Master Thesis

Testing the effectiveness and consistency of feed-in tariffs in the development of PV Solar: An empirical analysis of the OECD region.

"I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that."

Thomas Edison, 1931

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Abstract

Growing concern for climate change and rising scarcity of fossil fuels are on the basis for governments to stimulate the development of renewables. Photovoltaic solar (PV) as one of them has made its growth spurt most recently with an average yearly growth of 47% over the last decade. The feed-in tariff (FiT) is evolved to be the most popular policy in supporting PV generation. A few studies have assessed the effectiveness of this specific policy, but the role of FiT-structure and policy-consistency are not taken into account yet. Panel data estimations are employed for 30 OECD-members over the period 1990-2011. This paper empirically tests whether feed-in tariff policies have been effective in the development of PV Solar, explicitly taking into account structure and consistency of feed-in tariffs. Two new indicators will be composed: one to measure policy-consistency and another to analyse the effectiveness of feed-in tariffs, based on six separate design features. We find a positive relation between the presence of a FiT and the development of a countries' share of PV in the electricity-mix. The design feature that primarily explains this relation is contract duration. We find limited proof for the role of policy-consistency: there is some evidence that a sustainable FiT-policy is on average more effective than a very strong FiT.

Preface

My passion for renewables, and especially PV solar, started a few years ago when I joined Solarplaza International BV. They gave me the opportunity to develop a strong conviction that PV is the key electricity source for the future. It is not only an increasingly suitable replacement for non-conventional electricity sources but more important it will become a major contributor in the fight against poverty and inequality.

PV solar is becoming a viable alternative. I am hopeful that this research helps governments to realize that their support made a difference in the development of the PV-industry, and not only for their own good but also for a wider use; for people with a greater need for cheap electricity. Let’s work together to realize the potential of this clean electricity source; let it be a solution for everyone!

At first I would like to thank Prof. dr. Elbert Dijkgraaf for his continuous support during the writing process of this master thesis. His experience and knowledge have been of great value to me. I really appreciated his personal involvement. One thing I want to mention specifically: his response time was always amazingly fast which kept me focused and motivated.

I want to give special thanks to my girlfriend and my parents. Pauline, you have been of great help and encouragement to me, you were always there to inspire me with new energy. Your love and care are valuable! Mom and dad, thank you for your support and involvement!

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Table of figures and tables

Glossary of key terms and abbreviations

Abbreviation	**Fully written**
AC	*Alternating Current*
BIPV	*Building integrated PV*
CPI	*Corruption Perception Index*
c-Si	*Crystalline-Silicon*
CSP	*Concentrated Solar Power*
DC	*Direct Current*
EPIA	*European Photovoltaic Industry Association*
EPT	*Energy Payback-Time*
EU ETS	*European Union's Emission Trading System*
FiT	*Feed-in Tariff*
GTM	*Greentech Media Research*
GWh	*GigaWatt-hour*
IEA	*International Energy Agency*
kWh	*kiloWatt-hour*
MWh	*MegaWatt-hour*
MWp	*MegaWatt-peak*
OECD	*Organisation for Economic Co-operation and Development*
PV	*Photovoltaic solar*
RD&D	*Research, Development &Demonstration*
ROI	*Return on investment*
RPS	*Renewable Portfolio Standards*
Solar LCOE	*Levelised cost of solar electricity*
UN	*United Nations*
UNISEO	*United Nations International Sustainable Energy Organisation*
Wp	*Watt-peak*

1. Introduction

In the last decades an increasing number of national governments started to stimulate the development of renewable electricity sources. Important motivations have been the growing concern for climate change and the rising scarcity of fossil fuels, key ingredient for most conventional electricity sources. Significant positive influence flows out of government objectives to reduce its dependence on energy imported from abroad (Marques et al, 2010). As a result international agreements on carbon emission reduction and renewable energy targets have been established, pushing governments to promote new, mainly renewable, energy sources.

From the most common sources of renewable electricity - biomass, wind, solar, geothermal and hydropower – photovoltaic solar (PV) has made its growth spurt most recently, with a worldwide average yearly growth of 47% over the last decade (OECD Dataset). This development has increasingly resulted in up-scaled manufacturing facilities and technology improvements. Both have driven the price of a PV-system down, so that PV is gradually becoming a competitive electricity source. At the start of development of the PV-industry in the 1990’s, important conventional electricity sources as nuclear and coal-fired power plants were able to produce electricity at only a fraction of the costs at which you could generate one solar kilowatt-hour (kWh). For bridging the gap to competitivity, the role of governments is generally considered as a crucial enabling factor.

The development of PV started in the early 90´s in Germany and Japan; these two countries were the first to adopt policy-instruments. Since 2005 governments all around the world have begun to promote PV. Policy-makers have introduced several combinations of instruments. The most common instrument is a Feed-in Tariff (FiT), 22 of the 30 countries covered in this research include a FiT in their set of policies. The general idea: the owner of a PV system receives a guaranteed price for every produced kWh that is fed into the grid; this is agreed on contract basis during a fixed period. FiTs can differ in various characteristics, including tariff amount, limitations on available budget or installed capacity, contract duration and the presence of a degression in the tariff of the FiT.

In the past years uncertainty raised about how effective Feed-in Tariff policies have been in the development of PV until now. Policy-makers also wrestle to find the optimal structure of a FiT. Lacking the right FiT-structure can be a reason that some countries are lagging behind in development compared to others. Seen in that light, it is of value to analyse the relationship between effectiveness and structure of a FiT. Besides that, theoretical literature is pointing out the importance of consistent policy implementation as a key factor to improve the effectiveness of a FiT. Investors seek maximum returns with minimum risk. If government support is vital to provide a reasonable return, policy-consistency is considered as crucial to limit the risk. To summarize, both FiT-structure and policy-consistency are important in testing the effectiveness of a FiT. But not one existing literature study actually tests the role of these factors in an empirical or quantitative way. This paper fills in this gap. The main question in this paper is whether feed-in tariff policies have been effective in the development of PV Solar, explicitly taking into account structure and consistency of feed-in tariff policies.

Two new indicators will be composed: one to get an eye on consistency, the other to be able to perform a detailed analysis on the effectiveness of FiTs in general and its relationship to FiT-structure.

The consistency-indicator consists of four separate measures. The first measure compares the current tariff amount with tariffs in the past. The second makes a comparison with future tariffs. If the differences between tariffs in consecutive years are close to zero it is expected that potential investors gain confidence in the continuity of a policy, so that the effectiveness of a FiT grows. The third measure that is relevant for our consistency-indicator takes the presence of limitations on available budget or installed capacity into account. In their presence investors have to deal with the uncertainty that a FiT application is rejected because the pre-set limit is reached, it makes a FiT less consistent. The fourth and last part focuses on sustainability of the tariff that is in place. An extremely high tariff in terms of expected return on investment is an example of an unsustainable FiT. A gold-rush could start with the consequence that a tariff-cut is often carried out soon after implementation of the FiT. It could be the cause of a sharp downturn in market development. A sustainable FiT-policy gives investors a good but realistic return on their investment.

The second new indicator measures the strength of the FiT-policies in each country and for each year. It consists of six measures for the various FiT design features. Three for the tariff amount, since it can be split in three categories: tariffs for small, commercial and utility scale PV systems. The higher the tariff amount for a specific category the more effective the tariff is expected to be. The fourth measure indicates contract duration. If a period over which an investor is compensated for its electricity production is relatively short, the corresponding expected return of an investment is lower causing the FiT to have less impact. As fifth feature, the presence of a cap on cost or capacity. This has a negative influence on the strength of a FiT due to the fact that it limits the development of the PV-industry in the country concerned. It can be that every aspect of a FiT that is in place seems to be great, but due to a cap the development is inhibited. The last feature that will be measured is the average cost of generation of one solar kWh. The level of this measure is important for an investor, the lower the average cost of one solar generated kWh the higher the expected return on investment will be. These costs vary primarily because of the difference in insolation[1] between countries. But price, lifetime and efficiency of a PV-system also contribute to its variation. Countries with high insolation numbers are able to generate more electricity in a certain period, resulting in a relatively low average cost for the generation of one solar kWh. Each of the six features will be rated with points on a pre-defined scale. This creates the possibility to test the effectiveness of the design features separately. If we add the six ratings we get one variable to test the combined effectiveness of the design features.

To give an answer on the main question, panel data regressions will be conducted explaining differences in the use of PV using data over the period 1990-2011 for the OECD region. Besides the two new composed indicators for consistency and FiT strength the analysis will include binary variables for several other policy instruments and a set of other explanatory variables. An important note is that this paper in general test the effectiveness and consistency of FiT-policies on country-level.

The remainder of the paper is divided in four parts. First the literature study; theoretical and empirical literature are discussed simultaneously. Secondly the selection of data and the used methodology for the econometric analysis will be addressed step by step. The third part contains the econometric analysis followed by a sensitivity-analysis to test the robustness of these results. The paper ends with conclusions, limitations and suggestions for further research.

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[1] The intensity of incoming solar radiation incident on a square meter horizontal surface.

2. Literature

The literature study is split in five sections. The first two sections form an introduction about the definition of PV and the development of the PV industry. The third section appoints the different drivers of this development. These three sections together provide important background information including facts and figures to give the reader a good understanding of this industry. The last two sections give a combined theoretical and empirical literature overview of respectively policy consistency and the effectiveness of feed-in tariffs.

2.1 Defining PV

PV stands for photovoltaics. This word can be broken down in two parts, photo and volt. Photo is light and volt is a unit of electric potential. A photovoltaic cell converts sunlight directly into electricity by making use of the photoelectric effect. PV is one of the major ways to generate energy from the sun; the other two are concentrated solar power (CSP) and solar thermal. CSP uses sunlight to generate electricity by concentrating sunlight from a big surface to heat a receiver to high temperatures; the heat is transformed in electricity by turbines. Solar thermal applications are mainly used for heating water. Every solar technology has a different potential and is supported with different government incentives. This research focuses specifically and only on PV.

The two main components of a PV solar system are the solar module and the inverter. The module consists of a pack of photovoltaic cells. The cells collect and transfer the sun's energy into direct current (DC) electricity. The inverter converts the DC electricity into 240 volt alternating current (AC) electricity. The generated electricity can be used for consumption or can be fed into the grid. The network meter ensures that one exactly knows how much electricity is fed into the grid and consumed from the grid; the sum of both numbers determines the electricity bill. Figure 1 gives a simplified overview of a PV-system.

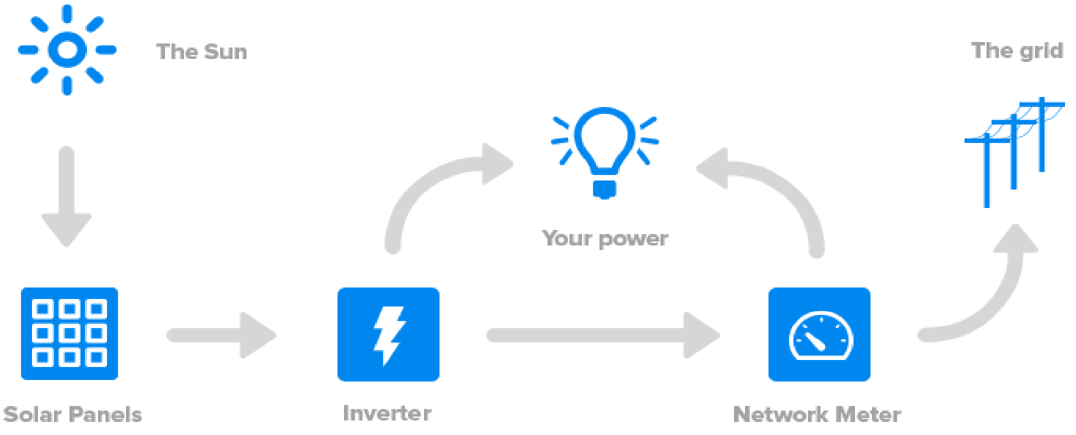


Figure 1 Simplified PV Solar System (Zincsolar)

The two main photovoltaic solar panel technologies are Crystalline-Silicon (c-Si) and Thin-Film. A c-Si module reaches high efficiency rates, is reliable and easy to fabricate. On the downside c-Si solar panels have relatively high initial costs due to the expensive components. Thin-Film solar cells are less fragile and generally cheaper but reach lower efficiency values. To compare the impact of both technologies: Greentech Media Research (GTM) reported that the market share of Thin-Film solar panels was 18% in 2009 (Shiao, 2012). But due to a 40%-drop of c-Si prices in 2011, its share decreased to only 11%. C-Si took the total remaining 89% of market share.

2.2 Defining grid parity

The implementation of government incentives to stimulate the PV-industry is temporary according to one of the world's leading associations in the PV industry, the European Photovoltaic Industry Association (EPIA). Policy interventions will end when PV is competitive, in other words when overall grid parity is reached. To place the role of government incentives in the right perspective it is important to understand what the term grid parity means. The simple definition of grid parity according to research institute Greentech Media (Kann, 2011):

"Grid parity is the point at which the cost of solar power matches that of grid electricity"

But it is more complex than it seems to be. Grid parity is not reached at one single moment in time. It is a process starting in each country at a different time in a different industry-segment.

