THE FINANCIAL SECTOR AND RENEWABLE ENERGY DEVELOPMENT IN NON-OECD COUNTRIES: AN EMPIRICAL ANALYSIS

By

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ABSTRACT

This paper examines the role of the financial sector in the development of renewable energy generation in non-OECD countries. A panel dataset of 156 countries is constructed from 1980-2006. The estimations suggest a positive impact of commercial banking on non-hydro energy production such as wind, solar and geo-thermal. None of the equity market indicators suggest a positive relationship. There is also strong evidence that the Kyoto Protocol has had a positive impact on renewable energy development.

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CHAPTER 1: INTRODUCTION

This paper discusses the relationship between the financial sector and the growth in the renewable energy sector in non-OECD countries. Regions and countries with well-developed financial sectors tend to be wealthier and more developed than regions without a strong financial system. In this paper, I will extend this assumption to the case of renewable energy development; if having a strong financial sector fosters growth in the overall economy, it should also foster growth in the renewable energy sector.

In the last few years, we have experienced a renewed interest in renewable energy as a source of energy production. Although overall renewable energy production is on the rise all over the world, renewable energy production still faces many challenges. High start-up costs, and in some cases high running and maintenance costs, and financing challenges tend to create significant obstacles. Moreover, one of the bigger challenges is that renewable energy projects have to compete with fossil fuel projects; which are usually subsidized, are able to exploit economies of scales, and have proven track records. In the next few decades, most of the world's energy demand will generate from developing or non-OECD countries, and these non-OECD countries will mostly use fossil fuel production to fulfill their growing energy needs, and in the process of doing so, they are expected to become major polluters. This increased fossil fuel production will further deteriorate the earth's environment. It is important to curb reliance on fossil fuels in order to reduce their hazardous environmental impacts and to explore new ways to enhance growth of the renewable energy sector. One of the ways in which we can enhance growth in renewable energy production is to understand the relationship between financial sector and renewable energy growth. Out of the many challenges faced by renewable energy production in non-OECD countries, the lack of a well-developed financial sector is an important one; not having a well-developed financial sector makes financing of renewable projects very difficult. In this paper, I will carry out an empirical analysis to understand the relationship between the financial sector and renewable energy growth, and also analyze the impact of Kyoto protocol on renewable energy production.

In the first part of this paper, I provide an analysis and description of reasons for the importance of renewable energy; how reliance on fossil fuel production makes us vulnerable to energy price volatility and supply disruption. I also outline and discuss the environmental implications of fossil fuel production. Then I discuss the two main reasons for the growth in world energy demand; population growth and growth in income levels of non-OECD countries. I also discuss the various challenges faced by renewable energy projects and then I discuss some policy initiatives such as Kyoto protocol, and also mention Clean Development Mechanism (CDM) and Joint Implementation Program (JM). I haven't discussed other policy initiatives because for the purpose of my analysis I only wanted to focus on the Kyoto Protocol. My literature review discusses various papers that emphasize the importance of having a strong financial sector for the growth of the overall economy, and also the importance of having a strong financial sector in minimizing financing obstacles for businesses. I also discuss banking structure. The literature review also discusses the importance of a well-developed financial sector for the growth of renewable energy development. My empirical analysis is based on the analysis carried out by Brunnschweiler (2009), I have extended her analysis by adding additional variables, and instead of using random effects model as she did, I have used a fixed effects model. I use my methodology to test if having a strong financial system fosters growth in renewable energy production.

CHAPTER 2: UNDERSTANDING THE IMPORTANCE OF RENEWABLE ENERGY

Renewable energy is important for both current and the future generations. In the last few decades, renewable energy has been at the forefront of global energy debate. The reason for this is largely because of the negative impacts fossil fuels have had on global environment in the last century. Furthermore, as global demand of energy increases, fulfilling this demand will not only strain our current fossil fuel resources but also pose further climate change and security challenges (Sadorsky, 2009). "Global energy demand is projected to grow by around 45 percent by 2030: more than three-quarters of the increased demand is predicted to come from developing and transition countries" (IEA, 2008). This increased energy demand will continue to be fulfilled mainly by conventional fossil fuels, such as coal, oil, and natural gas, and consequently energy-related pollution is predicted to increase by up to 45 percent by 2030 (Brunnschweiler, 2009). Although OECD countries will still be major polluters, 97 percent of the estimated increase in pollution will come from non-OECD countries, especially China, India, and the Middle East (Brunnschweiler, 2009). India and China will account for 45% in this increase in energy demand (International Energy Agency, 2007, page 117). Furthermore, many estimates predict that oil and possibly natural gas production will plateau around the same time, casting doubt on future energy security (Brunnschweiler, 2009). Given that fossil fuels are likely to be used to fulfill the predicted increase in global energy demand and that their use will further deteriorate the environment, it is important to find ways to enhance and grow renewable energy sources.

Renewable energy is thought to have the potential to alleviate energy supply and security challenges, and it can also mitigate climate change effects by reducing carbon dioxide and other greenhouse gas emissions (Sadorsky, 2009). Renewable energy is expected to grow at an annual rate of 6.7% between 2005 and 2030 (IEA, 2007, page 74). Although renewable energy continues to grow, its growth is slow and not keeping pace with both the current and the expected future energy demand. Renewable energy still faces many challenges. It is very important to continue to grow renewable energy supply especially when we consider that growing world energy demand will continue to pose even more environmental challenges and energy security concerns such as supply disruption and price volatility for both our current and future energy demand.

2.1: ENERGY SECURITY CONCERNS

Most of the world's proven oil reserves are concentrated in volatile regions where political instability and conflicts have caused oil price fluctuations and supply disruptions in the past and also quite recently. Organization of Petroleum Exporting Countries (OPEC); which includes Middle Eastern countries, Russia and Venezuela hold most of the world's proven oil reserves (British Petroleum, 2008). While OPEC accounts for 75% of global conventional oil reserves (IEA, 2007, page 13), Organization of Economic Cooperation and Development (OECD) member countries account for only 8% of the total reserves but consume over 50% of the world's total oil production (BP, 2005). Four Middle Eastern countries; Saudi Arabia, Iran, Iraq and Kuwait account for 21.3%, 11.2%, 9.3%, and 8.2 % respectively of the world's 1.238 trillion barrels of annual oil production, and these countries collectively account for 50 % of the world's proven oil reserves[1] (British Petroleum, 2008). This uneven global distribution of fossil

[1] Proven oil reserves are defined as the quantity of energy sources that are estimated with reasonable certainty, from the analysis of geologic and engineering data, and these energy

fuel reserves exacerbates energy market volatility (IEA, 2007, page 13). Trade embargoes, sanctions such as the recent sanctions on Iran, conflicts such as Arab-Israeli wars, the Iran-Iraq war in the 80's and the current conflicts and crises in the Middle East and parts of Africa, cause energy supply constraints. Furthermore, energy supply disruptions and constraints can also be caused by accidents or natural disasters such as Hurricane Katrina, and the recent earthquake in Japan. These events can affect any part of the supply chain such as power stations, oil and gas exploration installations, and rail and road networks (IEA, 2007, page 14).

U.S Energy Information Administration (2008) projected that "oil demand will become increasingly insensitive to price which reinforces the potential impact of supply disruption on international oil prices" Oil is required for just about any thing and everything, from transportation to home heating, supply disruption can disrupt our every day life as well as impact business cycles. Furthermore, the International Energy Agency (2006) states that global transport demand, relative to other energy services, is already insensitive to energy price levels. The insensitivity of energy demand to price levels makes it important to maintain a steady energy supply in order to fulfill global transportation demand (IEA, 2007, page 13). The development of renewable energy would not only help in fulfilling global energy demand in an environmentally friendly and sustainable manner but will also reduce our reliance on traditional fossil fuels. Its growth and development will help stabilize energy price fluctuations and will also help mitigate the effects of energy supply disruptions.

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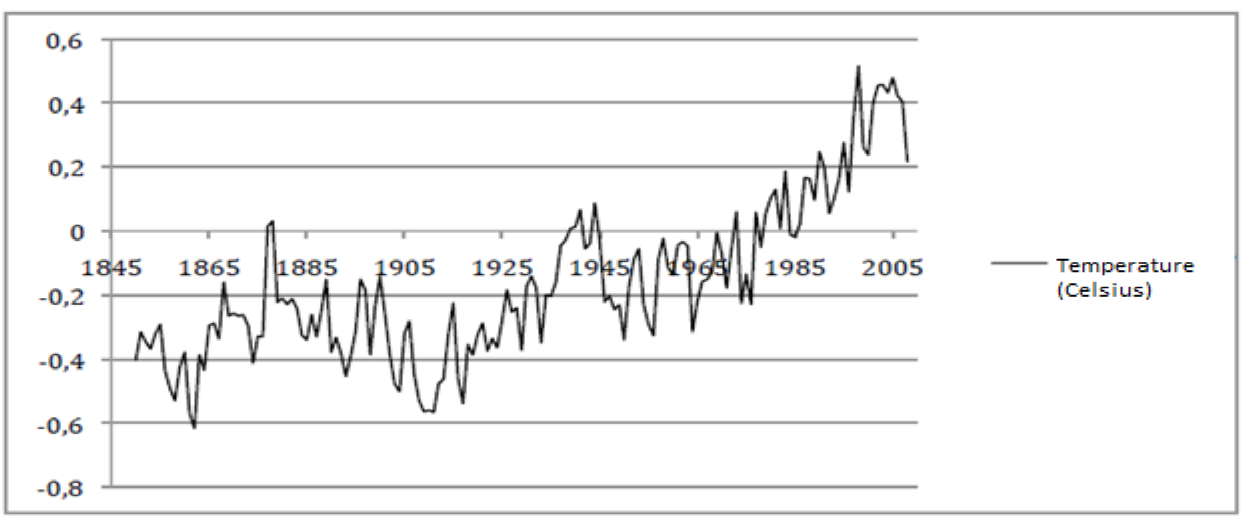
sources are recoverable from well established or known reservoirs with the existing equipment and under the existing operating conditions

2.2: ENVIRONMENTAL CHALLENGES

Burning of fossil fuels causes greenhouse gas emissions, which adversely affects global climate. "If current emission trends continue, the atmospheric build-up of carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), tropospheric ozone (O_3), chlorofluorocarbons (CFCs), and other greenhouse gases released by human industrial, agricultural, and forestry activities, along with the accompanied rise in water vapour concentrations, is likely to turn the planet's atmospheric "greenhouse" into progressively warmer place "(Hoolwerff, 2008). "The average temperature over the first decade of the 21st century was significantly warmer than any preceding decade in the instrumental record, stretching back over 160 years" (UK Met Office, 2012). Figure 1 below shows the variations in the earth's atmosphere over the past 140 years.

