the factor analysis. The difference here is mainly due to the fact that, though there is an independent regulator and independent power producers, Colombia has few other NTRE-specific regulations in place. Finally, Colombia does have a biofuels blending mandate, which is a big plus factor for the Climatescope index, but is not part of our analysis.

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[10] Wind and land potential variables were converted to standardized values for the factor analysis.
[11] We evaluated the robustness of the ranking outcomes by looking at a number of alternative specifications, such as equal weighting, as well as the inclusion of legally and non-legally binding agreements as well as public competitive bidding and feed-in tariffs.

Table 5: Country NTRE Expansion Favorability Rankings, Factor Analysis vs. Climatescope

	Factor Analysis Rankings	**Climatescope Rankings - Overall Score**
Countries		
Brazil	1	1
Argentina	2	11
Mexico	3	6
Uruguay	4	10
Peru	5	4
Nicaragua	6	2
Honduras	7	12
Dominican Republic	8	15
Costa Rica	9	8
Chile	10	5
Panama	11	3
Guatemala	12	9
El Salvador	13	13
Jamaica	14	16
Colombia	15	7
Trinidad and Tobago	16	23
Ecuador	17	14
Paraguay	18	18
Belize	19	17
Bolivia	20	19
Guyana	21	24
Barbados	22	20
Venezuela	23	25
Suriname	24	26
Antigua and Barbuda	25	
Bahamas, The	26	21
Grenada	27	
Haiti	n/a	22

5. Concluding Comments

The above analysis uses a unique dataset on 27 countries for 10 years in order to assess evidence of the impact of the regulatory framework on the probability that countries will transition into positive growth rate regimes. Results highlight the importance of policy variables in inducing positive growth rates, though they have mixed effects on which positive growth rate regime will be realized. Transitioning to high growth rates is most strongly influenced by fiscal incentives and guaranteed access to the grid, whereas transitioning to moderate growth rates is most strongly influenced by import duty waivers and fiscal incentives. Binding and non-binding agreements as well as the fixed price contracts generally have negative elasticities with respect to negative and zero growth rates, but mixed effects on transitioning into the positive growth rate categories. The results indicate that the terms of the fixed price contracts employed thus far may not be optimal in generating the hoped-for expansion in NTRE, and that both binding and non-binding agreements are having relatively limited impacts on moderate and high growth rates in and of themselves. The results also highlight the strong impacts of NTRE potential on achieving high growth rates. This implies that countries with more limited potential face additional hurdles, perhaps related to economies of scale, in achieving high growth rates. Interestingly, fossil fuel reserves have relatively muted impacts, likely capturing the benefits of having a relatively mature energy sector against the opportunity costs of developing NTRE. Finally, the policy-based loans do not perform as one would expect. Though GEF loans have a positive elasticity with respect to moderate growth, elasticities are negative with respect to other positive growth categories and positive with respect to negative and zero growth categories. IDB policy-based loans appear to pull countries out of negative and zero growth, though only into the low growth rate regime. Greater analysis of these types of loans and their performance could potentially lead to much greater influence of such loans on NTRE expansion.

There are a number of outstanding issues that require better, and longer-term, data to be rigorously addressed. First, we note that most countries adopted more than one policy, but there were too many combinations in the data to control for each mix chosen. As noted by Fischer and Preonas (2010), there is likely to be more than one barrier or market distortion inhibiting expansion in NTRE, and following Tinbergen (1952), multiple regulatory instruments are required to address these multiple barriers and distortions.

Finally, the analysis above does not shed light on how expensive each particular policy is. Obtaining cost data for implementing each policy across a large number of countries and a wide range of renewable energy source is a daunting task that remains to be done. However, there have been some studies comparing a few renewable energy sources across a few countries with different specific instruments in place, e.g. Butler and Neuhoff (2008). Much more remains to be done to increase the data required to perform such calculations, particularly in the Latin American and Caribbean context.