To determine when grid parity is reached we distinguish two important parameters, the wholesale and retail electricity price on one hand and the levelised cost of solar electricity (solar LCOE) on the other hand. If the solar LCOE of a PV-system is equal to the grid price of electricity, it means that grid parity is reached and as a result PV is competitive.

Levelised cost of solar electricity

The solar LCOE displays the calculated cost of one solar generated kWh. It takes into account all the investment, operation and maintenance costs over the lifetime of a PV system. The solar LCOE mainly differs between countries due to variations in solar irradiation. Within the panel of countries that is covered in this research average solar irradiation (kWh per m2 per year) differs between 811 in Norway and 2094 in Israel, with an average of 1248. The expected generation of a PV system in Israel, purely based on solar irradiation, is about 70% higher than the generation of a PV system in the average OECD country. Electricity price and other additional factors disregarded, Israel has a competitiveness-advantage to all other countries in our data-panel. Besides solar irradiation, the price of a PV-system (in other words, the investment) also has its impact on the level of the solar LCOE. The investment differs between countries partly due to differences in transport costs but more because of differences in the size of PV projects. The bigger a project, the larger its scale advantage, the lower the investment and the lower the solar LCOE of one solar generated kWh. Technology and scale effects will drive the level of solar LCOE downwards through time. Figure 2 displays the potential range of solar LCOE in Europe in relation to the irradiance level. Forecasts are made over the period 2011-2020. The figure also shows 2011´s real range of PV's generation cost in Europe (the red bar at the right side). The difference between best (0.12 €/kWh) and worst solar LCOE is huge (0.40 €/kWh, mainly experienced in northern parts of Scandinavia and in Iceland, with solar LCOE levels below 800 kWh/m2). This clearly underlines that PV will not reach grid parity at one moment in time but that it will be a gradual development over countries and industry-segments.

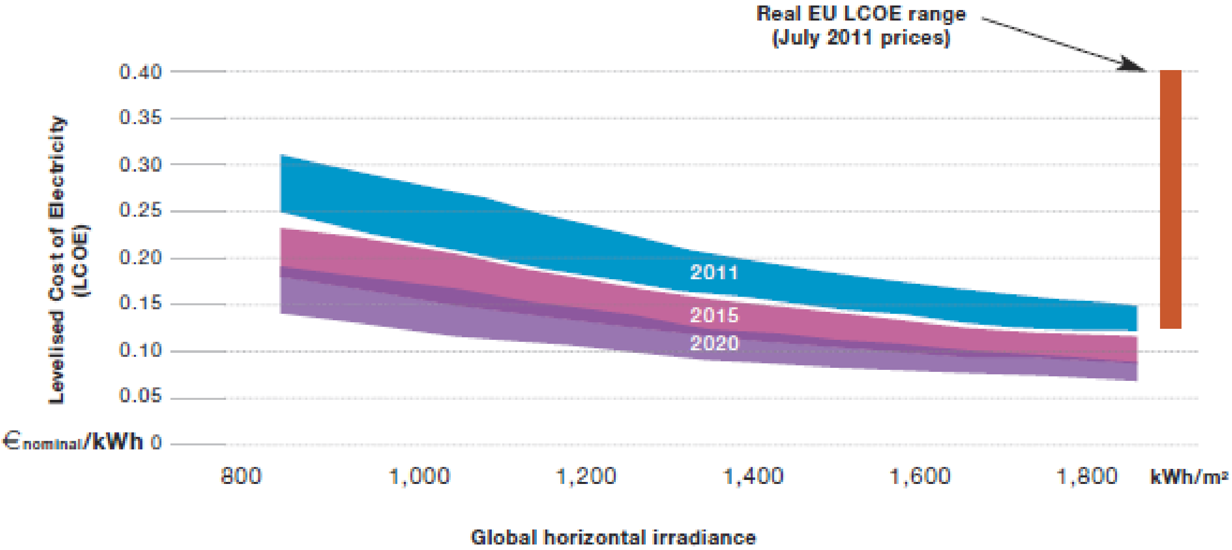


Figure 2 Real solar LCOE range in Europe for 2011 and forecasts for the period 2011-2020 (EPIA)

Electricity price

The question whether grid parity is within reach is obviously for an important part determined by the price of electricity in a country. Electricity rates typically vary for different users. This variance is determined by the level of electricity that is consumed, the more one consumes, the lower the corresponding price. In general two price classes are distinguished: the retail price of electricity and the wholesale price.

Figure 3 shows us that over the last twenty years electricity prices have increased substantially. Over the last decade both the wholesale and retail electricity price more than doubled, taken the average over our country-panel (OECD-iLibrary). Future continuation of increase in electricity prices will fasten the process of reaching grid parity. The figure also gives an impression of the variation between wholesale and retail electricity prices between and within countries. A quick look on the figure learns us that the wholesale and retail price of electricity in Italy have strongly converged in the past decade whereas the price-difference was roughly stable in Japan and have diverged in Germany and the Netherlands. From here it is straightforward to assume that Germany and the Netherlands reach grid parity earlier in the residential segment whereas Italy will start to experience grid parity in the industrial and utility segments. This assumption is important for governments in implementing the right policies. For PV solar to become competitive in all industry-segments different levels of stimulation have to be set, simply since one segment needs more support to become competitive than the other. Combined with the observation that solar LCOE differs between countries, this assumption again shows us that PV solar is not competitive at the same time in all industry-segments.

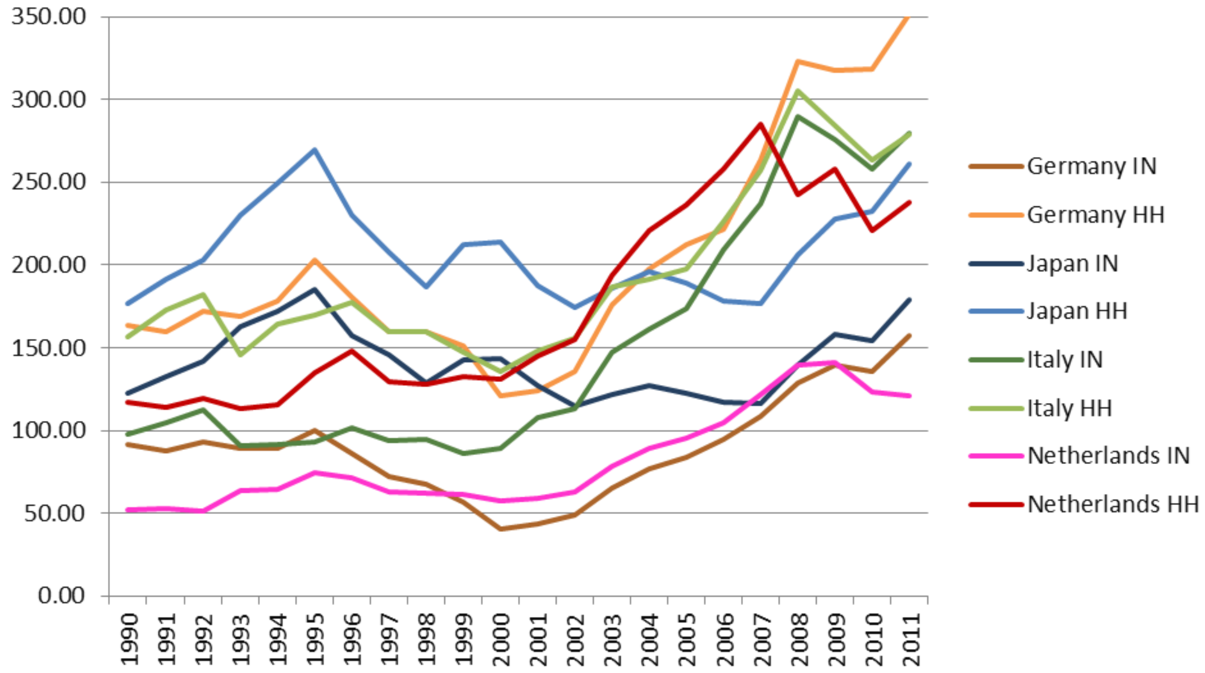


Figure 3 Retail (HH) and wholesale (IN) electricity prices of Germany, Italy and Japan ($/MWh)

Electricity prices vary between countries but even within countries. It is quite common that different distribution networks charge different electricity prices, prices can also differ between regions. Obviously, the level of solar irradiation can also be more beneficial in one region compared to the other, certainly in bigger countries this is the case.

In the literature some authors do not make the distinction between unsubsidized grid parity and subsidized grid parity. Obviously due to policy instruments PV is already competitive for years in several countries. In this paper, the term grid parity is only used in a situation that PV solar becomes competitive without being supported by subsidies.

In essence, grid parity will be a gradually developing phenomenon, occurring over a number of years across various countries (Kann, 2011). Still it is considered as an important milestone to reach, indicating that further use of policy instruments is unnecessary and competitiveness is achieved.

2.3 PV-Industry development in numbers

Solar PV was the fastest-growing renewable power technology worldwide over the period 2000-2011, according to the International Energy Agency (IEA). Figure 4 displays the yearly growth of the worldwide cumulative capacity of solar PV.

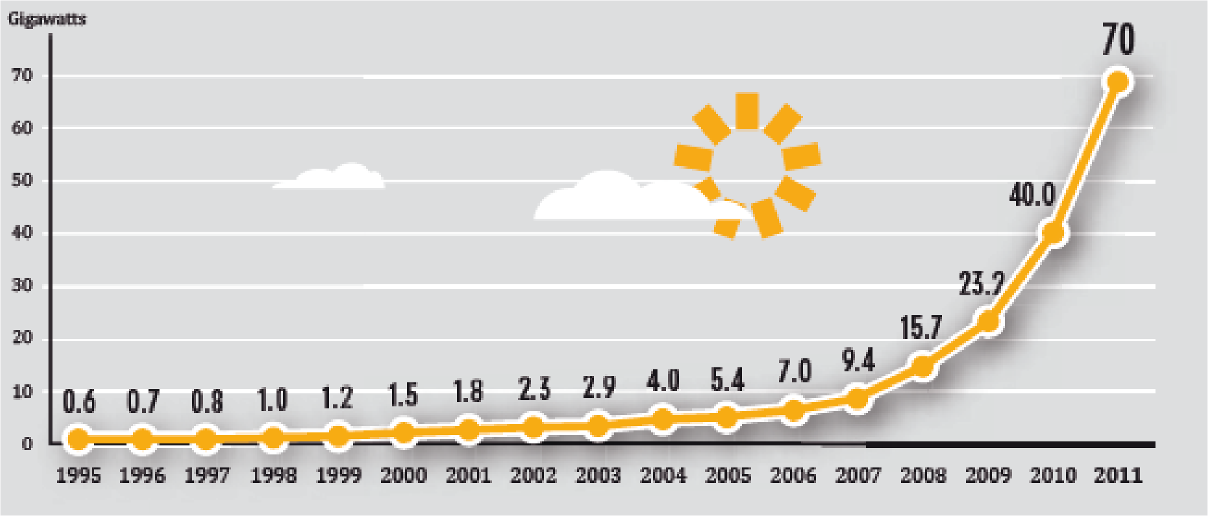


Figure 4 Solar PV total worldwide installed capacity in gigawatts, 1995-2011 (REN21)

Western Electric began to sell commercial licenses for PV technologies in 1955, just after the development of the first solar cell capable of converting enough sunlight to electricity to run everyday electrical equipment (US Department of Energy, 2002). In subsequent years, research intensified to achieve more efficient PV cells. NASA started to do experiments with PV cells on satellites and spacecraft's during the sixties and seventies. In 1983 worldwide photovoltaic production exceeded 21.3 megawatts (MWp) with sales above 250 million dollar. To put in perspective, 1 MWp of installed capacity is sufficient to provide 250 average households of electricity. Germany was the first that started to accelerate development and adoption of PV by making use of policy support mechanisms. In 1991 the first feed-in tariff (FiT) was introduced: the Electricity Feed Act. This introduced the obligation for the large electricity utilities to accept the electricity generated by small renewable electricity producers, and to remunerate them for the electricity fed into the grid. PV solar producers received a tariff equal to 90% of the (average historical) electricity retail price, for an indefinite period. Simultaneously, Germany introduced the so called 1000 Roofs Programme: grid connected PV systems on small roofs were compensated with a grant of 70% of the investment. Japan was the second country that subsidizes PV with its Subsidy Programme for Residential PV systems in 1994. Together Japan and Germany were responsible for the major share in the increasing growth of the worldwide PV-industry. Their combined share of the cumulative installed capacity in the OECD reached 78.5% at its peak in 2006 (OECD-iLibrary). At that time several other countries in the OECD started to promote PV through policy instruments. It is clearly visible in Figure 4 that the development of the PV-industry exploded in the last decade; the average yearly growth was 47%. Comparing 2010 to 2009, growth numbers even exceed 75%. Figure 5 maps the distribution of global installed capacity (in 2011) over the ten most important countries. Germany is on top of the list, followed by Italy. Japan lagged behind since its expansion drift slowed down in the last years. European markets are dominant with a cumulative share of 74%. The Dutch share of global installations is with 0,015% negligible.