Figure 1: Global average temperature 1850-2007

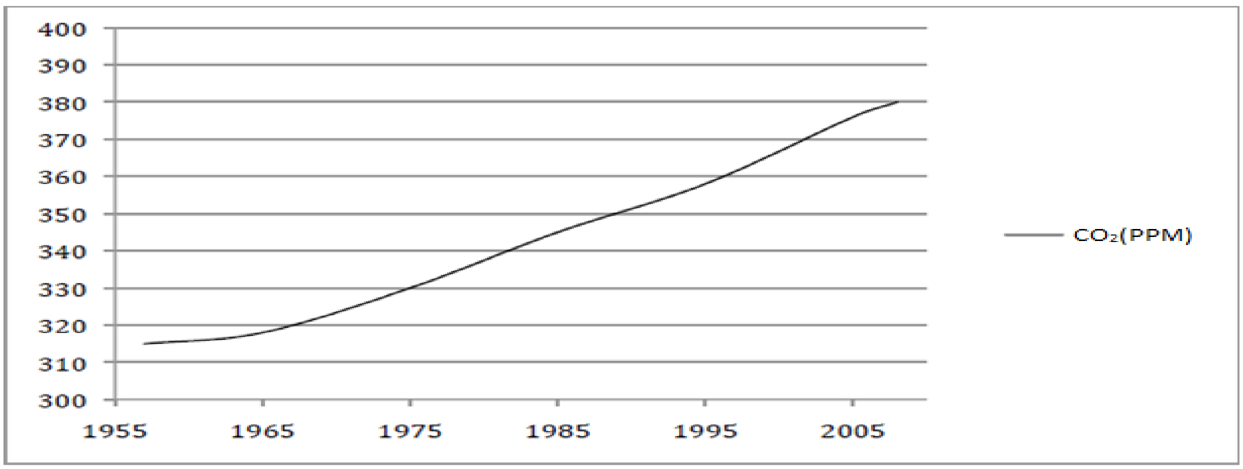


Source: UK Met office, 2012

Figure 1 shows the increase in global temperature from 1850 to 2007, this rise in temperature is a result of greenhouse emissions. The resulting climate change from this rise in temperature is predicted to have detrimental and possibly irreversible effects on earth's natural systems and societal systems that we have become accustomed to (Hoolwerff, 2008).

CO_2 is one of the greenhouse gases that affect global temperature. Since industrialization, CO_2 has increased in the atmosphere by more than 35 percent, and it is also responsible for 63% of global warming (NOAA, 2008). The build-up of CO_2 since 1958 is shown in Figure 2 below.

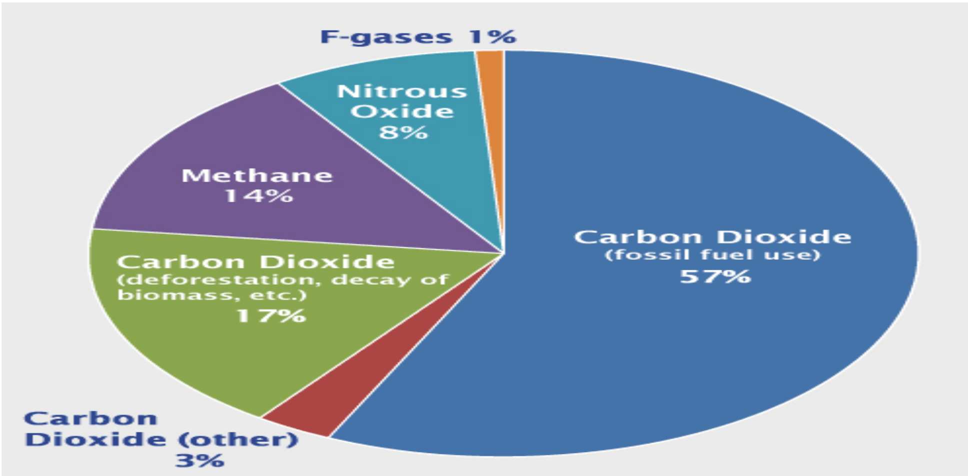
Figure 2: CO_2 levels in the atmosphere 1958-2008



Source: NOAA (2012)

The figure above shows significant increase in CO_2 levels from 1958 to 2008. Although CO_2 has been the major contributor of global warming, other potent gases such as CH_4, N_2O and F-gases have also contributed to global warming. Figure below shows global greenhouse gases by emission.

Figure 3: Global greenhouse emissions by gas



Source: IPCC (2007)

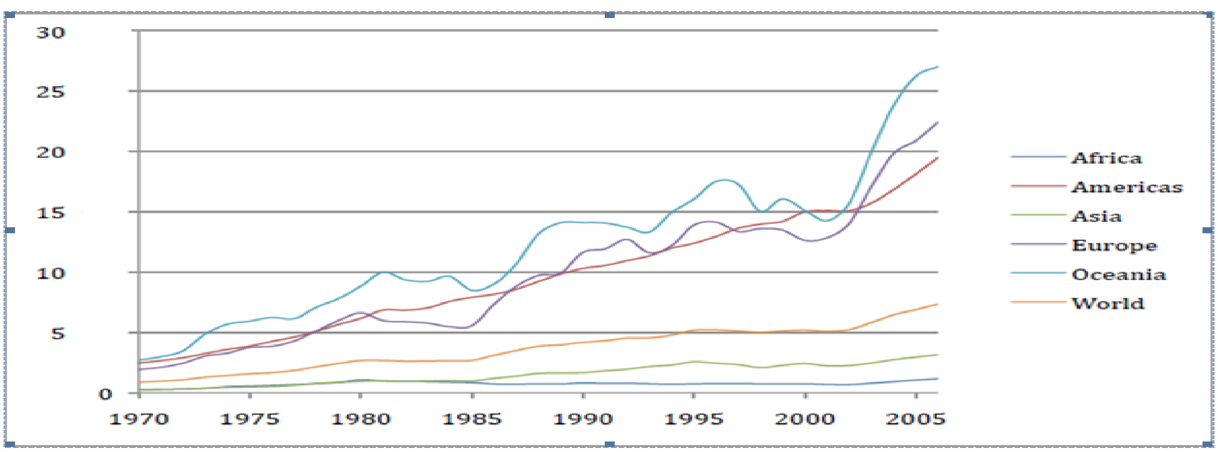
Figure 3 shows that most of CO_2 is emitted through use of fossil fuels, followed by deforestation and decay of biomass. Given that fossil fuel combustion makes up for more than 50 % of CO_2 emissions and other green house gases, it is important to curb our reliance on fossil fuel usage.

2.3: GROWTH IN WORLD ENERGY DEMAND

Global energy demand is expected to increase as a result of growing world population and the rising world income. The world's population is expected to increase by 47 percent between 2000 and 2050, which means that it is projected to grow from 6.1 billion in 2000 to 8.9 billion people in 2050 (UN world population survey, 2004) Furthermore, Asia has a formidable population size, with an estimate of 3.9 billion people (UN statistics division, 2008). Asia also has had an annual population increase of 1.3 percent, from 2000 to 2005, which means that its impact on energy demand continues to expand, especially coupled with its rise in per capita income, which has been the highest in the last few decades, and continues its upward trend (UN statistics division, 2008). If the global energy demand grows as expected, and the supply is met by continuing to use fossil fuels, greenhouse gases are predicted to rise to dangerously high levels. It is important to adopt low greenhouse emitting substitutes to prevent or minimize irreparable environmental damages.

The rise of per capita income in high income countries in the last century significantly increased global energy demand (Hoolwerff, 2008). The majority of the current and future energy demand is expected from the rise in per capita income in emerging market economics in the next few decades (HSBC, 2011). In 2050, 19 of the 30 largest economies will be emerging economies and their collective GDP is expected to be greater than the developed worlds' GDP (HSBC, 2011). According to HSBC's global research report (2011), China and India are predicted to be the largest and the third largest economies in the world, and the emerging world's economy is expected to increase five times by 2050. Figure 3 below shows global rise in per capita income from 1970 to 2005.