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Appendix 1: Laws Reviewed

Argentina

Ley 25.019, 1998
Decreto 1597/99, 1999
Ley 26.190, 2006
Decreto 562, 2009

Brazil

Lei No. 9427, 1996
Lei No. 9648, 1998
Lei No. 10.438, April 2002
Resolution ANEEL 219, 2003
Decreto No. 5.025, March 2004

Chile

Ley Nacional No. 19940
Ley Nacional No. 20257
Boletin 7201-08, 2010

Colombia

Decreto 2629, 2007
Decreto Energia No. 1135, 2009

Costa Rica

Ley No. 7447, 1994
Decreto No. 8829, 2010

Dominican Republic

Ley No. 57, 2007
Decreto 202, 2008

El Salvador

Ley No. 462, 2007

Guatemala

Ley No. 52, 2003

Honduras

Ley No. 70, 2007

Jamaica

National Renewable Energy Policy 2009-2030, Ministry of Energy and Mining Paper 124, 2009

Mexico

Ley para el Aprovechamiento de Energías Renovables y el Financiamiento de la Transición Energética, 2008.

Diario Oficial de la Federacion, September 7th, 2001

Diario Oficial de la Federacion, February 26th, 2004.

Nicaragua

Ley No. 532, 2005

Panama

Ley No. 45, 2004

Peru

Decreto No. 021, 2007

Decreto Legislative 1002, 2008

Uruaguay

Decreto 45515, 2007

Decreto 354, 2009

Appendix 2: Data sources

Dependent Variable:
NTRE growth rates, 2000-2010. Data were obtained from the US Energy Information Administration, countries, international energy statistics, electricity generation, total non-hydroelectric renewables. http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=6&pid=29&aid=12

Policy Variables:
In addition to the laws consulted and noted above, we also collected country level information from the Renewable Energy and Energy Efficiency Partnership REEGLE database, http://www.reegle.info/policy-and-regulatory-overviews, and the Renewable Energy Policy Network for the 21st Century (REN 21) database, http://www.ren21.net/RenewablePolicy/GSRPolicyTable.aspx .

NTRE Potential:
Arable land per capita: World Bank, http://data.worldbank.org/indicator/AG.LND.ARBL.HA.PC

Wind potential (Area in square kilometers, of Class 3-7 Wind): Solar and Wind Energy Resourde Assessment (SWERA). http://en.openei.org/apps/SWERA/

Solar Potential (MWh per year>5): Solar and Wind Energy Resource Assessment (SWERA). http://en.openei.org/apps/SWERA/

Geo-Thermal Potential (MWh, from upper bound): from the Geothermal Energy Association. http://geo-energy.org/reports/Geothermal%20Potential%20Preliminary%20Report%20April%201999.pdf

Fossil Fuel Reserves:
Data were obtained from the US Energy Information Administration, countries, international energy statistics, petroleum, natural gas and coal reserves.
http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=6&pid=29&aid=12

Multilateral Investments:
Inter-American Development Bank Renewable Energy Investments (approved), 2000 – 2011. Note that we could not separate out large-hydropower from small hydropower, so that large hydropower investments were included in the investment data used in the above analysis. We included information from projects in the energy sector and the following sub-categories: energy efficiency and renewable energy in end use, low carbon energy technologies, new hydropower projects, new thermal power plants, and rural electrification. http://www.iadb.org/en/projects/projects-by-sector,6785.html

World Bank Investments in Renewable Energy (approved), 2000-2011. Sector Energy and Mining, sub-sectors, other renewable energy, thermal power generation. http://web.worldbank.org/WBSITE/EXTERNAL/PROJECTS/0,,category:majorsector~menuPK:51561~pagePK:95868~piPK:224066~theSitePK:40941,00.html

Clean Development Mechanism Investments (approved), 2000-2011. Project search category "energy industries". http://cdm.unfccc.int/Projects/projsearch.html.

Multilateral Policy Based Loans:
Inter-American Development Bank Renewable Energy Policy Based Loans, 2000 – 2011. We used information from the energy sector, sub-sector: institutional strengthening and capacity building. http://www.iadb.org/en/projects/projects-by-sector,6785.html

Global Environmental Facility Policy Based Loans (approved), 2000-2011. Search for renewable energy, and verified projects that were policy-based versus direct investments. http://www.thegef.org/gef/project_list?keyword=renewable+energy&countryCode=&focalAreaCode=all&agencyCode=all&projectType=all&fundingSource=all&approvalFYFrom=all&approvalFYTo=all&ltgt=lt&ltgtAmt=&op=Search&form_build_id=form-Sl

Wealth:
GDP per capita: constant 2000 US$, World Bank
http://search.worldbank.org/data?qterm=gdp+per+capita&language=EN&op=