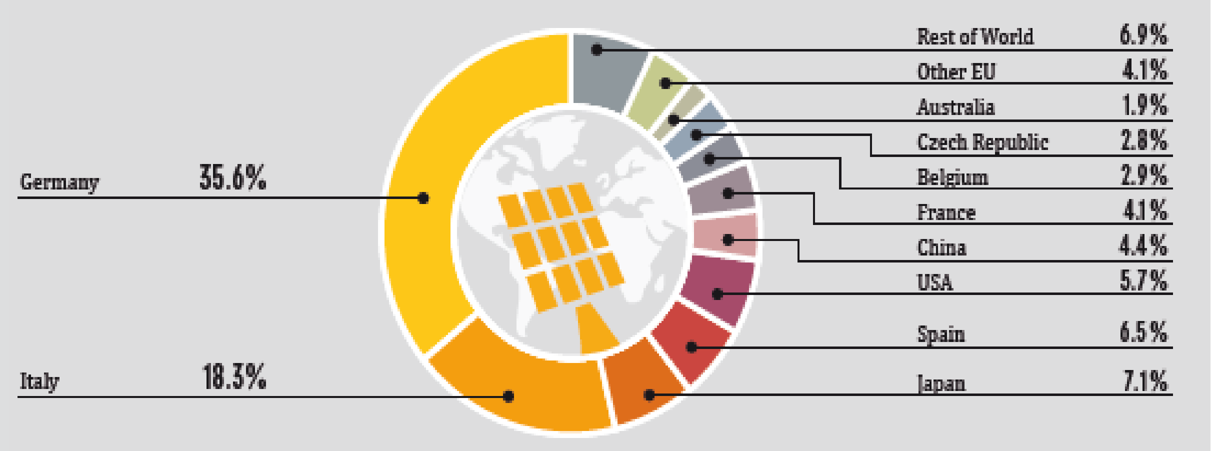
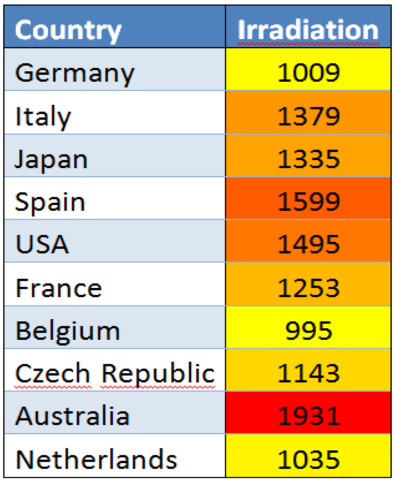


Figure 5 Distribution of global installed solar PV capacity, 2011 (REN21)

This European dominance is remarkable since the development of the PV-industry seems not primarily led by solar irradiation. Table 1 displays solar irradiation in kWh per m2 per year for ten of the major PV Solar markets (OECD Library). The countries are ranked on percentage share of global cumulative installed PV capacity.



Country	Irradiation
Germany	1009
Italy	1379
Japan	1335
Spain	1599
USA	1495
France	1253
Belgium	995
Czech Republic	1143
Australia	1931
Netherlands	1035

Table 1 Solar Irradiation

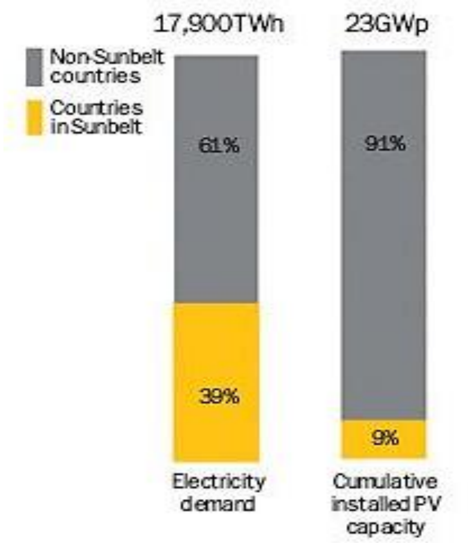


Figure 6 Share in power demand and PV capacity (EPIA)

Additionally Figure 6 shows that less than 10% of cumulative installed PV capacity was installed in so called Sunbelt countries in 2009 (including Australia, India, China, Indonesia, Brazil, Chile and South Africa). The average solar irradiation on the Sunbelt is above 1600 kWh/m2/year. This is more than 31% higher than the weighted average solar irradiation (1214) of the major PV solar markets of Table 1. Instead of intensity of the sun as main driver we can infer that PV-industry growth is more explained by financial returns.

2.4 Drivers of PV-industry development

The focus of this paper is to test the effect of feed-in tariffs on the development of the PV-industry. But it is not said that this has been the only determinant of growth. In fact existing literature has proven the relevance of several other factors. This section elaborates on the different drivers of the development of the PV industry.

Combining several existing studies gives a good overview of potential influences on the growth that the PV-industry has experienced in the last two decades. Some of those influences have caused the birth of others, or are at least strongly related to other factors. It all started with the growing concerns of climate change. A major cause of climate change was designated: the emission of greenhouse gases. This resulted in worldwide discussions about potential solutions. Emission limits and renewable energy targets were set, motivating governments to implement adequate renewable energy policies to reach those compulsory targets and to stimulate technology progress. This in turn led to more investment potential for PV solar applications; demand increased. Demand seeks supply, so that production expanded. Combined with technology improvements this led to price decreases, increasingly attracting new investors. And so the PV-industry started to develop.

This section gives background information of all drivers that have (potentially) contributed to the development of the PV-industry. Several, but not all, drivers will be included in the empirical study in chapter 5. The assumptions made at the basis of this selection will be further explained in chapter 4: data.

Drivers that will be described are political factors, policy instruments, country-specific factors and technology and scale effects. Country-specific drivers that will be addressed are electricity consumption, conventional electricity sources, wealth, solar irradiation and electricity price.

If we consider the market for PV capacity, the political factors mainly influence development from the demand side of the market, whereas technology and scale effects have more impact on development of the supply side. Policy instruments and country-specific factors can have influence on both the demand and supply side of the PV-market. An overview of all drivers and its relevance is displayed in Table 2.

Driver	Relevance	Par.
Political factors		**2.4.1**
Renewable energy targets	International agreements created a worldwide movement to a more sustainable environment	2.4.1.1
Energy import dependency	Concerns about dependency on imported energy motivated governments to internalize energy production	2.4.1.2
Energy lobby	Powerful fossil fuel cooperation’s inhibit the promotion of renewable energy sources	2.4.1.3
Technology and scale effects		**2.4.2**
Technology progress and production expansion	Acceleration of technological improvements and production expansion have led to strong decrease in cost-price of PV-systems	2.4.2.1
Policy instruments		**2.4.3**
An overview of policy instruments	A variety of economic and political interventions have been implemented to stimulate development of the PV-industry	2.4.3.1
Feed-in Tariffs	Most popular support mechanism, key-driver in this research	2.4.3.2
Country-specific factors		**2.4.4**
Wealth	Developed countries invest more in expensive and advanced technologies like PV	2.4.4.1
Solar irradiation	Variations in solar irradiation can have strong impact on the profitability of PV	2.4.4.2
Electricity price	Countries with high electricity prices are in general more attractive to develop	2.4.4.3
Electricity consumption	PV-demand may be higher in countries with high or growing electricity consumption	2.4.4.4
Conventional electricity sources	High shares of conventional electricity sources in a countries' energy-mix ensue growing demand for renewable energy sources	2.4.4.5

Table 2 Overview of the drivers of PV-industry development and its relevance

2.4.1 Political factors

2.4.1.1 Renewable energy targets

The globally growing concern on climate change has pushed governments and leading institutions to come into action. It is undisputed that renewable energy sources are essential to achieve the worldwide goal of reducing greenhouse gases (EPIA, 2011b). On the other hand, international agreements on renewable energy targets were needed to motivate governments (and companies) towards promotion of renewable energy sources.

On worldwide level the United Nations (UN) adopted the well-known Kyoto protocol, which is established on 11 December 1997 and entered into force on 16 February 2005. This protocol sets binding obligations to reduce the emission of greenhouse gases of industrialised countries. It was adopted on the UN Framework Convention on Climate Change in pursuit of its ultimate objective: “stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system”. 191 parties have ratified the protocol, of which 37 industrialised countries and the European Community have committed themselves to limit or reduce their emissions of greenhouse gases. These targets amount to an average of five per cent against 1990 levels over the period 2008-2012 (United Nations, 1998).

A quote from G8 Leaders’ Summit in Genoa in 2001 summarizes the worldwide awareness of and attitude towards the need of renewable energy sources:

“We recognize the importance of renewable energy for sustainable development, diversification of energy supply, and preservation of the environment. We will ensure that renewable energy sources are adequately considered in our national plans and encourage others to do so as well. We encourage continuing research and investment in renewable energy technology, throughout the world.”

Additionally to the Kyoto Protocol, in 2007 the European Commission implemented ambitious targets for all Member States to fight against climate change. Targets are set to be reached by 2020: the European Union (EU) should reach a 20% share of energy from renewable sources combined with a 20% reduction in EU greenhouse gas emissions from 1990 levels and a 20% improvement in the EU’s energy efficiency. This so called Climate and Energy Package is a set of binding legislation. The three mentioned targets are also known as the “20-20-20” targets (European Commission, 2012). Although several countries have implemented own climate targets, the Climate and Energy Package moved more responsibility for European climate policy to the European level. National emission caps disappeared and more trade in emissions is allowed under the European Union's Emission Trading System (EU ETS). An emission cap is introduced over time so that emissions fall. Within the cap, companies receive emission allowances which they can trade with others where needed. The number of available allowances is limited and decreasing, so that emissions have to decrease. The value of the allowances is dependent on its demand, which is on its turn dependent on the economic situation. The higher the market value of allowances, the higher corresponding pressure on companies. At the end of each year heavy fines will be imposed to companies with insufficient allowances to cover their emissions. This system made climate change more a concern for companies across Europe and less for governments, together the 11.000 involved companies cover 45% of EU's greenhouse gas emissions. Companies are pushed towards investments in cleaner technologies to achieve emission reduction (European Commission, 2013).

The Kyoto Protocol and the Climate and Energy Package are two important international agreements that helped to create a worldwide movement to a more sustainable environment; this includes more attention for the implementation of PV Solar.

Besides international targets, national targets may play a role as well in the described movement. Several national agreements have leaded to targets that are even more ambitious than the international ones. The German government adopted a target of 35% renewable-share in gross electricity consumption (Federal Ministry of Economics and Technology, 2010).

2.4.1.2 Energy import dependency

It is not only climate change that does an appeal on governments to reconsider the composition of their energy-mix. According to Marques et al (2010) government objectives have significant positive impact on the reduction of a countries' dependence on energy imported from abroad. Being dependent of energy from abroad can cause several uncertainties for governments, the two main issues are that supply is not always guaranteed and prices fluctuate heavily (e.g. 2000s energy crisis).

The average energy import dependency of the EU members was 54% in 2006 (Bosch et al, 2009), while some of the major economies in the EU were even more dependent on import (Germany 59%, Italy 85%, Spain 78%). The Netherlands, as one of the exceptions, was and is less dependent with an average dependency of 20% over the last decade. Average electricity import dependency of the EU members is on average much lower but this has to be adjusted upwards because natural gas and coal, a big part of total energy imports, are imported to generate electricity locally.

Günther Oettinger (European Commissioner for Energy) mentions that energy security policy is no longer only a question of the protection of existing supply of energy sources. The unrest in the Middle-East and the impending depletion of fossil fuels underline the need of a safe, secure, sustainable and affordable energy supply for Europe’s economic and strategic interests as a global player. Mr. Oettinger directly links this need to the importance of a gradual shift to a low-carbon society since conventional energy resources are becoming scarcer as well (Oettinger, 2011).

All together the tendency of the European Union to internalize energy production is one that will continue to stimulate the development of renewables including PV solar. Gan et al (2007) conclude that the tendency to energy security is a major incentive for renewable energy deployment; energy import will be more and more substituted by local generated means. And the position of the EU is not unique in this matter; most countries covered in this research are more or less following the movements of the EU. Summarized, energy is one of the main inputs to secure economic stability and pursue its development, and therefore has to be secured. It can be expected that the bigger a countries’ dependence of energy import, the more PV solar is stimulated.

2.4.1.3 Energy lobby

Although the pro-renewables lobby is increasing in power, it can be expected that the fossil fuel lobby (from here on: energy lobby) still has a negative or at least inhibitory impact on the development of renewable energy sources. Paid representatives of electric utilities and fossil fuel corporations are investing huge amounts of money to secure their fossil fuel based interests. The United Nations International Sustainable Energy Organisation for Renewable Energy and Energy Efficiency (UNISEO), as an example, claims that the energy lobby is behind the decision of the USA to boycott the Kyoto Protocol. Governments are often closely intertwined with the big conventional energy producers, the economic importance of sufficient energy supply is simply crucial. The energy lobby sometimes even blackmails governments to secure support for fossil fuels (Corporate Europe Observatory and Spinwatch, 2010). Although G20 leaders in 2009 pledged for phasing out fossil fuel subsidies, minimal progress has been made until 2012. According to Oil Change International (2012) at least $775 billion of fossil fuel subsidies can be reliably estimated, compared to only $66 billion subsidy for renewables in the year 2010 (Ochs & Rogers, 2012).