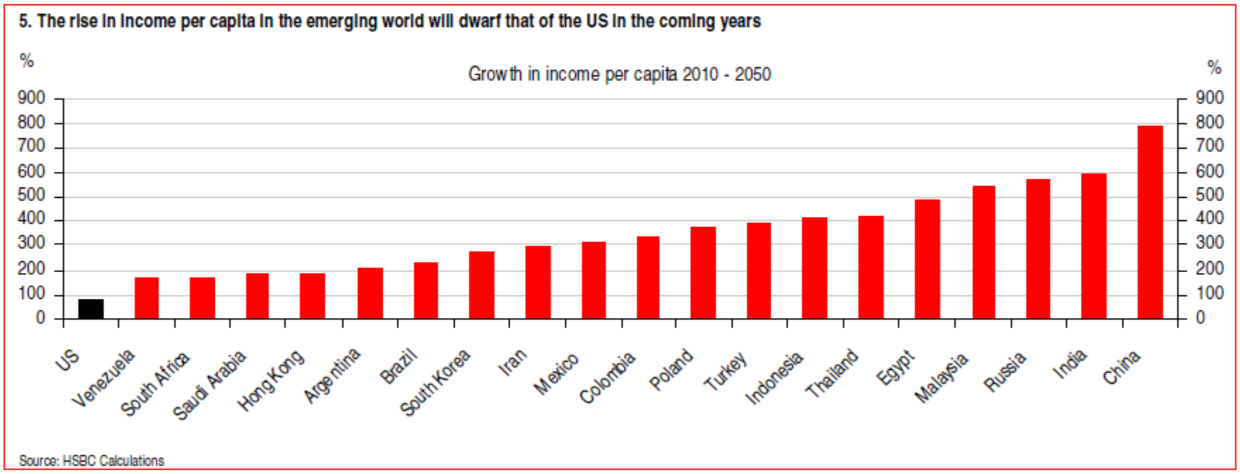
Figure 4: World and regional per capita income in thousands (constant 2005 USD)



Source: UN Statistics Division

The figure above shows that global and regional incomes rose significantly for the world and its many regions. From 1970 to 2005, this increased income also increased global energy demand. This income increase is expected to continue to grow in the next few decades as shown by Figure 4 below.

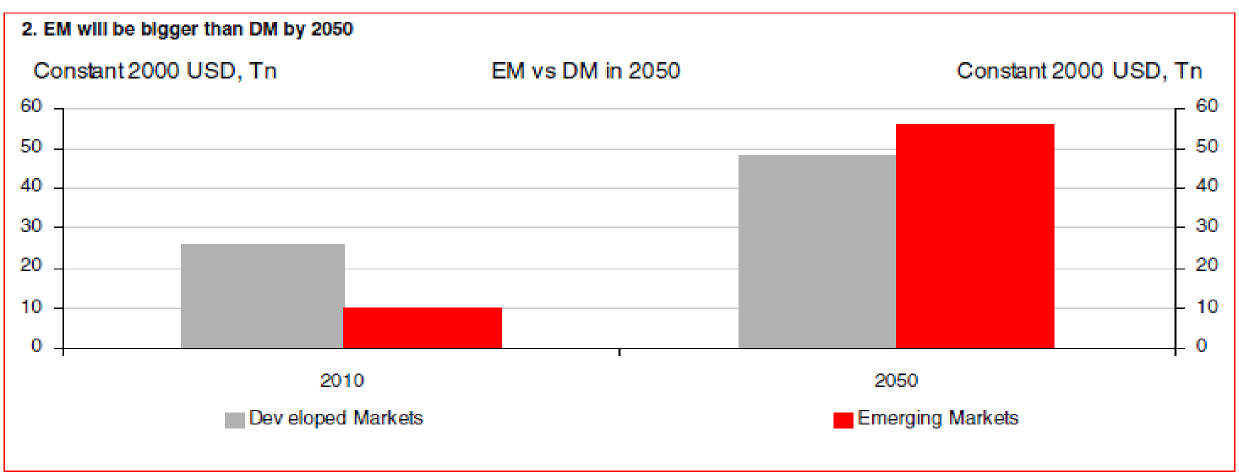
Figure 5: Per capita income rise in percentages for emerging economies in 2050



Source: HSBC global research, 2011

Growth in income per capita would reach around 800% for China and 600% for India, followed by between 500 to 600 % for Russia, Malaysia and Egypt, by 2050. The increased income would inevitably increase energy demand in these countries. Furthermore, Figure 5 shows that the GDP of emerging economies collectively are predicted to become larger than that of developed economies in 2050.

Figure 6: Emerging economies’ GDP versus developed economies’ GDP in 2050



Source: HSBC global research, 2011
Tn: Trillions of constant 2000 USD

The combined GDP of emerging markets will exceed that of developed markets in 2050. Emerging markets' GDPs would be close to $58 trillion by 2050 compared with $49 trillion for developed markets. This shows that most of the world's increased energy demand is expected to come from emerging economies as a consequence of the emerging world's increased income levels. The rise in per capita income in the emerging economies coupled with the rise in world population will strain the current fossil fuel supply. Even though fossil fuel production globally has been on the rise to fulfill current energy demand, and presumably will continue to increase in the future (we assume not many regulations would be in place that discourage fossil fuel production) usage of fossil fuel production and consumption will exacerbate the already existing detrimental and possibly calamitous environmental imprint caused by these fossil fuels since industrialization. Therefore, it is imperative to curb our reliance on fossil fuels in order to achieve a greener, healthier and more sustainable environment.

CHAPTER 3: CHALLENGES AND INITIATIVES

Although renewable energy has tremendous potential, its production is also faced with tremendous challenges.

3.1 CHALLENGES

SCALABILITY, TIMING AND COMMERCIALIZATION:

Scalability, timing and commercialization of renewable energy projects are significant challenges. Renewable energy must be supplied in the time frame and volume needed, and at a reasonable cost (Fridley, 2010). Many alternative energy projects have been successful at a smaller scale but these small scale demonstration projects do not predict success of large scale projects. Another problem is intermittency. Wind doesn't blow all the time and sun doesn't shine all day. It is not possible to generate energy using these sources throughout the day or throughout all seasons, when these sources are not in use, it's important to store the energy that has already been generated. Storage has been a considerable challenge, even though some storage devices have made progress in the last few years. Fridley (2010) also describes that alternative energy sometimes is unable to increase production as required or in a timely manner because its production capacity is dependent on engineering and construction of equipment, and can increase its production only when certain equipment becomes available, and as a result its production capacity can only increase in stages or steps, and not incrementally. Commercialization is another obstacle. It refers to the time it takes a proposed alternative energy source from being fully commercialized. An alternative source can take between twenty to twenty five years from laboratory demonstration to full large scale commercialization (Fridley, 2010). The Hirch report[2] noted that in order to mitigate effects of any sort of supply shortage, US needs to redesign its energy infrastructure at least twenty years in advance.

SUBSIDIES FOR FOSSIL FUELS:

Fossil fuels receive large subsidies, which make renewable energy sources competitively disadvantageous. World Bank and International Energy Agency put global annual subsidies for fossil fuel in the range of $100 to $200 billion (Beck and Martinot, 2004). These public subsidies can take many forms such as tax incentives, direct budgetary transfers, R and D spending, liability insurance, leases, and right of way, waste disposal, and guarantee to mitigate project financing or fuel price risks (Beck and Martinot, 2004).

LIMITED ACCESS TO FUNDING:

Financing of renewable energy projects often proves to be difficult compared to fossil fuel projects. Brunnschweiler (2009) finds that renewable energy firms have limited access to financing because renewable energy projects compete against fossil fuel projects, such as oil and gas projects, which have longer and proven track records; they have been ongoing for at least a few decades, and their profits and cost recovery times have more certainty than some renewable energy projects. She also mentions that fossil fuel projects often have more political backing than renewable projects. This is not only true for developing countries but also for developed countries such as US and Canada.

[2] Robert L. Hirsch, Roger Bezdek, and Robert Wendling, *Peaking of World Oil Production: Impacts, Mitigation, & Risk Management*, U.S. Department of Energy report, February 2005, http://www.netl.doe.gov/publications/others/pdf/ oil_peaking_netl.pdf.

HIGH COSTS:

Renewable energy projects require higher start-up costs, and also at times higher running and maintenance costs. Higher start-up costs for some renewable energy projects such as nuclear, ocean or tidal energy can mean that it provides less installed capacity per initial dollar invested than conventional energy sources (Beck and Martinot, 2004). Therefore, renewable energy projects demand high levels of financing (Brunnschweiler, 2009). Additionally, capital markets may require a higher rate than conventional energy projects because more capital is being risked upfront (Beck and Mertinot, 2010). Renewable energy projects generally require long-term loans (Demirguc-Kunt and Maksimovic, 1999). These long term loans are more accessible for renewable projects in countries with well-developed banking systems than in countries with less developed banking systems (Demirguc-Kunt and Maksimovic, 1999). In developing or less developed countries, a less developed banking system constrains funding for renewable projects (Brunnschweiler, 2009). Therefore, renewable projects of all sizes; large, medium and small, struggle to secure adequate funding in developing countries (Brunnschweiler, 2009). Furthermore more, renewable energy has to be produced at a much larger scale especially for larger projects such as tidal energy in order to realize cost reductions due to economies of scale.

IMPERFECT INFORMATION:

Renewable energy projects also face the challenge of imperfect information (Brunnschweiler, 2009). Brunnschweiler mentions that projects aimed at developing new technologies bear greater information costs to investors, which are borne mostly by a highly developed financial sector. Further lack of a highly developed financial sector is likely to create market distortion in favour of less risky investments, such as the more established fossil fuels projects like oil and gas.

Furthermore, the lack of effective policy, institutional framework, financial intermediaries and the resulting financial difficulties have been a constant challenge in renewable energy technology implementation (Brunnschweiler, 2009). Therefore, the presence of highly developed financial systems is important for development of renewable energy projects. Since renewable energy projects depend on the banking system for external financing, especially when they compete with traditional fossil fuel projects, the lack of a developed financial system can constrain growth of renewable projects in less developed countries.

3.2 INITIATIVES: KYOTO PROTOCOL

In recent years, many countries have undertaken initiatives that have had favourable effects on renewable energy development. The signing and ratification of the Kyoto protocol by various countries, both directly and indirectly, contributed to the growth of renewable energy development (Brunnschweiler, 2009). Furthermore, two important mechanisms in particular have helped in curtailing financial hurdles for the Kyoto protocol's implementation and success. These are the Clean Development Mechanism (CDM) and the Joint Implementation Program (Brunnschweiler, 2009). The CDM allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, which can be sold and traded, and used by other industrial countries to meet their emission targets. Joint Implementation program allows any Annex I country to invest in an emission reduction project in any other Annex I[3] country as an

[3] http://unfccc.int/parties_and_observers/parties/annex_i/items/2774.php. This provides a list of all Annex I countries.

alternative to reducing emissions domestically. Both of these mechanisms are designed to help Kyoto Protocol member countries meet their emission targets and to encourage private sector's contribution to emission reduction (Brunnschweiler, 2009). Since inception in 2006, more than 1000 projects have been approved under the clean development mechanism (Brunnschweiler, 2009). It has also been very successful in developing countries because it allows Annex B (developing) countries to implement emission reduction projects in non-Annex B countries and earn certified emission reduction credits in the process (Brunnschweiler, 2009)[4].

Other important initiatives have been taken by various countries in order to promote and develop renewable energy projects, but for the purpose of this paper, I will focus solely on the effects of the Kyoto protocol on development of renewable energy.

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[4] Both clean development mechanism and joint implementation have shown encouraging results in terms of CO_2 reduction but critics argue that they have slowed the invention of low greenhouse emission technologies. For example , we replace inefficient Russian Coal plants but we are still using coal plants. Without the offsets, Annex I may have moved further with respect to renewable energy development (wind, solar, tides, geothermal) and 4th generation nuclear and potentially carbon storage and capture. Under Kyoto, these offsets were limited.

CHAPTER 4: LITERATURE REVIEW

A well developed financial system fosters economic activity and growth. King and Levine (2001) carried out a cross country analysis of 80 countries over of a period from 1960-1989. They suggest that various measures of financial development are strongly associated with real per capita GDP growth, the rate of physical capital accumulation, and improvements in the efficiency with which economies employ physical capital. Furthermore, their analysis also shows a linear and positive relationship between predetermined component of financial development and future rates of economic growth, physical capital accumulation, and economic efficiency improvements. Beck et al. (2006) use survey data on a sample of over 10,000 firms from 80 countries to assess the determinants of financing obstacles to firms. In addition to financing constraints faced by various individual firms in different industries, they also tested country specific financial sector characteristics to understand how they impact the financial constraints faced by these firms. They find that firms in countries with higher levels of financial intermediary development, stock market development, legal system efficiency, higher GDP per capita and institutional development report lower financing obstacles. Private credit, stock market development, law and order, institutional development, and GDP per capita have the expected negative and significant relationship in Beck et al, 2006. Based on the correlations of their regression model, they suggest that firms in financially and economically more developed countries face lower financing obstacles, and that the underlying financial institutions that drive both economic and financial development seem to be the most important country characteristic explaining firm's financing obstacles.

The structure of the banking sector is also important to economic growth. Bank concentration can hinder financing for businesses, and these financing difficulties can impact overall economic growth. Beck et al. (2003) study and analyze the structure of the banking system. Most of the studies on bank structure focused on the US only but Beck et al. (2003) focus on the cross section of 74 developed, developing and transition countries. Most of the previous literature prior to Beck et al. (2003) had tested both the theoretical hypotheses; namely a structure-performance hypothesis and an information-based hypothesis. The structure-performance hypothesis predicts a negative relationship between bank concentration and access to credit, while the information-based hypothesis predicts a positive or non-linear relationship. In previous literature, both theoretical and empirical results have been contradictory. Beck et al. (2003) test the relationship of bank concentration to financing obstacles for different firms and if these obstacles vary across regulatory regimes and institutional environments. They conclude that banking concentration increases financing obstacles for firms, with stronger effects for small and medium firms compared to large firms. However, when Beck et al. (2003) use an interaction term; GDP per capita with bank concentration, this relationship holds for only low-income countries and becomes insignificant for medium-income and rich countries. Furthermore, Beck et al. (2003) also suggest that regardless of economic development, regulatory and institutional characteristics of a country either dampen or exacerbate the effects of bank concentration. Richer or high income countries tend to have higher levels of institutional development, fewer restrictions on banking activities, less government owned banks, and as a result tend to have less of a negative effect of bank concentration. Factors such as restrictions on bank activities, high government interference in banking system, a higher share of government owned banks, enhances the negative effect of bank concentration for a country. This is mostly common in low and middle income countries.

A well-developed financial sector not only fosters economic growth but also renewable energy growth. Brunnschweiler (2006) extends King and Levine's financial sector analysis to the renewable energy sector and her findings suggest that better developed financial sector positively impacts the development of renewable energy sector. She examines the determinants of credit allocation to renewable energy firms in developing and transition countries. A standard endogenous growth model is used to show that development of a renewable energy sector depends on the factors such as debtor information costs to banks, the quality of financial intermediation, and the financing needs of renewable energy firms. Furthermore, she suggests that the banking sector distortions, higher information costs for financiers in evaluating potential creditors, and the higher reliance of renewable energy producers on external financing, will have a negative effect on growth of renewable energy. She suggests that the aforementioned challenges in the financial system also make it difficult for banks to charge a reasonable interest rate for a given loan amount, which could lead to lower overall growth rates in renewable energy sector. Similarly, she suggests that higher resource costs to primary renewable energy producer, not just depresses growth in the renewable energy sector but also the overall economy. In her analysis, she tests the effects of an un-restricted financial sector and low information costs for renewable energy technologies. Two dependent variables are chosen as proxies for renewable energy sector development. The covariates include four different indicators of financial sector development and a vector of control variables. All four financial sector variables are statistically significant when regressed on both measures on renewable energy sector development, and they are also robust to controlling for other effects both in statistical significance and the magnitude of their coefficients. In sum, the results of empirical analysis support the basic hypothesis from the theoretical model that financial intermediary development encourages renewable energy sector growth. Furthermore, Brunnschweiler (2009) extends her analysis carried out in 2006. She introduces additional dependent variables, and a more detailed empirical analysis is carried out. Also, additional financial sector intermediaries are used for this analysis. Her paper empirically analyzes the relationship between financial sector and renewable energy sector development, with a focus on non-OECD countries. She focuses on non-OECD countries because most of the world's energy demand is expected to come from these countries and these countries are expected to use traditional fossil fuels to fulfill demand, and consequently these non-OECD countries are expected to become major polluters, more so than OECD countries. Empirical research is carried out by constructing a panel data set for up to 119 non-OECD countries for the period of 1980-2006, using electricity generation per capita from renewable energy technologies as a proxy for renewable energy sector development. Financial sector effects are then isolated by controlling for energy relevant policy and institutional quality measures. The results in Brunnschweiler (2009) also supports the hypothesis that financial sector development, especially commercial banking development, has a positive effect on renewable energy development in developing and transition countries. These effects are stronger on non-hydro renewable energy which includes wind, solar, geothermal and biomass, while the impact of the financial sector on hydro power generation is more limited. The results in her paper also support the hypothesis that adoption of the Kyoto protocol will have a positive effect on renewable energy sector development. Robustness tests, which incorporate coal, oil and natural gas production and prices, and proxies for renewable energy potential, confirm the positive relationship between financial sector development and renewable energy development.

The literature discussed in this section suggests that a well-developed financial sector, not only enhances the overall economic activity and growth, but it also positively impacts development of the renewable energy sector. Lower banking sector distortions, lower information costs, and reasonable borrowing rates for renewable energy projects, would foster renewable sector growth. Renewable energy generation tends to increase with the presence of relevant policy and institutional measures. The commercial banking sector has an especially strong effect, particularly on non-hydro energy generation, such as wind, solar, geothermal, biomass and ocean energy. The literature also suggests a positive impact of the Kyoto protocol on renewable energy development. Furthermore, private credit, stock market development, law and order, and institutional development, are likely to have positive effects on renewable energy development. Additionally, any negative effects of banking concentration on renewable energy development can be dampened with high levels of institutional development, fewer restrictions on banking activities and less government owed banks. The literature discussed in the literature review doesn't mention any specific restrictions on banking activities, but refers to general lending procedures, export financing, leasing, credit requirements and red tape, they do not take into consideration any specific acts such as the Glass Steagall Act in the US.

CHAPTER 5: DATA AND METHODOLOGY

I use data from Energy Information Administration (EIA), World Development Indicators (WDI), World Bank (2012) for my panel data covering 156 non-OECD countries for period from 1980-2006[5]. All data are annual. This data set is unbalanced. Table 1 below provides summary statistics of my data set. Electricity generation data are freely available for the three dependent variables from U.S. Energy Information Administration (EIA) on a yearly basis since 1980. All measures of financial sector development and equity market variables are taken from World Bank (2012).