The power of world´s biggest oil corporations is endorsed by CNN´s yearly Fortune Global 500 list of biggest companies, which includes BP, Royal Dutch Shell and Exxon Mobil in the top 5 since years already (CNN, 2011). Total revenues of the three companies summed up to 1.323 billion dollars over 2011. This number is comparable to the total GDP of a country like Australia in the same year, the thirteenth economy in the world (The World Bank - data). An increasing number of conventional energy producers are investing in research and development of alternative energy sources but still sparsely. A radical example of the reluctance of some of them is Exxon Mobil. CEO Rex Tillerson is known for his strong conviction that “U.S. energy independence is undesirable and impossible”, he dismisses renewable energy as “uneconomic”, and he agitates against renewable energy incentive programs with words like “interventions only distort the market” (Expose Exxon, 2007).

Newell & Paterson (1998) demonstrate in their article that companies involved in production, processing and distribution of fossil fuels have been systematically able to secure their interests in relation to on-going political negotiations concerning global warming. And for the future, it can be reasonably assumed that the energy lobby continues to have its inhibitory effect on promotion of PV solar and other renewables.

Summarizing, worldwide increasing attention is drawn to renewable energy development. Renewable energy sources, including PV, are considered as crucial to achieve worldwide targets to reduce emission of greenhouse gases. Simultaneously these alternative sources are needed to secure safe, sustainable and affordable local energy supply. But long-established dependency on fossil fuels makes the road to achieve these goals one not without obstacles.

“Shifting official support from fossil fuels to renewables is essential for decarbonizing the global energy system. Such a shift could help create a triple win for national economies by reducing global greenhouse gas emissions, generating long term economic growth, and reducing dependence on energy imports.” – Ochs & Rogers (2012)

2.4.2 Technology and scale effects

2.4.2.1 Technology progress and production expansion

Technological progress and scale effects are the basis of decline of the cost-price of a PV solar system. Growing investments in research and development of both governments and companies have accelerated these two factors. The PV-industry is continually striving to achieve higher solar cell efficiency levels, lower production costs, extend the lifespan of each component and reduce the energy payback-time (EPT)[2]. At the same time world-wide installation of systems is growing each year, causing companies to scale-up their production

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[2] The time (in years) in which the energy input during the module life-cycle is compensated by electricity generated by the PV module.

facilities. As the proven microeconomic theory of economies of scale already shows, when production grows, production will become more efficient. In other words, production expansion brings cost advantages. But only until the optimum is reached, this is where cost decrease stagnates. EPIA and the A.T. Kearney predict that the solar LCOE could drop from €0.22-0.27/kWh in 2010 to only €0.06-0.10/kWh in 2020 (EPIA, 2011b), which is underlined by Figure 2. From these predictions we can distract that the optimum is far from reached.

Analysing the last decades of price development we find that the combination of technological progress and scale effects has resulted in a strong decline of prices. Figure 7 shows the experience curve of the PV-industry for solar modules, the major component of a solar system. The vertical axis is the price-per-watt of a module, which is considered as the most fundamental price metric for PV (Bazilian et al, 2012). The horizontal axis represents cumulative installed module-capacity. According to IEA the price-per-watt of a module declined with 24% for each doubling of cumulative sales. The decline of the average total system price is somewhat lower with 15% (IEA, 2010).

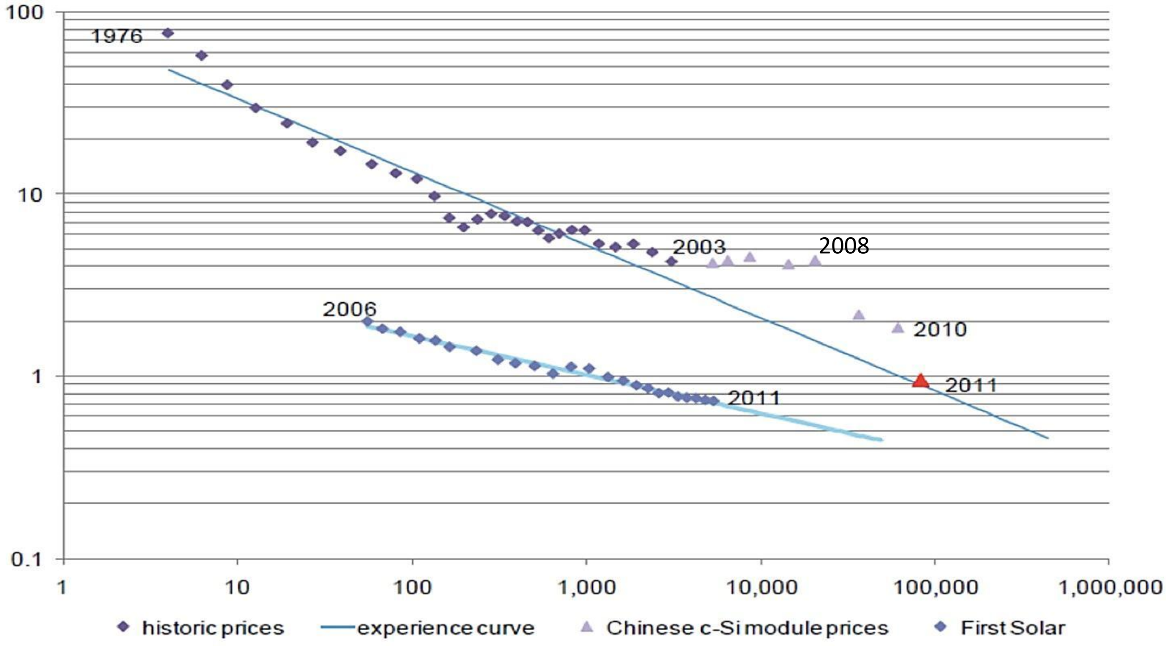

Figure 7 PV Module Experience Curve 1976 – 2011 (Bazilian et al, 2012)

The development path of c-Si module prices in Figure 7 shows that historical prices were quite stable in the period 2003-2008. Prices remained constant around 4 dollars. This was caused by a temporary shortage of silicon, one of the main elements of a c-Si module. Most manufacturers already entered into long-term silicon contracts, so that the cost-price of module production was not affected. The shortage mainly constrained further production expansion. At that time operation margins were quite high, the eighteen largest solar companies reached margins between 14.6% and 16.3%. These margins followed from increasing demand in especially Germany and Spain. High feed-in tariffs went together with high expected returns on investment, allowing investors to buy modules at higher prices. Price competition did not really take place because demand was sufficiently high and significant production expansion was impossible because of the silicon shortage. The other major technology, thin film (in Figure 7 indicated by “First Solar” which has been its largest producer), was mainly sold in the USA at that time and not yet a competitor of size on the European market.

Silicon production was expanded rapidly and module manufacturers were expanding production almost as fast. Demand was increasing even faster in 2008 because of Spain’s installation-boom[3], total global demand increased with about 70% in one year. But in the year 2009 demand did not increase as fast as expected, manufacturers were confronted with excess capacity. Prices dropped with about 50%, from 4 dollar at the end of 2008 to only 2 dollar in December 2009. High existing operation margins, gave manufacturers the opportunity to significantly cut the price-per-watt without losing their complete margins (Bazilian et al, 2012). Competition continued to increase, more and more Chinese brands were introduced to the market, quickly taking over market share from manufacturers in mainly Germany and USA. Cheap labour and low interest loans from Chinese government and banks, combined with most often German production facilities gave them the opportunity to offer comparable quality for less money. Chinese manufacturers were aggressively expanding their production so that margins declined. Most of the manufacturers could still end 2010 with an acceptable corporate trade-off between revenue growth and lower margins (Barker, 2012). But 2011 demand did not grow as fast as production did. The supply/demand situation was completely out of balance and margins were evaporated instantly. A price-war ensued, module prices dropped with another 35% to about 1 dollar at the end of 2011 (Stubenrauch, 2003 & Wissing, 2011). As a consequence only those that could offer the lowest price and could bear enormous losses could survive. Several Western manufacturers went bankrupt. China and Taiwan have expanded their combined market share of the supply of PV modules to 62% in 2011 (Pietzsch, 2012).

The described industry developments of the last decade seem to be a result of demand and supply market mechanisms. But key-drivers on the background are the continuously forth going technology and scale effects. As a consequence of massive production expansion, oversupply was the main cause of the drop in prices in 2011 (Liang, 2012).

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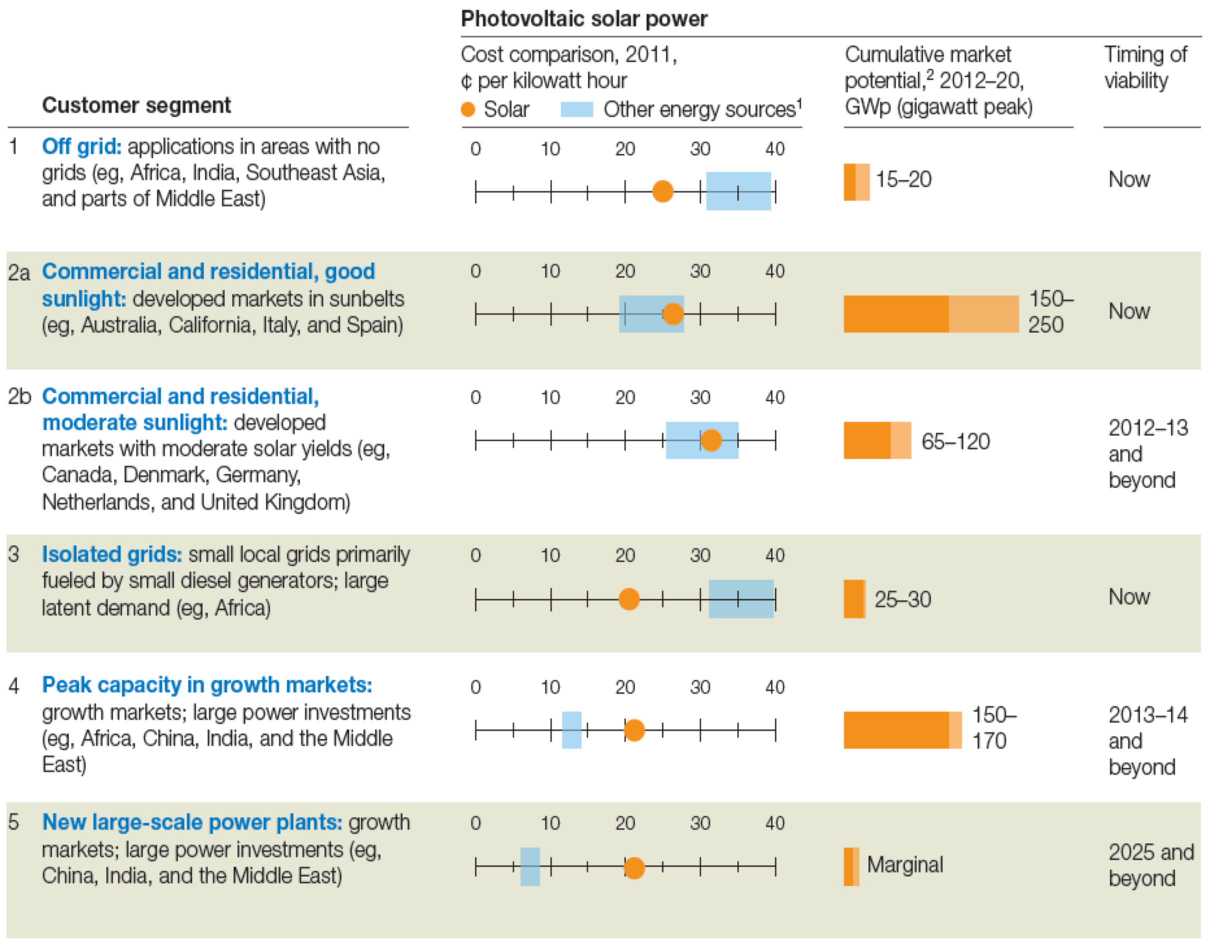
[3] Spain has removed the installation restriction in the year 2008, installations were 5 times higher than during the year 2007.

Technology improvements on its turn have led to an approximate doubling of efficiency of solar cells since 1990. Simultaneously improvements in several manufacturing techniques took place, resulting in thinner cells (simply decreasing material costs), decreased energy payback time and increased automation (IPCC, 2011).

As a result Figure 8 displays that the competitiveness gap between PV solar and conventional alternatives is becoming smaller and in some consumer segments the gap is already closed. The corresponding predicted total market potential until 2020 is promising.



Photovoltaic solar power

	Customer segment	Cost comparison, 2011, ¢ per kilowatt hour (● Solar ▨ Other energy sources[1])	Cumulative market potential,[2] 2012–20, GWp (gigawatt peak)	Timing of viability
1	**Off grid:** applications in areas with no grids (eg, Africa, India, Southeast Asia, and parts of Middle East)		15–20	Now
2a	**Commercial and residential, good sunlight:** developed markets in sunbelts (eg, Australia, California, Italy, and Spain)		150–250	Now
2b	**Commercial and residential, moderate sunlight:** developed markets with moderate solar yields (eg, Canada, Denmark, Germany, Netherlands, and United Kingdom)		65–120	2012–13 and beyond
3	**Isolated grids:** small local grids primarily fueled by small diesel generators; large latent demand (eg, Africa)		25–30	Now
4	**Peak capacity in growth markets:** growth markets; large power investments (eg, Africa, China, India, and the Middle East)		150–170	2013–14 and beyond
5	**New large-scale power plants:** growth markets; large power investments (eg, China, India, and the Middle East)		Marginal	2025 and beyond

Total market potential = 400–600 gigawatts
(compared with 2011 installed base of 65 gigawatts)

[1] Alternative to solar power in given segment--eg, for residential customers, price for power from grid.
[2] Adjusted for implementation time.