TABLE 1: SUMMARY STATISTICS OF 156 NON OECD COUNTRIES FOR 27 YEARS 1980-2006 INCLUSIVE (ANNUAL DATA)

Variable	Observations	Mean	Std. Dev.	Min	Max
Hydro energy generation million KWh per capita	3911	281.7177	754.803	0	10026
Non hydro energy generation million KWh per capita	3911	6.1676	22.7462	0	344
Total renewable energy generation million KWh per capita	3911	287.8872	757.0786	0	10033
Commercial banks asset share ratio (the ratio of commercial banks' asset share versus that of central bank)	3321	0.7432	0.2339	0.1088	1.3362
Private sector credit allocation ratio (amount of credit provided by financial institutions to the private sector as a share of GDP)	2901	0.2699	0.2271	0.0004	1.6956
Financial depth ratio (liquid liabilities of financial system-currency plus demand and interest bearing liabilities of banks and other financial	2914	0.4131	0.2698	0.0013	1.5712

[5] The original data set that I used for this paper has 179 countries in total. The number of OECD countries is 23 in this data set. The dataset for non-OECD countries is 156 countries.

intermediaries or, more generally, M2-divided by GDP)					
Oil production per capita (thousand barrels per day)	3967	0.0433	0.1705	2.46E-07	2.1051
Foreign direct investment	3376	3.3043	9.2207	82.8921	348.1892
Income per capita (thousands of dollars in constant 2005 USD)	3911	4.2490	8.2371	0	80.79
Stock market capitalization ratio(value of listed shares to GDP)	1290	0.2887	0.3904	0.0002	2.8243
stock market turnover ratio (ratio of value of total shares traded to average real market capitalization)	1335	0.3261	0.7757	0.0001	16.78062
Number of publically traded companies per capita ratio (number of publically listed companies per 10k population)	1408	0.2142	0.4602	0.0001	5.3335

This paper will carry out an empirical analysis of development of the financial sector in non-OECD countries from 1980 to 2006 and how it relates to the development of renewable energy projects and renewable energy's share in the overall energy production. My reasoning for using non-OECD countries is similar to Brunnschweiler (2009); most of the world's energy demand is expected to come from non-OECD countries and these countries are also expected to become major polluters, though China is already a major polluter, other smaller non-OECD countries are expected to increase their pollution, and China is expected to continue to pollute even more. I will initially test the hypothesis of Brunnschweiler (2009) as it is carried out in her paper. Brunnschweiler (2009) tests the hypothesis that the financial sector has a positive effect on the renewable energy sector development. It also tests the hypothesis that the Kyoto Protocol has a positive effect on the growth of renewable energy sector. In the first phase of my analysis, I will test Brunnschweiler (2009)'s hypothesis by using fixed effects estimation to minimize effects of country specific time invariant factors. Brunnschweiler (2009) uses random effects Generalized Least Square (GLS) estimation to minimize the effects of correlation between observations and to minimize the effects of heteroscedasticity. Furthermore, I will also introduce three additional equity market variables and test the hypothesis that these variables positively impact renewable energy generation. These equity market indicators are measures of stock market development as indicated by Beck et al (2012). I will also use oil production per capita measure and determine if having fossil fuel industry makes it less likely for a country to invest in renewable energy development.

Hydropower has been a significant contributor to renewable energy generation whereas non-hydro resources such as wind, solar, tidal, geothermal, have only contributed a small portion to overall renewable production. For this paper, I will consider total renewable energy, hydro and non-hydro energy generation. I have left out biomass production, or bio fuels as a mix of renewable energy production, due to its negative impact on agricultural food production (see Brunnschweiler, 2009). The financial development variables are commercial banking asset share, private sector credit share and financial depth. Stock market variables that I use in my analysis are stock market capitalization, stock market turnover and number of publically traded companies per capita. Detailed list of all variables and sources are in Appendix A.

Following Brunnschweiler (2009), I use three separate measures for dependent variables. The first variable measures the overall renewable energy electricity generation. This measures hydropower and non-hydro renewables such as wood and waste, geothermal, solar, and wind, in million KWh per capita. The second variable considers only hydroelectric power generation, also measured in million KWh per capita. The third variable measures electricity produced from all non-hydro renewable energy methods such as solar, wind, geothermal, etc, measured in million KWh per capita.

I also determine the effect of Kyoto protocol on renewable energy development. The adoption of the Kyoto protocol in late 1997 was a significant achievement in global environment policy and it also positively affected renewable energy policy and development (Brunnschweiler, 2009). Kyoto Protocol adoption variable is zero-one dummy variable. All signatories of the Kyoto Protocol who signed from 1998 onwards are given values of 1 and the countries that didn't sign are given the value of zero. Since my data set is from 1980-2006, all countries in the data set prior to 1997 have a dummy variable of zero because the Kyoto protocol was only introduced in 1997. In my data set, out of the 156 non-OECD countries, 136 countries are signatories of Kyoto. I expect a positive impact of the Kyoto protocol dummy on the renewable energy development (see Brunnschweiler, 2009).

Since 1997, there has been an increase in electricity generation with renewable energy technologies in non-OECD countries; on average, overall renewable energy electricity generation went from an average of 263.4 million KWh before Kyoto to 393.8 million KWh post Kyoto (Brunnschweiler, 2009). This was largely due to the increase in hydropower but non-hydro electricity production also doubled from an average of 5 million KWh to 9.6 million KWh (Brunnschweiler, 2009). Furthermore, this increase in renewable energy production is common for all non-OECD country income groups, across all regions, and especially in South-Eastern Asia (Brunnschweiler, 2009). In this region, overall renewable energy generation went from 295.8 billion KWh per capita to 507.8 billion KWh post Kyoto (Brunnschweiler, 2009). Though most of this increase in this region comes from hydropower, non-hydro power generation increased more than 27-fold from comparatively very modest 21 thousand KWh per capita to an average 569.4 thousand KWh per capita in the period after 1998 (Brunnschweiler, 2009).

The explanatory variables for this paper include three variables of financial sector, three variables of equity markets, and a vector of control variables. The three financial development variables are commercial bank asset shares, private sector credit share, and financial depth. The first indicator of financial sector development is the ratio of commercial banks' asset share versus that of central bank. My hypothesis states that the commercial banking asset share ratio should positively correlate with renewable energy development. The second variable in my analysis is a ratio that captures the amount of credit provided by financial institutions to the private sector as a share of GDP. Higher levels of private credit indicate higher levels of financial services and therefore greater financial intermediary development (Brunnschweiler, 2009). Levine et al. (2000) have shown that this variable is a reliable measure of financial sector development. Therefore, I expect this variable to have a positive relationship with renewable energy generation.

The third financial variable is a ratio, which is a general measure of financial sector development commonly known as financial depth. "It is defined as liquid liabilities of financial system-currency plus demand and interest bearing liabilities of banks and other financial intermediaries or, more generally, M2-divided by GDP" (Brunnschweiler 2009). "Financial depth is the broadest measure of financial intermediation, giving an indication of overall size of financial sector without distinguishing either between commercial and non-commercial banks and other financial intermediaries" (Brunnschweiler 2009). I assume that the relative size of the financial intermediary sector is positively correlated with the quantity and quality of the financial services provided (see Brunnschweiler, 2009). Therefore, for this paper, I expect a positive influence of financial depth on the development of renewable energy. I will run these financial sector development variables separately to minimise multicollinearity.

The equity market indicators are stock market capitalization, stock market turnover, and number of publically traded companies per capita. The stock market capitalization ratio is the total value of traded shares as a percentage of GDP[6]. The second equity indicator is the ratio of total shares traded to average real market capitalization[7]. The average real market capitalization is the total stock market capitalization divided by average annual CPI. Stock market turnover is an efficiency indicator of the stock market. It measures the activity or the liquidity of the stock market relative to its size (Beck et al., 1999). An active and liquid stock market will have a high turnover ratio, while a less liquid stock market will have a low turnover ratio (Beck and Levine, 1999). The third equity indicator is the ratio of number of listed companies per ten thousand of the population. Beck and Levine (1999), shows that greater equity market indicators have a positive effect on economic development. Therefore, for the purpose of my analysis, my hypothesis states that all three equity market indicators would have a positive relationship with renewable energy development.

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[6] Stock market capitalization is the total value of all stocks traded, which is calculated by multiplying the total number of stocks traded by the price per share of these traded stocks

[7] Ratio of the value of total shares traded to average real market capitalization, the denominator is deflated using the following method: Tat/P_at/{(0.5)*[Mt/P_et + Mt-1/P_et-1] where T is total value traded, M is stock market capitalization, P_e is end-of period CPI P_a is average annual CPI. (World Bank, 2012)

Furthermore, I will also test if oil production per capita negatively impacts renewable energy production. Al-Saleh (2009) suggests that most oil producing economies, especially oil dependent economies, have limited interest in the production of renewable energy.

Other variables that are included are income (GDP) per capita in 2005 constant USD and ratio of net foreign direct investment inflows to GDP. Income per capita is added to control for the effect of the higher income countries, which are expected to produce greater electricity compared with less developed countries. Foreign direct investment ratio is expected to have a positive effect on renewable energy production (see Brunnschweiler, 2009). Foreign direct investment ratio is calculated as foreign direct investment inflows to GDP for non-domestic investment.

For this analysis, I use panel data estimations using fixed effects regression, for equation

$$Y_{it} = \beta_1 F_{i(t-1)} + \beta_2 X_{i(t-1)} + \alpha_i + \mu_{it} \text{ ,} \qquad (1)$$

Where Y_{it} is the dependent variable (total renewable energy which includes both hydro and non-hydro energy production, total hydro energy production and total non-hydro renewable energy production), in country *i* at time *t.* $F_{i(t-1)}$ denotes the financial sector development variables with one year lags, and $X_{i(t-1)}$ the vector of control variables with one year lags. I use time lags because financial sector and equity market variables, income and foreign direct investment per capita variables are not expected to have immediate effects on electricity generation (Brunnschweiler 2009). The error term is denoted by u_{it}. The time invariant individual effects is denoted by α_i. I use fixed effects within transformation using Stata econometric package to eliminate the effects of time invariant country specific effects.

CHAPTER 6: RESULTS

In this analysis, I observe the sign, magnitude and statistical validity of β_1 and β_2. β_1 measures the impact of financial sector development variables and equity market variables on renewable energy development. β_2 measures impact of income per capita, foreign direct investment, Kyoto and oil production per capita on renewable energy development. The objective is twofold: firstly to determine if financial sector development and equity markets have a positive influence on renewable energy sector development, and secondly the magnitude of the influence. The proxies of financial sector are commercial banking asset share, private sector credit allocation and financial depth measure. The proxies for equity markets are stock market capitalization, stock market turnover, and number of publically traded companies.

My initial analysis presents fixed effects estimations as stated in equation (1), for my unbalanced panel of non-OECD countries. Table 1A shows results for the total renewable energy produced per capita, Table 1B gives results for hydroelectric energy produced per capita, and Table 1C gives results for non-hydro renewable energy produced per capita.

TABLE 1A

IMPACT OF FINANCIAL SECTOR DEVELOPMENT ON ANNUAL TOTAL RENEWABLE ENERGY PER CAPITA GENERATION IN NON-OECD COUNTRIES

	Total renewable energy per capita	Total renewable energy per capita	Total renewable energy per capita
Commercial banking asset share ratio	53.4518 (23.9146)		
Private sector credit share ratio		32.4098 (32.3280)	
Financial depth ratio			-36.1992* (31.4022)
Foreign direct	1.1232**	-0.1345	-0.1137

investment ratio	(0.3299)	(0.6791)	(0.6777)
Income per capita in constant (2005 USD)	1.4924*** (2.6991)	0.3564** (2.6332)	1.4004*** (2.5751)
Kyoto dummy variable	44.4643*** (6.2952)	54.2991*** (6.9816)	58.5825*** (7.0799)
Observations	2943	2632	2645
R^2 : within[8]	0.0338	0.0314	0.0320
R^2*: between*	0.0062	0.0268	0.0437
R^2*: overall*	0.0046	0.0060	0.0143

Notes: The dependent variable is total renewable energy produced per capita measured in KWh per capita. All regressions are Fixed effects on sample panel of non-OECD countries from 1980-2006 with 1-year lags for all indicators except Kyoto protocol. Standard errors are in parenthesis *, **, *** indicate statistical significance at 10,5, and 1 percent levels, respectively.

The table 1A above shows that both commercial banking asset share and private credit share ratios have insignificant relationships with total renewable energy. Financial depth has a negative and significant relationship with total renewable energy. This negative relationship is opposite of my hypothesis; which expected that financial depth would have a positive relationship with total renewable energy production. Both income per capita and Kyoto have positive and significant relationships with total renewable energy, which is what I expected. Table 1B below shows the results of financial sector development ratios on hydro energy production.

[8] The three R^2 are: 1) within: The R-squared from the mean-deviated regression, i.e. the ordinary r-squared from running OLS on the transformed data. 2) between: first, this computes the fitted values using the fixed-effects parameter vector and the within-individual means of the independent variables. Then calculates the r-squared as the squared correlation between those predicted values and the within-individual means of the original y variable.3) overall: first, this computes the fitted values using the fixed-effects parameter vector and the original, untransformed independent variables. Then calculates the r-squared as the squared correlation between those predicted values and the original, untransformed y variable.

TABLE 1B

IMPACT OF FINANCIAL SECTOR DEVELOPMENT ON ANNUAL HYDROELECTRIC ENERGY GENERATION PER CAPITA IN NON-OECD COUNTRIES

	Hydroelectric generation per capita	Hydroelectric generation per capita	Hydroelectric generation per capita
Commercial banks asset share ratio	34.3669 (23.5671)		
Private sector credit share ratio		30.5454 (31.8348)	
Financial depth ratio			-31.6093 (30.9262)
Foreign direct investment ratio	1.1210*** (0.3251)	-0.0989 (0.6687)	-0.0785 (0.6674)
Income per capita in constant (2005 USD)	0.6647*** (2.6598)	1.0751* (2.5931)	0.5191** (2.5361)
Kyoto dummy variable	40.5317*** (6.2037)	48.6124*** (6.8751)	52.5508*** (6.9725)
N	2943	2632	2645
R^2: within	0.0276	0.0256	0.0261
R^2:*between*	0.0107	0.0277	0.0475
R^2: *overall*	0.0045	0.0060	0.0143

Notes: The dependent variable is hydroelectric renewable energy produced per capita measured in KWh per capita. All regressions are fixed effects on sample panel of non-OECD countries from 1980-2006 with 1-year lags for all indicators expect Kyoto protocol. Standard errors are in parentheses. *, **, *** indicate statistical significance at 10,5, and 1 percent levels, respectively.

None of the financial sector development variables have a significant relationship with hydro energy development. Foreign direct investment ratio has mostly an insignificant relationship. Income per capita and Kyoto, as expected, both have a positive and significant relationship with hydro energy production. Table 1C below shows the impact of financial sector development ratios on non-hydro renewable energy development.

TABLE 1C

IMPACT OF FINANCIAL SECTOR DEVELOPMENT ON NON- HYDRO RENEWABLE ENERGY GENERATION PER CAPITA IN NON-OECD COUNTRIES

	Non-hydro renewable energy generation per capita	Non-hydro renewable energy generation per capita	Non-hydro renewable energy generation per capita
Commercial banks asset share ratio	19.1307*** (2.4678)		
Private sector credit share ratio		-1.8899 (3.4414)	
Financial depth ratio			-4.5902* (3.3404)
Foreign direct investment ratio	-0.0020 (0.0340)	-0.0362 (0.0722)	-0.0358 (0.0720)
Income in constant (2005 USD)	0.8230* (0.2785)	0.7156** (0.2803)	0.8788*** (0.2739)
Kyoto dummy variable	3.9405*** (0.6490)	5.6884*** (0.7432)	6.0447*** (0.7531)
N	2943	2632	2645
R^2: within	0.0592	0.0390	0.0395
R^2:*between*	0.0016	0.0017	0.0022
R^2:*overall*	0.0105	0.0079	0.0091

Notes: The dependent variable is non-hydro renewable energy produced per capita measured in KWh per capita. All regressions are fixed effects on sample panel of non-OECD countries from 1980-2006 with 1-year lags for all indicators except Kyoto protocol. Standard errors are in parentheses *, **, *** indicate statistical significance at 10, 5, and 1 percent levels, respectively.

Table 1C above shows a positive and significant relationship between commercial banking asset share and non-hydro renewable energy development. Once again, financial depth's negative and significant relationship with non-hydro renewable energy is the opposite of what I expected. My hypothesis suggested a positive relationship between financial depth and non-hydro renewable energy. A one percent point increase in commercial bank asset share ratio produces an increase of 0.1913 (0.01*19.1307) kWh per capita in non-hydro renewable energy production. As expected, income per capita and Kyoto have a positive and highly significant relationship with non-hydro renewable energy.

Financial depth has a negative relationship with total renewable energy, but an insignificant relationship with hydro electric energy. Hence, two out of the three financial sector development variables have insignificant relationships with total renewable and hydro electric energy per capita. Financial depth has a negative relationship with non-hydro renewable energy production. Out of the three financial sector variables, only commercial bank asset share shows positive relationship with non-hydro renewable energy. The Kyoto Protocol has a positive and very significant relationship with total renewable energy, hydro-electric energy and non-hydro renewable energy production. As mentioned earlier in this paper, out of the 156 non-OECD countries in my dataset, 136 signed Kyoto Protocol since 1997. The table above shows that Kyoto Protocol has had a positive impact in non-hydro renewable, hydro renewable and total renewable energy.

Income per capita has a positive impact on renewable energy whether it be total renewable energy per capita, hydro energy production per capita and non-hydro energy production per capita (Table 1A, 1B and 1C). A unit increase in income per capita (an increase of one thousand dollars per capita) increases total renewable energy by 1.4924 KWh per capita column 2 Table 1A), 0.6647 KWh per capita (column 2, Table 1B) and 0.8230 KWh per capita (column 2, Table 1C)

Foreign direct investment inflow doesn't have a consistent sign in my analysis; It is positive and significant with commercial banking asset share (Table 1A), insignificant with private credit share and financial depth (Table 1A). It is insignificant in Table 1B and Table 1C, except with commercial banking asset share.

Stock market variables are also run separately in my analysis to minimize multicollinearity. I also run all three stock market variables with financial development variables to see if I get any different results. The results of the equity market variables are shown in Tables 2A, 2B and 2C.

TABLE 2A
IMPACT OF EQUITY VARIABLES ON ANNUAL TOTAL RENEWABLE ENERGY GENERATION PER CAPITA IN NON-OECD COUNTRIES

	Total renewable energy per capita	Total renewable energy per capita	Total renewable energy per capita
Stock market capitalization ratio	69.6313 (22.5143)		
Stock market turnover ratio		-14.3381* (6.1092)	
No of publically traded companies per capita ratio			-40.2074* (23.5606)
Foreign direct investment ratio	3.3571 (1.8974)	4.5783 (1.8421)	3.2348 (1.8995)
Income per capita in constant 2005 USD	2.1657*** (4.3384)	1.7349*** (3.3053)	6.3648*** (4.1984)
Kyoto dummy variable	48.3097** (10.2770)	50.6188** (9.7293)	57.3268*** (9.9134)
N	1181	1217	1278
R^2: within	0.0581	0.0469	0.0527
R2: between	0.0180	0.0017	0.0124
R2: overall	0.0022	0.0007	0.0001

Notes: The dependent variable is total renewable energy produced per capita measured in KWh per capita. All regressions are fixed effects on sample panel of non-OECD countries from 1980-2006 with 1-year lags for all indicators except Kyoto protocol. Standard errors are in parentheses. *, **, *** indicate statistical significance at 10, 5, and 1 percent levels, respectively.