Source: US Energy Information Administration; McKinsey analysis

Figure 8 PV Solar cost comparison, 2011 + predictions total market potential (Aanesen et al, 2012)

2.4.3 Policy instruments

This section elaborates on the different policy instruments that have been implemented to stimulate the development of the PV-industry in the past decades. Feed-in tariffs form the core of this research, but this does not mean that other instruments cannot play an important role. This section starts with a general introduction about the history and relevance of policy instruments. Before we address the role of feed-in tariffs in paragraph 2.4.3.2 an overview of all possible policy instruments will be given in paragraph 2.4.3.1.

Renewable energy can be an obvious choice to reduce emission of greenhouse gases. The high cost of the different renewable energy sources was and still is a major obstacle for its diffusion. At the time that concerns about climate change grew, especially PV solar was extremely expensive compared to existing conventional electricity sources (IEA, 2010). Economic and political interventions were inevitable to develop the PV-industry (Mehzer et al, 2012). An appropriate regulatory framework and corresponding favourable market-conditions was and is (in decreasing order) still needed to make sure that PV can roll-out its increasingly promising potential in world's future energy mix (EPIA, 2011). Figure 8 demonstrates this in more detail.

Decades ago governments started to support research, development and demonstration (RD&D) of PV Solar. Although this happened on a small scale, it gave companies the opportunity to invent new and more efficient solar cells. Together with deployment of demonstration projects, these early investments of governments but also companies helped to develop solar systems for commercial use.

As said in paragraph 2.2 Germany was the first that started to accelerate deployment of PV by making use of policy support mechanisms other than R&D investments. They adopted their first feed-in tariff in 1991. But governments such as the USA and Japan began to implement policies shortly after Germany. The USA adopted The Federal Business Investment Tax Credit in 1992; commercial entities could take a tax credit up to 10% of their investments for purchase and installation of renewable electricity production capacity when filing annual tax returns. Japan was the first that introduced an investment grant in 1994, this grant reimbursed 50% of de purchase-price of a residential PV system (IEA 2010).

In general feed-in tariffs are considered as a major driver for development of most PV solar markets (Gipe, 2006; Mendonca, 2007; Cory et al, 2009; Timilsina et al, 2012). But it's not true that only this specific policy type is a potential driver of development. It is important that every implemented policy is relevant and sustainable enough to boost the commercialisation of a certain market (Timilsina et al, 2012). To achieve that, a FiT is often implemented together with complementary policies, as one support scheme. Examples are penalties on the use of competing (conventional) energy sources, improvements of grid accessibility and reduction of technical- or institutional barriers. Several of the discussed instruments below can be adopted to complement a FiT. Complementary policies are required to address market failure (Denniss et al, 2012). Separate market failures require separate policy instruments (Fischer & Preonas, 2010).

EPIA underlines the fact that a policy on itself is often not sufficient to boost commercialization of a market. According to them, a successful renewable energy support scheme (set of policy instruments) consists of four elements:

1. A clear, guaranteed pricing system to lower the risks for investors and suppliers and to lower the costs for the industry.
2. Clear, simple administrative and planning permission procedures.
3. Priority access to the grid with clear identification of who is responsible for the connection, and what incentives are.
4. Public acceptance and support. (EPIA & Greenpeace International, 2011)

When composing a support scheme, a fundamental distinction can be made between direct and indirect policy instruments. Direct policies focus on immediate stimulation, whereas indirect instruments aim to improve long-term framework conditions (Haas et al, 2011). One can also distinguish regulatory and voluntary approaches on promotion. Since indirect policy instruments and instruments with a voluntary approach are only supportive and for complementary use, we will focus on the direct instruments with a regulatory approach. Two main dimensions can be characterized. On one hand a policy regulates either price or quantity. On the other, either investment or generation is supported (Jenner et al, 2012; Haas et al, 2011b). A classification of policy instruments along the two dimensions is shown in Table 3.

	Price	**Quantity**
Generation	Feed-in tariffs Net metering	Calls for tender for FiT contracts Renewable Portfolio Standards Green Certificate trading
Investment	Tax exemptions/refunds Investment grants	Calls for tender for investment grants

Table 3 Direct instruments with a regulatory approach

2.4.3.1 An overview of policy instruments

Based on combined input from the OECD and the IEA, a list of six main categories of instruments can be composed, below an overview. Each category contains of one or more instruments. Between brackets the number of countries, included in our panel, that make use of that specific instrument. Every mentioned instrument is shortly discussed afterwards; feed-in tariffs are as said addressed in a separate paragraph.

- **Financial Instruments**
    - Taxes and Tax Incentives (credits, exemptions) *(6/30 countries**)*
- **Incentives/Subsidies**
    - Feed-in Tariffs *(22/30 countries**)*
    - Investment grants or capacity payments *(12/30 countries**)*
    - Preferential Loans *(2/30 countries*)*
    - Rebates *(3/30 countries*)*
- **Research, Development & Demonstration (RD&D)**
    - Demonstration Project *(4/30 countries*)*
    - Research Programme *(5/30 countries*)*
    - Technology Development *(4/30 countries*)*
- **Regulatory Instruments**
    - Mandates (Net Metering) *(4/30 countries**)*
    - Quota Systems (Renewable Portfolio Standards) *(2/30 countries*)*
- **Tradable Permits**
    - Green Certificate Trading *(2/30 countries*)*
- **Calls for tender** *(3/30 countries**)*

***** *Obtained from IEA/IRENA Global Renewable Energy Policies and Measure database.*

*** Obtained from and checked with several databases including IEA/IRENA, PVTECH and Wind-works.org*

Several instruments are implemented less frequently within our country-panel. Renewable Portfolio Standards (RPS), as an example, are only adopted (as complementary policy) in Germany and Japan. An RPS gives the electricity utilities the obligation to generate a specified amount of electricity from renewable energy sources, sometimes defined to PV Solar as well. This policy clearly regulates quantity and supports generation. It is seen as the counterpart of the feed-in tariff, which regulates price instead of quantity.

Investment grants and tax incentives

Investment grants are a typical example of a policy type that supports investment via regulation of the price of a PV-system (Table 3). It gives the investor a predetermined subsidy on the purchase of a PV system. Often it is restricted to small scale, mostly residential, projects. Comparable instruments are the ones that provide tax exemptions, tax refunds or rebates.

Preferential loans

Financing PV-systems can be an obstacle in the development of a project. Preferential loans can help to make an investment profitable. The loan terms of a preferential loan are often beneficial compared to commercial banks.

Research, Development & Demonstration (RD&D)

An important characteristic of RD&D instruments is harnessing the learning potential of new technologies (Fischer & Preonas, 2010). Besides this the investment in demonstration projects can be an icebreaker for the development of a countries' PV-industry. RD&D investments can help to commercialize a technology that is not yet commercially viable. But even after a technology is commercially attractive for investors, RD&D remains important to further develop an industry. Besides governments, manufacturing companies are continuously investing in the development of cheaper and more efficient solar systems.

Net metering

Net metering is an instrument sometimes implemented on its own, but also introduced to complement one or more other policies. It includes elements of both a quota system and feed-in tariffs. The two main characteristics:

1. It allows the renewable generator to feed (excess) generated electricity into the grid
2. The yearly electricity bill is determined by subtracting electricity outflows from electricity inflows.

A household that consumes 3000 kWh of electricity each year and now decides to invest in a PV-system that generates on average the same amount; as a result the electricity bill decreases to zero. Accordingly, the price of generation is equal to the retail price of electricity (Gipe, 2006). The grid can be seen as a kind of energy storage facility. When generation exceeds consumption on a certain moment during the day, the generator feeds excess electricity into the grid. When consumption exceeds generation, electricity is withdrawn from the grid. Often net metering is focused on residential generators and therefore the quantity of electricity fed into the grid is limited to a certain amount of kWh's per year. An upcoming but still expensive alternative for net metering are energy storage systems, a technology that simply gives a generator the possibility to temporary store excess electricity in batteries. Energy storage is an attractive solution for off-grid application and already frequently used for by example lampposts.

Tradable permits

The most frequent used form is green certificate trading. A renewable generator receives one or more green certificates for every MWh of produced electricity from the government. Simultaneously electricity utilities are obliged to hand in green certificates to the government, up to a predetermined quota. The renewable generator sells its green certificates to the electricity utilities. If an electricity utility does not reach its quota, fines are handed out.

Call for tender

A call for tender is an instrument that is comparable to the more known ‘public tender’. It is an invitation for companies to take part in a bidding process for investing in a predetermined quantity of PV projects. Calls for tender are often restricted in one way or the other. France issued a few calls for tender in the past years that were only accessible for French project developers and manufacturers.

2.4.3.2 Feed-in Tariffs

The core of this research is the feed-in tariff; hence this instrument is described in a separate paragraph. FiTs are evidently the most popular mechanism to promote the PV-industry within our country-panel. Out of 30 OECD members included in this research 22 have implemented a FiT. In 20% of the observations a FiT was in place; during the last decade of our data-period (2002-2011) even 43% of the years include a FiT-policy.

The general idea of a FiT is that the owner of a PV system receives a guaranteed price for every produced kWh that is fed into the grid. This is agreed on contract basis during a fixed period. An important requirement is that the solar electricity producer has the right to feed generated electricity into the public grid.

FiTs can differ in various characteristics, including tariff amount, limitations on available budget or installed capacity, contract duration and the presence of a degression in the tariff of the FiT. In the sub-paragraphs below each of those design features will be discussed separately.

2.4.3.1.1 Tariff amount

Often FiT-policies consist of different tariffs for a variety of policy targets. The tariff amount can differ on the basis of system size, location, receiving party and technology. It is very common that a country implements different tariff amounts for different PV-system sizes. Each tariff provides an improved return on investment for the potential investor, although it may be that one system size segment is granted more favourable conditions than another[4]. Some countries have cut the market in more than ten segments with for every segment another tariff amount. On the opposite, some only promote one segment, for example small size systems. Most of the different segments can be divided into three main groups: small, commercial and utility scale systems.

France is an example of a country that gives preference to a specific technology: building integrated PV (BIPV)[5]. Simultaneously they have adopted different tariffs to adjust for location. This ensures that expected return on investment in the north of France is comparable to the south. Greece in turn provides more favourable tariffs for some islands that are not connected to the grid on the mainland. PV is considered as a solution for the electricity shortage on some of these islands and therefore promoted more aggressively.

It also happens that a policy discriminates on the basis of the purpose of the host building or on receiving party (Jenner et al, 2012). Regarding the purpose of the host building, it can be that only government buildings are eligible for support. When a policy discriminates on the basis of the receiving party, a characteristic example is again a French subsidy scheme where education or health facilities receive a higher feed-in tariff than other buildings.

2.4.3.1.2 Limitations on budget or capacity

Some countries cap the expense or capacity of a certain policy. The restrictions can take various forms:

- Cost limits: all applications will be handled and approved until the predetermined budget for a given year or period is reached.
- Capacity restrictions: total capacity that is installed in a given year or period cannot exceed the predetermined limit.

In this way governments ensure that the development of the PV-industry stays within pre-set budget boundaries. Consciously or unconsciously, this policy-characteristic inhibits growth.

2.4.3.1.3 Contract duration

Contract duration is the period over which the tariff amount is paid to the generator. A balanced trade-off between contract duration and tariff amount is important to retain a profitable return on investment. One government might implement a relatively low tariff

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[4] A PV-system can be categorized on size, three main segments are generally distinguished: residential-, commercial- and utility-scale systems.

[5] The BIPV technology is used for the replacement of conventional construction materials in buildings. It can be used for different parts of the buildings' exterior such as roofs, walls or windows.

combined with long contract duration (e.g. 20+ years); the other combines a high tariff with somewhat shorter contract duration (e.g. 15 years).

2.4.3.1.4 Degression rate

Profitability of an implemented feed-in tariff needs to be assessed on a regular basis to counteract excessive profitability. Mainly due to technology and scale effects prices are driven downwards so that the economic viability of a PV-system increases slowly (Figure 7). Tariff amounts have to be adapted accordingly, preferably in a predictable manner (EPIA, 2011b). Therefore governments often include a predetermined degression rate when a FiT policy is enacted. This does not adjust the tariff amount of existing FiT-contracts; a degression rate only adjusts the tariff amount for newly issued FiT-contracts. Germany is an example: until 2009 the degression rate was set at a fixed annual amount (5%). During 2009-2011 the German government adjusted the degression schedule to a volume-responsive “corridor” (Fulton & Mellquist, 2011). When a pre-defined installed volume was reached the tariff amount was automatically adjusted downwards.

For investors, the advantage of the presence of a degression rate is that adjustments are known on forehand. Nevertheless, several governments still carry out non-scheduled, often last-minute, adjustments of tariffs. Unpredictable changes in profitability lead to a less certain perspective for investors, which can reduce the effectiveness of a FiT.

2.4.4 Country-specific factors

2.4.4.1 Wealth

A countries' wealth can have an influence on the ability to invest in renewable technologies. Literature generally concludes that a higher income level is correlated with more renewable energy use. Marques et al (2010) found that the income effect is positive for all EU members. According to Sadorsky (2009), leads a 1% increase in real income per capita to an increase of approximately 3.5% in consumption of renewable energy per capita in emerging economies. But there are exceptions, Jenner et al (2012) does not find a significant connection between their wealth-measure GDP per capita and the development of the PV industry, their explanation is that solar PV is often installed at a small scale which makes the costs easier to bear for less wealthy societies.