Table 2A above shows that stock market turnover and number of publically traded ratios have a negative and significant relationship with total renewable energy. Income per capita and Kyoto have a positive impact on total renewable energy, similar to our results for financial sector development ratios. Stock market variables impact on hydro renewable energy is shown in Table 2B below

TABLE 2B

IMPACT OF EQUITY VARIABLES ON ANNUAL HYDRO ENERGY GENERATION PER CAPITA IN NON-OECD COUNTRIES

	Hydro renewable energy production per capita	Hydro renewable energy production per capita	Hydro renewable energy production per capita
Stock market capitalization ratio	66.1425 (22.1079)		
Stock market turnover ratio		-13.5107* (6.0218)	
No of publically traded companies per capita ratio			-25.9494 (22.9224)
Foreign direct investment ratio	3.3230 (1.8632)	4.5017 (1.8158)	3.1931 (1.8481)
Income per capita in constant 2005 USD	3.9843** (4.4601)	0.4912*** (3.2580)	3.7953*** (0.0041)
Kyoto dummy variable	42.1005** (10.0916)	43.3625* (9.5901)	48.0997*** (9.6452)
Observations	1181	1217	1213
R^2: within	0.0474	0.0372	0.0387
R^2: between	0.0068	0.0007	0.0126
R^2: overall	0.0012	0.0012	0.0001

Notes: The dependent variable is total renewable energy produced per capita measured in KWh per capita. All regressions are fixed effects on sample panel of non-OECD countries from 1980-2006 with 1-year lags for all indicators expect Kyoto protocol. Standard errors are in parentheses. *, **, *** indicate statistical significance at 10, 5, and 1 percent levels, respectively

None of the three stock market ratios have a positive relationship with hydro energy production. Stock market turnover ratio has a negative and significant relationship with hydro energy generation. These results are against my hypothesis, which expects a positive impact on hydro energy generation. Similar to Table 2A, income per capita and Kyoto have a positive impact on hydro energy generation. Table 2C shows the impact of stock market ratios with non-hydro renewable energy.

TABLE 2C

IMPACT OF EQUITY VARIABLES ON ANNUAL NON-HYDRO ENEWABLE ENERGY GENERATION PER CAPITA IN NON-OECD COUNTRIES

	Non hydro renewable energy generation per capita	Non hydro renewable energy generation per capita	Non hydro renewable energy generation per capita
Stock market capitalization ratio	3.5003 (2.1520)		
Stock market turnover ratio		-0.8199 (0.5268)	
No of publically traded companies per capita ratio			-14.2239*** (2.9911)
Foreign direct investment ratio	0.0326 (0.1814)	-0.0744 (0.1588)	-0.0393 (0.2411)
Income per capita in constant 2005 USD	1.8047*** (0.4146)	1.2334*** (0.2850)	2.5561*** (0.5330)
Kyoto dummy variable	6.2430*** (0.9822)	7.2895*** (0.8391)	9.2658*** (1.2585)
Observations	1181	1217	1213
R^2: within	0.1109	0.1206	0.1045
R2: between	0.0001	0.0000	0.0004
R2: overall	0.0010	0.0025	0.0057

Notes: The dependent variable is total renewable energy produced per capita measured in KWh per capita. All regressions are fixed effects on sample panel of non-OECD countries from 1980-2006 with 1-year lags for all indicators expect Kyoto protocol. Standard errors are in parentheses. *, **, *** indicate statistical significance at 10, 5, and 1 percent levels, respectively

Table 2C shows insignificant results for two out of the three stock market variables. Number of publically traded companies has a negative impact on non-hydro renewable energy, which is contrary to my hypothesis.

Stock market capitalization has an insignificant relationship with total renewable energy, hydro and non-hydro energy production. Stock turnover ratio has a negative relationship with total renewable energy generation, (Table 2A), negative relationship with hydro energy generation (Table 2B) and an insignificant relationship with non-hydro energy production (Table 2C). The results of number of publically traded companies per capita are negative for total renewable energy production insignificant for hydro energy production, and negative for non-hydro renewable energy production. These results suggest that stock market development in non-OECD countries may not encourage renewable energy development and are against my hypothesis. The negative relationship of stock turnover ratio and number of publically traded companies contrary to my hypothesis which suggests that these two variables would have a positive relationship with renewable energy development.

Income per capita is positive for all three equity variables for total renewable energy production, hydro renewable and non-hydro generation as shown in Tables 2A, 2B and 2C. These results suggest that in non-OECD countries, higher income countries produce more renewable energy. Foreign direct investment negative relationship only for non-hydro energy production. has an ambiguous relationship with total renewable, hydro and non-hydro generation. Kyoto has a positive relationship with total renewable energy, hydro energy and non-hydro renewable energy.

Finally, I analyze the impact of oil production per capita on renewable energy development. As Table 3A shows oil production per capita has a Foreign direct investment has an insignificant relationship with renewable energy production. Both Income per capita and

Kyoto protocol have positive relationships with total renewable, hydro and non-hydro energy production.

TABLE 3A: IMPACT OF OIL PRODUCTION PER CAPTIA ON TOTAL RENEWABLE ENERGY PRODUCTION PER CAPITA, HYDRO ENERGY PRODUCTION PER CAPITA, NON-HYDRO ENERGY PRODUCTION PER CAPITA IN NON-OECD COUNTRIES

	Total renewable energy per capita	Hydro renewable energy production per capita	Non hydro renewable energy generation per capita
Oil production per capita	-76.7803 (93.8151)	-54.9543 (92.4116)	-21.8033* (9.4679)
Foreign direct investment ratio	-1.1086 (0.3234)	1.1172 (0.3185)	-0.0087 (0.0326)
Income per capita in constant 2005 USD	2.5382*** (2.5707)	1.4544** (2.5322)	1.0806*** (0.2594)
Kyoto	48.9113*** (5.8152)	44.2322*** (5.7282)	4.6887*** (0.5868)
Observations	3210	3210	3210
R^2: within	0.0345	0.0294	0.0373
R^2: between	0.0121	0.0170	0.0090
R^2: overall	0.0044	0.0043	0.0110

Notes: The dependent variable is total renewable energy produced per capita measured in KWh per capita. All regressions are fixed effects on sample panel from 1980-2006 with 1-year lags for all indicators expect Kyoto protocol. Standard errors are in parentheses. *, **, *** indicate statistical significance at 10, 5, and 1 percent levels, respectively.

Hence, Table 3A suggests that oil producing countries are less likely to produce renewable energy, as shown by the last column in Table 3A. A one thousand barrels per day increase in oil production per capita, reduces non-hydro renewable energy production by 21.8033 KWh per capita. In the final part of my analysis, I use oil production per capita as an additional explanatory variable to determine if commercial banking asset shares' positive and significant relationship with non-hydro renewable energy still holds. I use oil production per capita with commercial banking asset share because earlier analysis in this paper shows that out of three financial variables and the three equity market variables, commercial banking is the only variable that has a positive relationship with non-hydro renewable energy. I wanted to see if this positive relationship holds if I add another explanatory variable. Table 3B shows that even when I add oil production per capita as an explanatory variable, commercial banking asset share still shows a positive relationship with non-hydro renewable energy per capita. Table 3B also shows results of adding this additional explanatory variable with commercial banking for total renewable energy, hydro energy and non-hydro energy. Both these relationships are insignificant.

TABLE 3B: IMPACT OF COMMERCIAL BANKING RATIO ON TOTAL RENEWABLE ENERGY PER CAPITA, HYDROENERGY PER CAPITA AND NON-HYDRO ENERGY PER CAPITA WITH OIL PRODUCTION PER CAPITA AS AN EXTRA VARIABLE

	Total renewable energy production per capita	Hydro renewable energy production per capita	Non-hydro renewable energy production per capita
Commercial banking asset share ratio	54.2075 (23.9205)	34.9193 (23.5756)	19.3340*** (2.4646)
Foreign direct investment ratio	1.1228** (0.3298)	1.1213** (0.3257)	0.0019 (0.0340)
Income per capita in constant 2005 USD	3.3611*** (3.1012)	2.0304*** (3.0565)	1.3256** (0.3195)
Oil production per capita (thousands of barrels per day per capita)	-137.0004* (112.0111)	-100.1214* (110.3966)	-36.8508* (11.5411)
Kyoto dummy variable	43.4877*** (6.3451)	39.8180*** (6.2536)	3.6778*** (0.6537)
N	2943	2943	2943
R^2-within	0.0344	0.0279	0.0626

R-between	0.0042	0.0068	0.0052
R-overall	0.0037	0.0036	0.0124

Notes: The dependent variable is non-hydro renewable energy produced per capita measured in KWh per capita. All regressions are fixed effects on sample panel from 1980-2006 with 1-year lags for all indicators expect Kyoto protocol. Standard errors are in parentheses. *, **, *** indicate statistical significance at 10, 5, and 1 percent levels, respectively.

Hence, Table 3B shows, even with the presence of oil production per capita as an explanatory variable, commercial banking asset share is the only financial sector variable that has a positive relationship with non-hydro energy production. A one percent point increase in commercial banking asset ratio increases non-hydro renewable energy by 0.1933 KWh per capita. This is similar to the results in Table 1C, where without the oil per capita explanatory variable; a one percent point increase in commercial banking asset ratio also increases non-hydro energy production by 0.1933 million KWh per capita.

Table 3C below shows regressions of all three financial sector variables and equity market variables. Even though these six variables might show correlation I wanted to regress them simultaneously on renewable energy just to see if I get any surprising results. Commercial banking asset share shows positive relationship with non-hydro renewable energy, which is consistent with my earlier analysis (Table 1C, 3B). However, financial depth shows a positive relationship with non-hydro energy generation, in my earlier analysis (Table 1C), this relationship was negative. In my hypothesis, I expected financial depth to have a positive relationship with non-hydro renewable energy but my previous results do not show an expected positive relationship. Private credit shows insignificant relationships. The results of stock turnover ratio and list of publically traded companies are insignificant, whereas these results showed mostly a negative relationship with renewable energy generation (Table 2B, 2C).