2.4.4.2 Solar Irradiation

Solar irradiation is clearly the main input for the production of electricity with a PV-system. Section 2.1 already addressed the relevance of solar irradiation as a driver of PV-industry development. We concluded that the solar LCOE mainly differs between countries due to variations in solar irradiation. Within our panel of countries average solar irradiation (kWh per m2 per year) differs between 811 in Norway and 2094 in Israel, with an average of 1248. The expected generation of a PV system in Israel, purely based on solar irradiation, is about 70% higher than the generation of a PV system in the average OECD country. Based on this observation it can be assumed that a high level of solar irradiation has positive influence on the development of a PV-industry.

2.4.4.3 Electricity price

PV solar has to compete with the grid electricity price. As we have seen in section 2.1, over the last decade both wholesale and retail electricity prices are on average more than doubled. Expectations are that this development continuous in a slower pace: "Electricity prices are expected to increase everywhere in real terms over the coming decade by 15 per cent on average (IEA executive director, Ms. Van der Hoeven, 2012)" Besides the price increase the electricity price differs substantially between countries and within countries (Figure 3). It can be reasonably assumed that the higher the electricity price in a country the faster an industry develops.

2.4.4.4 Electricity consumption

Marques et al (2010) and Marques & Fuinhas (2012) states that larger consumption needs, exert strong pressure on the level of energy use. They find a significant positive relation between energy consumption and the development of renewable energy use. Jenner et al (2012) includes a variable ‘total installed electricity-generating capacity’, they conclude that total electricity market size has a positive effect on PV solar capacity growth.

2.4.4.5 Conventional electricity sources

According to literature greater use of coal and oil can either decrease the focus on renewable energy sources (Marques et al, 2010). A high fossil fuel share in the energy mix of a country suggests the existence of an industrial lobbying which hampers the development of renewables. On the other side strong dependency on fossil fuels can increase the necessity of investments in renewable energy sources, as we have seen in paragraph 2.4.1.2. There we concluded that it can be expected that the bigger a countries’ dependence of energy import, the more PV solar is stimulated. Jenner et al (2012) gives an additional explanation with regards to one of their findings; the positive connection between onshore wind development and the share of generation from both coal and oil might be caused by negative externalities from pollution and therefore incentivize a transition to cleaner sources. Summarizing, existing literature gives arguments for both a positive and negative influence of a high share of conventional electricity sources in developing the PV-industry.

2.5 Policy consistency

Consistency of policy enactment is a topic that is not widely covered in the literature. Nevertheless this section explains the importance of consistency and sketches the assumptions and experience that flows out of the scarcely available literature. The chapter is starts with an introduction. The first section analyses and compares policy consistency in Germany and Spain. The second section discusses different policy risk factors that are on the basis of policy consistency.

A seemingly attractive FiT does not always drive the PV-industry to a developed sector with high growth numbers. Investors do not invest at all risk; they are seeking for a reasonable trade-off between return on investment and risk. The reluctance of investors can have a variety of causes. An important cause is policy-related shortcomings. In this section we grasp the different potential causes of uncertainty together, assuming that they can be traced back to one term: policy consistency. It is expected that the more consistent a policy the more effective it will be.

According to White et al (2013) one must first understand how potential investors make decisions to understand the importance of policy consistency:

“*Firms and households make rational choices; the best choice from the point of view of the person making the decision. Choices are made based on the information that is available at the time the decision is made. When a household must consider a favourable governmental policy when making a decision, the government’s past performance in maintaining their policies becomes an important consideration*.”

Important in influencing the behaviour of investors is coherence and consistency in policy instruments. Simply since the greatest degree of change in behaviour most often occurs when different instruments are combined in a consistent manner (Owens & Driffill, 2008, Gardner and Stern, 1996).

2.5.1 Germany versus Spain

In general, the literature praises the German FiT structure (Lüthi, 2010, Cory et al, 2009 & Held et al, 2007). Although the FiT is less profitable than those of other European countries; the yearly added PV capacity in absolute numbers is increasing each subsequent year (OECD-iLibrary). The key strength according to the paper of Lüthi is the long-term security that it provides to its investors. The tariff amount is fixed for a period of 20 years. And due to the included degression rate, investors knew on forehand when adjustments of the FiT would be carried out. Important was that Germany did not set any abrupt negative adjustments and repeatedly improved the regulatory framework and corresponding administrative process.

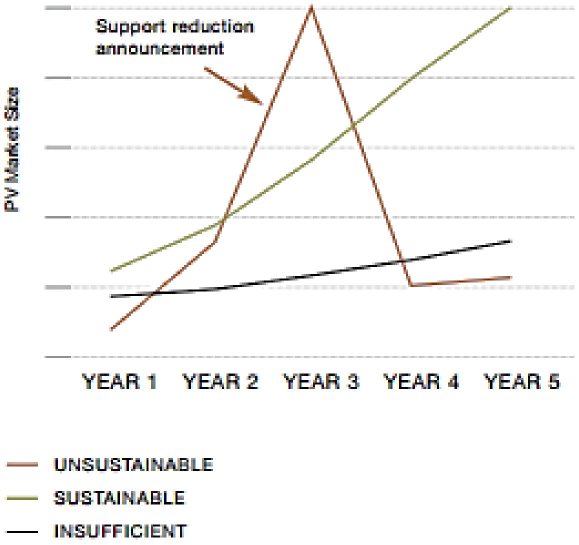

Figure 9 PV market development under different support strategies (EPIA)

A clear counter-example is the Spanish case. In 2005 Spain started to promote PV solar with a FiT. From the start they have put a cap on capacity. In 2008 they took away the cap and the market exploded. The government did not expect such an increase in demand. By the end of the year the government introduced an unexpected policy change by adopting a new cap on capacity. As a consequence installations in 2009 collapsed, only 100 MWp was installed compared to 2650 MWp in 2008. Figure 9 shows three different market development schemes. The horizontal axis displays the first five years during which a support strategy is implemented. On the vertical axis PV market size is displayed, this stands for yearly added installed capacity. The green line symbolizes the sustainable German development scheme; the market develops quickly and the yearly installed capacity grows each year. The blue line shows the development of a market with insufficient support, this market grows very slowly. The red line can be seen as the Spanish unsustainable development scheme, it shows an explosion of installations in year 2/3, this was above expectations and budget, as was the case in Spain in 2008. The reintroduction of the cap at the end of 2008 can be considered as the support reduction announcement in the figure, installations in year 4 and 5 collapsed.

2.5.2 Policy risk factors

Lüthi (2010) has performed a cross-case study analysis of the German, Spanish and Greek PV markets. Their analysis shows that, beyond a certain point, risk-related factors play a more crucial role in investment decisions than for example the tariff amount of a FiT. Although expected financial returns are higher in Greece and Spain, it turns out that market diffusion is higher in Germany. Based on their theoretical analysis, a significant correlation can be assumed between policy risk and market diffusion. The effectiveness of a feed-in tariff is apparently mediated by policy risk factors. The following risk factors can be identified:

1. *PV policy stability,* which can be largely clarified by addressing the following aspects:
    a. *Long-term planning security*
    b. *Degression rate*
    c. *Corruption*
2. *Presence of a cap*
3. *The administrative process*

2.5.2.1 PV policy stability – Long-term planning security

The key to an effective PV policy is to provide planning security. Radical development of the market but also innovation within the PV industry will only occur if governments provide a long-term market (Loiter & Norberg-Bohm, 1999, Lüthi, 2010 and EPIA, 2011). The more predictable the revenues of an investment in PV are, the more confidence developers and financial investors will have. If an investment is economically viable and stable over the medium and preferable long term, a market will develop (Bustos, 2003). To secure both, the tariff amount must be fixed and guarantee an attractive margin for a sufficiently contract duration.

White et al (2013) recently did research to the importance of policy consistency. They use a descriptive perspective to exemplify the effect of unexpected changes in renewable energy policies on firms and industries. By means of a case study approach they describe two recent example situations from Norway and Canada. Their main conclusion is that when investments are carried out, a prognosis for future policies must be made. Unexpected policy changes give difficulties in attracting capital. Due to a drastic unannounced subsidy cut in Ontario (Canada) in 2010, the industry lost all confidence that the government would offer consistent support in the future. White et al states that the manner in which policies are adjusted plays an important role in the development of a renewable energy sources.

2.5.2.2 PV policy stability – Degression rate

To create a stable and trustworthy regulatory framework some governments include a degression rate in the FiT policy. By doing so the tariff amount will be adjusted slowly over the period that a FiT is in place, the time and size of the adjustments are known on forehand. On one side a degression rate keeps the financial return of a FiT on a sustainable level, on the other side it gives potential investors medium to long-term planning security. Alternatively governments adjust the tariff amount manually on a non-scheduled time; these kind of unexpected policy-changes cause uncertainties for the market about both the time and the size of the adjustment.

2.5.2.3 PV policy stability – Corruption

Not solely a seemingly good combination of a simple administrative process, sustainable policy design and long-term planning security is sufficient to secure consistent policy and corresponding effectiveness of a FiT. Sometimes governments are simply regarded as unreliable. Poor governance hampers economic growth and development. Põlajeva (2010) performed a research on the credibility of economic policy in the Baltic Sea region, pointing out that corruption in the public sector is a serious obstacle in development processes. Although to my knowledge no literature deals with the impact of corruption in a renewable energy setting, it is reasonable to assume that corruption leads to inconsistent policy, hindering the development of the PV industry.

2.5.2.4 Presence of a cap

Limitation on budget or capacity, like the Spanish capacity cap, is a common included design feature in the structure of a FiT that can lead to uncertainty about the (near) future. Project developers have to deal with the uncertainty whether their FiT-application will be granted or not. A cap often inhibits growth of the market.

2.5.2.5 The administrative process

Complementary to the above mentioned factors, a government needs to provide clear and simple administrative processes. According to Lüthi administrative hurdles are mainly hindering the process due to the high number of involved authorities which can cause delay or even failures. Investors are not at all helped by long lasting extensive procedures. Azuela et al (2011) state that institutional and administrative efficiency is crucial to the effectiveness of renewable energy policy. Clearly, administrative hurdles have to be restricted to a minimum.

To create security for market players, policy consistency has to be pursued. Uncertainties need to be minimised. In other words, clear and stable policy objectives are required to stimulate investments sustainably. Otherwise it is at the expense of the effectiveness of a feed-in tariff. Either a big change in policy (e.g. the cap introduction in Spain), large uncertainty about possible policy change or frequent change of policy will all have a negative impact (Van Rooijen & Van Wees, 2006 and Cory et al, 2009).

2.6 Effectiveness of a FiT

Several existing literature studies have addressed the effectiveness of feed-in tariffs on the development of renewable energy technologies. This section gives an overview of the main findings that can be derived from these studies.

Effectiveness of a FiT is in general dependent on how a specific FiT is structured; its design features determine for a great part its strength (Jenner et al, 2012). Consequently not every FiT is necessarily a success in developing the local PV-industry. The granted tariff per generated kWh needs to be of sufficient height to reach a good return on investment and it also needs to be high enough to compete with conventional electricity sources and more important the grid electricity price in a country. The European commission (2009) recently stated the following:

"Only in those countries in which the tariff has been high enough to recuperate the investment cost in a reasonable time, have photovoltaic installations increased and competition in production and trade developed substantially."

2.6.1 Relevant literature overview

Authors	Year	Sample	Time-frame	Type of analysis	Technology
Jenner et al	2012	26 EU members	1992-2008	Panel data	On shore wind, solar PV
Marques & Fuinhas	2012	24 EU countries	1990-2007	Panel data	Renewable Energy
Haas et al	2010	7 EU members		Theoretical analysis	Renewable Energy
Jenner	2012	26 EU members	1990-2010	Panel data	Renewable Energy

Table 4 Relevant studies on FiT' effectiveness

The majority of the existing literature is limited to a descriptive approach in analysing the effectiveness of policy instruments on the development of renewable energy sources. Haas et al (2010) states that FiT policy instruments are more effective than others (this article will be discussed in more detail below). He even underpins that a well-defined FiT policy provides a certain deployment of renewable energy sources in the shortest time and at the lowest costs for society. Jenner et al (2012) adds that investors prefer a FiT above other policy instruments (Bürer & Wustenhagen, 2009). These qualitative policy evaluation studies generally agree that feed-in tariffs are important in explaining the development of renewable energy sources in Europe.

Jenner et al (2012) and Jenner (2012) are the only two empirical studies that dedicate an econometric analysis specifically to the effectiveness of feed-in tariffs in explaining the development of PV in the OECD or EU region. These two are also the only studies that attempt to capture the strength of feed-in tariffs in a variable. Jenner et al (2012) develop a new indicator for FiT strength that captures several design features as tariff size, contract duration, digression rate but also electricity price and production cost. As a result they estimate the corresponding return on investment (ROI) for each observation. They find that for a 10% increase in ROI, countries will install 3.8% more PV capacity on average per year. All together their conclusion is that FiT policies have stimulated the development of PV in Europe. An important shortcoming of this research is that they do not include both the individual design features of a FiT or the price of electricity as separate variables in the regression. Therefore it is hard to determine the impact of the different elements on its own. Besides that they do not consider policy-consistency as an indicator with impact on the effectiveness of a FiT, they even state that "FiT levels and capacity development in previous years are unlikely to affect the investor's decision." Their argument is that ROI alone is a large enough decision-making factor for investors that it provides incentive for PV deployment beyond that provided by these other factors. By stating that they ignore not only the impact of policy-consistency but they also ignore the possible presence of a cap on cost or capacity which can significantly hinder further development. Our research does include these indicators.

Jenner (2012) also researches the question whether there is a significant link between the strength of FiT policies and electricity generation by renewable energy sources. Besides PV and onshore wind he also includes econometric analysis for geothermal and biomass sources. He uses the working paper Jenner et al (2012) as the base for his article. But not at all aspects; instead of annual solar capacity he now uses generation in GWh as dependent variable. In addition to a FiT binary and a FiT tariff amount variable to measure the effectiveness of feed-in tariffs, he uses an indicator that represents the return on investment that is caused by the FiT and its design (SFIT). Part of the data of Jenner et al (2012) is used but it's unclear to what extent he uses their ROI-indicator. Based on the descriptive statistics of both papers I assume that there is a difference between both. Nevertheless Jenner (2012) also finds that FiT policies have effectively supported PV power generation in the EU over the period 1990-2010; a 1% increase of the SFIT increases PV generation by approximately 27 GWh. Besides underlining this significant relation he concludes that enacting a policy in order to support renewables is not just enough, the policy design is crucial for its effectiveness. He suggests that the binary and nominal indicators can produce misleading results, since part of the heterogeneity is not captured. A small critic on their nominal variable selection: by only including tariff amount there is indeed a strong bias in the result since several other design features are ignored. Question marks can also be placed by his data for the tariff amounts in eurocents which reaches in some cases even over 100 eurocents, which is surprisingly high compared to our data (highest tariff amount is 60 eurocents). With regards to his SFIT variable it is inaccurate not to capture tariff differences due to installation size since this is in our opinion a crucial determinant to measure the effectiveness of a FiT correctly. Other shortcomings are the same as of the article of Jenner et al (2012): individual FiT design features and electricity price are not taken into account separately; the role of policy-consistency is ignored just as the presence of a cap on cost or capacity.

In contrast with the papers of Jenner and Jenner et al, Marques & Fuinhas (2012) do not analyse the impact of policy incentives on the development of PV solar separately. Instead they use as dependent variable the total contribution of renewables to total energy supply. A strong disadvantage of this one-size-fits-all approach is that it ignores all differences among technologies. For their empirical analysis they use a Panel Corrected Standard Errors estimator and include different policy variables. Their results give empirical support for the assumption that the included public policy measures contribute to the wider use of renewables, both together and disaggregated. Mainly direct interventions like incentive and subsidy policies, including feed-in tariffs, have been effective. Quota obligations, R&D programs or tradable certificates did not increase renewables in the period concerned. In contrast they also find that strategic planning processes[6] contribute to the PV development. An important shortcoming of their analysis is that the approach is imprecise and unsophisticated; all policy variables are composed just by counting the number of active policies of that policy type that are in place in that specific year and country. They do not capture any of the heterogeneity that comes for the policy design; they neither differentiate on market circumstances. Furthermore, they have only data until 2007, while the development of PV is dominated by the recent increases.

Haas et al (2010) contribute to the existing literature by making a comparison between effectiveness and efficiency of different renewable energy promotion systems. One shortcoming, they only perform a theoretical analysis and a small case study; they do not add any econometric proof before drawing their conclusions. Their main objective is to compare quantity-driven (e.g. tradable green certificates, based on quotas) and price-driven instruments (e.g. feed-in tariffs). There conclusions provide support for our decision to focus on the effectiveness of feed-in tariffs. According to Haas et al the success story of growth of renewables in the EU has been triggered mainly by FiT implementation in a technology-specific manner. Quantity-driven policies are considered to be relatively inefficient and less effective in the deployment of solar PV technology. A few arguments are: high administration costs, difficult to implement and not technology-focused. They conclude that a well-designed

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[6] Policies that outline specific programs and define strategies to promote specific renewable energy sources in a country.

(dynamic) feed-in tariff policy provides deployment of renewables in the shortest time and at lowest costs for society. Additionally their analysis is only focused on 7 EU countries and therefore limited. No further ground-breaking insights can be derived.

In general feed-in tariffs are profound to be effective in stimulating the deployment of PV solar. Stronger feed-in tariffs with higher returns on investment have a bigger impact on the development. Simultaneously, price-driven policies like feed-in tariffs are to a significant extent less expensive and more effective than quantity-driven policies. Nevertheless existing literature is still limited and it has shortcomings; one important shortcoming is that existing research does not perform any analysis on individual FiT design features.

3. Methodology

To test the effects of feed-in tariffs on the development of the PV-industry we perform an econometrical analysis. To achieve this it is important to determine the right approach. This chapter elaborates on the chosen approach and discusses the used techniques, potential problems and our strategy to deal with those.

3.1 Evaluation of consistency and effectiveness of feed-in tariffs

The main goal of this research is on one hand to test the effectiveness of feed-in tariffs on the deployment of the PV-industry, and on the other hand to measure the impact of policy-consistency and FiT-structure on that effectiveness. A FiT is effective if the share of PV in a countries' electricity-mix increases. Additionally it is expected that the more consistent a policy is the more effective it will be. Consistency contributes when obtained confidence of investors in a FiT-policy improves the effectiveness of a FiT. A macro-level approach is chosen for in total 30 OECD countries. This is preferable to a micro-level approach since we want to make a comparison between feed-in tariffs in different countries instead of focusing on one specific feed-in tariff. The main development of the PV-industry has occurred in the last years so it seems most relevant to focus our research on the last decade. But to be able to not only make a comparison between countries but to make a comparison in time as well, we have selected data over a longer period; 1990-2011.The first decade can function as a reference-period since no feed-in tariffs were implemented yet.

3.2 Determination of PV-industry development

We have chosen to take as dependent variable the ratio of PV electricity of total electricity that is generated in a country. We acknowledge the fact that in some countries the PV-ratio can even decrease although generation of PV actually has increased; it can happen that relatively more other generation capacity is added. An advantage of a ratio is that country-size does not affect the results. Besides that most countries in our data panel are striving to increase the share of renewables in their electricity-mix. Implementation of a feed-in tariff for PV can be considered as an instrument in reaching that. Therefore we consider a FiT to be effective if it contributes significantly to the increase PV-share in a countries' electricity-mix.

Having a ratio as dependent variable is in contrast with most existing empirical literature where absolute values are chosen instead of the ratio. Jenner et al (2012), to give an example, has chosen for capacity to reflect the investment decision as purely as possible. A disadvantage of absolute values (e.g. cumulative or added PV capacity) is that the results are dominated by bigger countries which results in heteroskedasticity[7]. Additionally, data on capacity is only available until 2010, where we consider the year 2011 as an important year in the development of the PV-industry given recent large increases. On the other side, a shortcoming of using PV's share of electricity generation as dependent variable is that the effect of a feed-in tariff in one year might be only partly observable in that year. The same problems, however, holds for installed capacity. Generation starts from the moment that the project is completed, which can be late in the year so that the effect is only fully observable in the year after. Taking the PV generation capacity is not a good alternative as one MW PV capacity does not produce the same amount of electricity in MWh as one MW capacity of an alternative electricity source. To control for the delay we will instead perform two sensitivity analyses that includes respectively one and two lagged FITSTRENGTH variables. In other words, the PVSHARE values for 2011 are assumed to be partly explained by the values of FITSTRENGTH in 2010 and 2009. We expect that mainly FITSTRENGTH(-1) is adding value to our model since most delay in our dependent variable is expected to be not longer than one year. Often governments require that you complete your project before the end of the year in which a FiT-policy was granted, so the actual effect is by the latest fully visible in the next year.

It is clear that there are arguments for choosing both absolute values and ratios as dependent variable. But in this research we consider a feed-in tariff to effectively support the development of the PV-industry if PV gains share in the electricity-mix of a country. So the share of PV in the electricity-mix of a country is selected as dependent variable. However, as a sensitivity analysis we will still make the comparison between our dependent variable and the natural logarithm of added PV capacity.

3.3 Model specification

The pooled least squares method will be applied to analyse our time-series cross-sectional data. To generate unbiased and consistent estimates it is important that we control for heterogeneity and omitted variable bias (also known as time-invariant bias in the error term) by including cross-section fixed effects. Additionally we correct for autonomous (technological) developments by including a country-specific linear and non-linear time-trend. Due to the simultaneous use of PV development drivers we have to control for collinearity among variables as well. Table A3 in the appendix shows a correlation diagram of all used variables. If we do not address these potential problems adequately there could exist inefficiency and bias in coefficient and standard error estimations.

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[7] Some authors argue that taking the natural logarithm is a solution but this solves only part of the problem

As explained, our dependent variable is the ratio of PV electricity generation of the total electricity that is generated in a country (PVSHARE). The development of PVSHARE in our base model will be explained by a feed-in tariff strength indicator (FITSTRENGTH), a set of control variables, a country-specific linear and non-linear time-trend and country fixed effects.

To test the robustness of the results for the more sophisticated FiT indicator FITSTRENGTH we both exchange and combine this variable for and with a binary FiT variable. Besides the binary variable we also test the FiT design features separately to specify the mutual difference in importance of these FiT characteristics. In additional models we will further test the robustness of the feed-in tariff strength indicator and analyse the impact of policy-consistency indicators, non-FiT policies, corruption and additional explanatory variables like CO_2 emissions and the impact of the presence of other non-conventional electricity sources. We will end with performing a few sensitivity analyses on the relevance of our feed-in tariff strength indicator FITSTRENGTH in relation to our dependent variable PVSHARE. One by replacing PVSHARE by the natural logarithm of added PV capacity, a second by including lagged FITSTRENGTH variables.

A 95% statistical confidence level is used when drawing conclusion about the significance of a coefficient. It means that we can assure with 95% certainty that a coefficient is not zero and therefore contributing to the model.

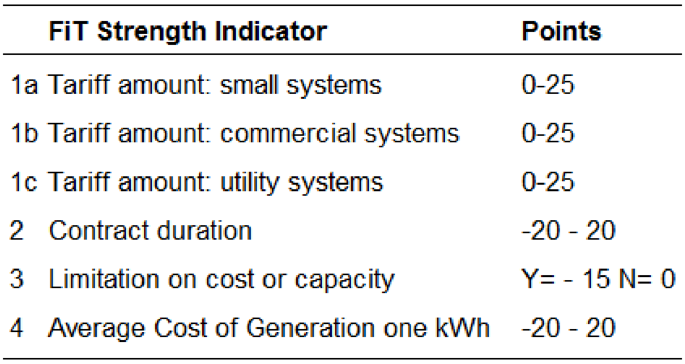
3.4 Measuring the strength of feed-in tariffs

A binary variable is one way to measure a FiT policy. But a feed-in tariff exists of several different design features or characteristics, as clearly explained in literature section 2.4.3.2. One feed-in tariff is often not comparable with another. In other words we need to compose a more sophisticated variable to be able to capture the heterogeneity of feed-in tariffs. To do so we have distinguished four different strength measures that together form one FiT-strength indicator. Three of them are the earlier discussed design features: tariff amount, limitation on cost or capacity and contract duration. Additionally we have composed one measure that determines the average cost of generating one solar kWh for each panel observation. This variable takes into account solar irradiation and PV-system price. In section 2.4.3.2 we also mention degression rate as a design feature, but we do not take this feature into account as an individual measure since it is not relevant for the strength of a FiT in one specific year.

To be able to combine the different characteristics we reward each of the four discussed measures with points on a pre-defined scale. The rewarded points added together form the FiT-strength indicator; a transparent alternative for the ROI indicator that is composed by Jenner et al (2012). By rewarding the four design features individually we are now able to test the effectiveness of the FiT design features both combined as FiT-strength indicator and separately.

Data on the feed-in tariff policies is obtained from a variety of sources including PV Grid, Wind-works.org, IEA Policies & Measures Databases, RES Legal and Europe's Energy Portal. A detailed database on FiT policies is composed. From that starting point we have carefully categorized the data so that it can be reasonably compared between countries. Let us give an example Governments often implement different tariffs for a variety of policy targets. The tariff amount can differ on the basis of system size, location, receiving party and technology. Most common is to differ on PV-system size. Each tariff provides an improved return on investment for the potential investor, although it may be that one system size segment is granted more favourable conditions than another. Some countries have cut the market in more than ten segments with for every segment another tariff amount, in contrast others only promote one specific segment. Where existing literature does not account for these differences we have distinguished three main system-size categories: small (0-100 KWp), commercial (100-1000 KWp) and utility scale (>1 MWp) systems.