According to my hypothesis, the results in tables 2B and 2C should have suggested a positive relationship between stock turnover and publically traded companies ratio. However, stock market capitalization ratio shows a positive relationship with hydro energy generation. Hence, the most consistent result I get is for commercial banking asset share's positive relationship with non-hydro renewable generation.

TABLE 3C
IMPACT OF FINANCIAL SECTOR DEVELOPMENT AND EQUITY VARIABLES ON ANNUAL RENEWABLE ENERGY DEVELOPMENT

	Total renewable energy production per capita	Hydro renewable energy production per capita	Non-hydro renewable energy production per capita
commercial banking asset share ratio	67.2328 (45.0779)	47.0392 (44.4359)	21.0604*** (4.1838)
Private sector credit share ratio	-15.3902 (50.5152)	-2.7600 (49.7958)	12.6035 (4.6885)
Financial depth ratio	-75.6773 (56.0911)	-99.6952 (55.2923)	23.9931*** (5.2060)
Stock market capitalization ration	67.7954 (21.3729)	64.2052* (21.0685)	3.5962 (1.9836)
Stock market turnover ratio	-16.3292 (5.5138)	-15.5752 (5.4353)	-0.7404 (0.5117)
Number of publically traded companies per capita ratio	-31.8996 (24.5202)	-24.8649 (24.1709)	-6.9919 (2.2758)
Foreign direct investment ratio	2.0545 (1.7633)	2.0321 (1.7381)	0.0216 (0.1635)
Income per capita in	8.6337* (4.4946)	6.2902 (4.4306)	2.3204*** (0.4171)

constant 2005 USD			
Kyoto	31.3028** (10.4975)	28.0056 (10.3481)	3.3271*** (0.9743)
N	1019	1019	1019
R2:within	0.0669	0.0533	0.2039
R2-between	0.0063	0.0039	0.0002
R2-overall	0.0001	0.0001	0.0039

Notes: The dependent variables are measured in million KWh per capita. All regressions are fixed effects on sample panel from 1980-2006 with 1-year lags for all indicators expect Kyoto protocol. Standard errors are in parentheses. *, **, *** indicate statistical significance at 10, 5, and 1 percent levels, respectively

CHAPTER 7: DISCUSSION AND CONCLUSION

In the last few years, we have experienced renewed interest in the renewable energy sector. This interest can be attributed to many factors, but primarily these factors are related to environmental issues, energy security, population growth and global economic growth. Energy production today and also for the most recent part of human history, has relied heavily on fossil fuels. It is important to reduce our dependence on conventional fossil fuels and explore different avenues of renewable energy production to reduce pollution and various environmental externalities, increase our energy security, and to foster sustainable economic development, both for ourselves and also for our future generations.

This paper builds on the analysis carried out in Brunnschweiler (2009), which analyzes the effects of financial sector on the development of renewable energy sector. In my paper, I not only test the impact of financial sector development on renewable energy, but I also tested the impact of stock market variables on renewable energy development. This analysis is conducted in a series of panel data estimations for the period 1980-2006. I focus on non-OECD developing countries because most of the energy demand is expected to generated by non-OECD countries in the next few decades. As these countries demand higher energy with the growth of their population and the rise in their income levels, they are expected to fulfill their energy demands by using fossil fuels, and this fossil fuel production and consumption would consequently make them major environmental polluters. I carried out Fixed Effects regressions to minimize the effects of time invariant country specific effects on a panel data set of 156 non-OECD countries. I used three financial sector development variables and three equity market variables. The three financial sector development variables were commercial banking asset ratio, private sector credit and financial ratio. The three equity market ratios were stock turnover ratio, stock market capitalization ratio and number of publically traded company's per capita ratio. My explanatory variables were income per capita, foreign direct investment, oil per capita and Kyoto. I used total renewable energy, hydro energy and non-hydro energy generation for my output measurements. My results suggest that out of the six variables I used in my analysis, commercial banking share is the only one that has a positive impact on renewable energy development, specifically with non-hydro renewable energy development. The analysis and estimations in this paper confirm my hypothesis that commercial banking asset share has a positive relationship with non-hydro renewable energy production. A Financial system that helps growth in commercial banking asset share will also encourage growth in non-hydro renewable energy. All other results for the six variables were against my hypothesis. Income per capita and Kyoto protocol showed strong positive results. Financial depth shows a relatively weaker correlation with renewable energy production. It mostly had a negative relationship with renewable energy development. The result for financial depth was surprisingly against my hypothesis. The reasons for these puzzling results would be a topic for future research and further study. The results of financial depth may be better understood with more available data and by carrying out an analysis for a longer time period, perhaps fifty or more years. The results of private credit were insignificant. Again, the reason for this insignificance could perhaps be determined if we had more data and for longer time period, fifty years or more.

My hypothesis suggested a positive relationship between equity market variables and renewable energy. As discussed in the literature, active and liquid stock markets encourage economic growth and are also expected to foster growth in renewable energy sector. However, my results were unlike my hypothesis. All three equity market variables show insignificant relationships with renewable energy development. Therefore, the results of equity market indicators in this paper do not suggest a positive effect on renewable energy development.

I also test the relationship between oil production per capita and renewable energy generation. Not surprisingly, my analysis shows that oil production discourages renewable energy development. Oil producing countries are less likely to invest in renewable energy production. All OPEC countries have signed and ratified Kyoto, although most of them ratified in 2005, which makes it hard to obtain data sets that measure the effects of ratification on oil production. However, when I introduce oil production per capita as an additional explanatory variable and test the relationship of commercial banking asset share with renewable energy, I still get positive relationship between commercial banking and non-hydro energy development. The coefficient of commercial banking asset share in relation to non-hydro renewable energy shows that a one percent point increase in commercial banking asset share will increase non-hydro renewable production by 0.1913 KWh per capita.

The results of the various estimations carried out confirm the positive effects of Kyoto Protocol on renewable energy development. Out of the dataset of 156 countries, 136 signed Kyoto since 1997. Although, my analysis only considers 10 years, 1997-2006 inclusive, and only takes into account signatories not countries that ratified Kyoto protocol, the results cannot suggest that signing of Kyoto protocol alone positively impacts renewable energy development, various domestic policies and overall environmental awareness might also be contributing factors, but nonetheless the positive impact of Kyoto on renewable energy development in non-OECD countries is encouraging. It would be interesting to analyse and study the future impact of Kyoto protocol.

Overall, my results in my empirical study are against my hypothesis, which suggested a positive impact of financial sector and stock market development. The results of these estimations do not suggest a positive impact of well-developed financial sector and stock market development on renewable energy production. A strong and well developed financial sector does have a positive impact on economic development and as discussed in this paper, it is likely to have a positive impact on renewable energy development. However, my analysis is contrary to my hypothesis and doesn't suggest a positive relationship of financial sector on renewable energy development in non-OECD countries. Perhaps a much larger data set spanning over fifty plus years can give us a more definitive relationship between financial sector and renewable energy development. A future empirical analysis from 1980 or before and up to 2030 is likely to give us more detailed analysis of the relationship between finance and renewable energy development in non-OECD countries. The availability of quality data on renewable energy development and investment is always a challenge and tends to hamper empirical studies in this area. Further work is needed to corroborate the results of commercial banking asset share with renewable energy development in this paper, especially in the form of case studies, which could be country or region specific, and these case studies could also help us better understand the overall relationship of financial sector with renewable energy development.

Appendix

Definitions and sources

All data were collected for non-OECD countries and OECD countries where applicable for comparison, for the years 1980-2006 (where available)

Variable	Definition	Source
Total renewable energy per capita	Net total renewable resource electric power in KWh per capita- including hydro, wood and waste, geothermal, solar and wind.	Brunnschweiler (2009) data from Swiss Federal Institute of Technology Zurich, Energy Information Administration (2006)
Hydro electric generation per capita	Net hydroelectric power generation in KWh per capita	Brunnschweiler (2009) data from Swiss Federal Institute of Technology Zurich, Energy Information Administration (2006)
Non hydro energy generation per capita	Net non-hydro power generation in KWh per capita- including wind, solar, geothermal, ocean, wood and waste	Brunnschweiler (2009) data from Swiss Federal Institute of Technology Zurich, Energy Information Administration (2006)
Commercial bank asset share	Deposit money bank assets/(deposit money + central) bank assets (i.e., commercial bank asset share versus Central Bank).	World Bank (2012)
Private sector credit share	Private credit by deposit money banks / GDP.	World Bank (2012)
Financial depth	Liquid Liabilities / GDP.	World Bank (2012)
Kyoto	Dummy variable taking value one from 1998 onwards (post-Kyoto period)	Brunnschweiler (2009) data from Swiss Federal Institute of Technology Zurich, Energy

		Information Administration (2006)
Income per capita	GDP in constant 2005 USD	World Development Indicators
Foreign direct investments	Foreign direct investments inflows (%GDP)	Brunnschweiler (2009) data from Swiss Federal Institute of Technology Zurich, World Development Indicators
Oil prod per capita	Per capita oil production in thousand barrels per day.	Brunnschweiler (2009) data from Swiss Federal Institute of Technology Zurich, World Development Indicators
Stock market capitalization	Value of listed shares to GDP	World Bank (2012)
Stock market turnover	Ratio of value of total shares traded to average real market capitalization.	World Bank (2012)
Number of publically traded companies per capita	Number of publically listed companies per 10k population	World Bank (2012)

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