Rewarding each of the four measures properly is crucial; both knowledge of actual data and a reasonable division of points are required to obtain a well-balanced and correct FiT-strength indicator. The chosen proportions between the points classification for one feature and the other are based on personal calculations and knowledge, it can be considered as an educated guess although the given proportions remain per definition subjective. This is a shortcoming of the chosen approach; it is hard to determine the right proportions between the impact of one feature compared to the other. Table 5 gives an overview of the scales on which points are assigned to each separate design feature. Additionally Table 6 on the next page displays the descriptive statistics of the involved measures. Since all measures have only values in the years that a FiT was in place we have shown the descriptive statistics for only these 130 observations. The minimum-maximum ranges of points that are actually rewarded, showed in Table 6, deviate somewhat from the classification in Table 5 for some of the indicators. This is mainly the case for the indicators Average Cost of Generation of one kWh (FSACG) and contract duration (FSDURATION). The reason for the deviation is that countries in our data panel did not



FiT Strength Indicator	Points
1a Tariff amount: small systems	0-25
1b Tariff amount: commercial systems	0-25
1c Tariff amount: utility systems	0-25
2 Contract duration	-20 - 20
3 Limitation on cost or capacity	Y= - 15 N= 0
4 Average Cost of Generation one kWh	-20 - 20

Table 5 Points classification of FiT strength indicators

implement feed-in tariffs with contract duration shorter than 10 years. In the case of FSACG this means that not one country implemented a feed-in tariff when average cost of generation was above 26 eurocents.

The division of points is linear and based on the actual minimum and maximum values of each indicator. To clarify on the basis of one of the indicators: the lowest tariff amount for small PV systems (indicator 1a) is 5.2 eurocent, the highest is 60 eurocent. Points are divided linearly between 0 eurocent (0 points) and 75 eurocent (25 points). A tariff amount between 3 and 6 eurocent is rewarded 1 point, a tariff amount between 60 and 63 eurocent is rewarded 20 points. In other words the feed-in tariffs that are included in our data panel have implemented tariff amounts for small systems in the range 5.2-60 eurocent with points assigned in the range 1-20. Comparable division is applied for tariff amounts of commercial and utility scale systems. For FSACG between 25.4 eurocent (5 points) and 3.8 eurocent (19 points). Finally for FSDURATION we have awarded points in the range 5 year (-20 points) up to 25 year (20 points). Table A1 in the appendix shows a more detailed overview of how the points are assigned.

As we have discussed above, the tariff amount is split in three different categories. Since scale has its impact on the return on investments, we have accounted for differences in the height of tariff amount by assuming that small systems have on average 15% higher tariff amounts than commercial and 30% higher than utility scale systems. In other words bigger systems are often rewarded with lower tariffs to compensate for the fact that the price per entity is lower. So an equal tariff amount for smaller and bigger systems is in favour of the bigger systems so that the tariff amount of the latter is rewarded with more points since we expect this tariff amount to be more effective. For separate measurement of the tariff amounts we take the combined average of the three measures (FSTARIFFS). Simply since correlation between them makes it impossible to include all three in one regression model.

Indicator	Observations	Mean	Std. Dev.	Minimum	Maximum
Points Small	130	11.87	5.26	1.00	20.00
Points Commercial	130	10.98	5.31	0.00	20.00
Points Utility	130	7.00	7.39	0.00	22.00
FSTARIFFS	130	9.95	4.98	0.67	20.33
FSDURATION	130	4.03	8.84	-10.00	20.00
FSCAP	130	-4.04	6.68	-15.00	0.00
FSACG	130	13.12	3.57	5.00	19.00
FSACG2	130	6.12	7.10	-10.00	18.00
FITSTRENGTH	130	42.94	20.65	0.00	82.00
CONSDUM	130	0.31	0.46	0.00	1.00
CONSAVER	130	6.85	1.60	0.00	10.50

Table 6 Descriptive statistics for both FiT and consistency measures

FSDURATION can be rewarded with both negative and positive points. A feed-in tariff that includes a contract duration longer than 15 year is generally considered as attractive since tariffs are paid over a longer period. A balanced trade-off between contract duration and tariff amount is important to retain a profitable return on investment. Nevertheless, not many investors have been able to obtain a good return on investment if the contract duration is short, so it is viable to reward contract duration below 15 years with negative points.

The inclusion of a limitation on cost or capacity, also known as a cap (FSCAP), is nothing more than a pre-defined maximum on either the budget or the installed capacity during a fixed period of time. A cap can cause uncertainty to potential investors, of course depending on the size of the available limitation. It can be that every aspect of a FiT that is in place seems to be great, but due to a cap the development is inhibited. Clear is that the presence of a cap is of negative impact on the effectiveness of a FiT and therefore negative points are awarded. We have decided to use a binary variable for this specific design feature since it is hard to sort the differences between caps in classes, there are relatively few feed-in tariff policies that include a cap and the variability between them is high. Nevertheless they have one thing in common, based on data and literature the impact of the inclusion of a cap is expected to be strong. Therefore a negative reward of -15 is on average justifiable.

At last we have included an indicator for the average cost of generation (FSACG). Two countries that implement feed-in tariffs with equal tariff amount and contract duration will not directly have a comparable development; return on investment is based on more factors than these two. The ROI varies primarily because of the difference in insolation between countries. As discussed in literature, purely based on solar irradiation, generation in Israel is about 70% higher than the generation of a PV system in the average country in our panel. But price, lifetime and efficiency of a PV-system also contribute to its variation. By keeping all other factors constant (lifetime = 25 years, PV system efficiency = 15% and one sq. meter of solar panels consist of 150 Watt peak (Wp)) we have calculated the average number of kWh’s that is generated by a system per Wp for each country-year. Dividing the current PV-system price per Wp by that number, gives us the average cost of generating one kWh of solar electricity over the lifetime of a PV system. The lower this number, the higher the reward in points. Table 6 shows one additional ACG measure: FSACG2. More weight is given to observations with higher returns on investments. The range of points assigned is still -20 – 20, and the division remains linear. Now a value of 25.4 eurocent is awarded -10 points instead of 5 points, the reward for 3.8 eurocents is now 18 points instead of 19. The spread of the assigned points is bigger and therefore the reward for lower ACG values is relatively higher. This FSACG2 measure is used for sensitivity analysis. Accordingly we also measure the impact of replacing FSACG for FSACG2 in the composition of our strength indicator: in an additional sensitivity analysis FITSTRENGTH will be replaced by FITSTRENGTH2.

The sum of the six rewards forms the FiT-strength indicator (FITSTRENGTH); this indicator will be included in the base model of our empirical study in chapter 5.

3.5 Measuring policy-consistency

As concluded from literature, governments need to pursue consistent policy enactment and corresponding uncertainties have to be minimised. In other words, clear and stable policy objectives are required to stimulate investments sustainably. We have defined five factors that have influence on our measure for the level of policy-consistency: long-term planning security, the administrative process, corruption and both the presence of a cap or degression rate. We have composed two variables to measure policy-consistency and its role in developing the PV-industry: CONSDUM and CONSAVER. The first is a binary variable that distinguishes sustainable policy support from unsustainable and insufficient support. The second is an indicator that is composed by taking the combined average of four separate measures. Some observations have only values for three out of the four measures; in that case the average of those three measures is taken. Descriptive statistics of both variables are displayed in Table 6.

The first part of CONSAVER compares the current tariff amount with tariffs in the past. The second makes a comparison with future tariffs. If potential investors gain confidence in the continuity of a policy, the effectiveness of a FiT is expected to grow. So the more constant tariffs in consecutive years are the higher the level of consistency. The first two represent the factor long-term planning security. The third measure of our consistency-indicator CONSAVER takes the presence of a cap on either cost or capacity into account. A cap causes uncertainty whether an investors' FiT-application will be granted or not, this is expected to have a negative impact on further market growth. Policy-consistency is characterized by certainty instead of uncertainty; the presence of a cap is therefore valued with zero points. The fourth and last indicator measures the sustainability of the FiT that is in place; it is a more sophisticated version of the CONSDUM variable. A sustainable FiT-policy gives investors a good but realistic return on their investment, which is expected to result in a stronger development of PV.

	Consistency Indicator	**Points**
1	Past FiTs	0 - 12
2	Future FiTs	0 - 12
3	Presence of a cap	Y = 0, N = 8
4	Sustainability of a FiT	2 - 10

Table 7 Points classification of consistency indicators

Table 7 gives an overview of the points classification of the four consistency measures. The higher the number of points that are assigned the more consistent is FiT-policy perceived to

be. For indicator 1 points are assigned based on the strength of feed-in tariffs in the past. A distinction is made between higher and lower FITSTRENGTH last year. An increase in FITSTRENGTH is expected to cause less uncertainty to investors and therefore to be more consistent (6 points) than a decrease in FITSTRENGTH (4 points). In those cases the difference with this years' FITSTRENGTH is at least 5 points. Comparability is valued even higher, a difference in FITSTRENGTH of maximum 5 points compared to last year is worth 8 points and a comparable FIT in the past two years is rewarded with 12 points. The same division of points is applied for indicator 2, Future FiTs, but now we compare with future FITSTRENGTH values. Indicator 3 measures the presence of a cap on cost or capacity, a policy is considered to be consistent if no cap is implemented, and in that case rewarded with 8 points. However when a cap is implemented zero points are assigned. The fourth and last indicator measures sustainability of a FiT. Insufficient (<35) or unsustainable (>65) levels of FITSTRENGTH are rewarded with 2 points. Sustainable levels (35-55) receive 6 points; very sustainable levels (55-65) of FITSTRENGTH are valued with 10 points.
A detailed overview of points classification is displayed in Table A2 in the appendix.

As said, CONSAVER is the average of the points that are assigned to the four different measures. One shortcoming is the correlation between CONSAVER and FITSTRENGTH. Out of the 660 observations both variables have only non-zero values in years that a FiT was in place which is the clear cause of the high level of correlation.

We have not included measures for the presence of a degression rate, corruption and the administrative process. The impact of corruption will be analysed by performing a separate regression. The other two factors are certainly relevant but difficult to measure. Only a few countries clearly announce the degression rates on forehand, but even then it happens that interim adjustments are made. With regards to the measurement of the administrative process it is the lack of transparency and knowledge about corresponding administrative processes that makes this factor incomparable and unquantifiable.

CONSDUM is a binary variable that measures the sustainability of a feed-in tariff. This variable is less correlated with FITSTRENGTH and is therefore a good replacement for part of CONSAVER. CONSDUM has value 1 for all observations of FITSTRENGTH between 35 and 65. We assumed that only 50% of the feed-in tariffs are sustainable, partly because we need to limit the correlation of CONSDUM with FITSTRENGTH. From the other 50% 2/3th is considered to have insufficient strength and 1/3th is unsustainable. These assumptions are based on own data analysis. Rounded upwards we find that all values above 65 are unsustainable and below 35 insufficient.

3.6 Non-FiT policy-, corruption-, exogenous- and control variables

Additional to the policy-consistency variables and FiT-measures we include non-FiT policy indicators, corruption measures, exogenous variables and a set of control variables. The table below gives an overview of the assigned names, its meaning and the source of each variable. Notation of each variable and more detailed argumentation on the selection of variables will follow in the next chapter.

Variable	**Meaning**	**Source**
GDPCAP	Gross domestic product per capita	The World Bank
ELECCAP	Electricity generation per capita	OECD-ilibrary
ELECPRICEHH	Wholesale electricity prices (households)	OECD-ilibrary
ELECPRICEIN	Industrial electricity prices	OECD-ilibrary
ENERGYIM	Energy imported, percentage of energy use	OECD-ilibrary
CO2EMCAP	CO2 emissions per capita	The World Bank
COMBSHARE	Share of electricity generated by combustibles	OECD-ilibrary
NUCLSHARE	Share of electricity generated by nuclear plants	OECD-ilibrary
OPENNES	Percentage export + import of GDP	The World Bank
POPDENS	Inhabitants per squared kilometer	The World Bank
LIFEEXP	Average life expectancy	The World Bank
RDENDBUDGET	RD&D budgets for investments in the PV-sector	IEA Database
POLINVEST	Combined binary for investment and tax incentives	IEA Policies & Measures Database
POLNETMET	Binary for years with net metering policy	IEA Policies & Measures Database
POLTEN	Binary for years with call for tender	IEA Policies & Measures Database
CORR	Corruption based on Corruption Perception Index	Transparency International

Table 8 Overview of variables, its meaning and source

4. Data

This chapter elaborates on our composed dataset. After addressing our dependent variable we will discuss respectively the FiT-indicators, non-FiT policy variables, policy-consistency measures, corruption and finally our exogenous and control variables.

Yearly data is collected for 30 OECD countries over the period 1990-2011, which sums up to 660 observations. Four OECD-members are not included in our panel: Iceland, Canada, Australia and the US. Iceland is not taken into account because of the fact that data was lacking on electricity price. The electricity industry is differently organized and when data is lacking it is hard to include Iceland in our panel data approach. Canada, Australia and the US are all excluded for the reason that their electricity markets are divided in regions or states with the consequence that different policies are implemented within one country. Since we perform country-level analysis it is not possible to include these countries.

Most of our data is obtained from the World Bank, OECD-iLibrary and IEA database.

4.1 Data PV development

As explained in the methodology-chapter we have chosen the share of PV generated electricity in a countries' electricity-mix as our dependent variable. Table 9 below shows its descriptive statistics. PVSHARE is still limited with a mean of only 0.06% over the whole panel. But one note has to be placed: until 2004 only one observation has a PVSHARE above 0.06%, Japan in 2003. To compare, the average PVSHARE for all observations in the last 5 years of our dataset is 0.24% and over 2011 even 0.61%. Figure 10 gives an overview of the development of the average PVSHARE in our dataset. Additionally it shows the number of countries with a feed-in tariff in place. The figure clearly shows that the share of PV grew strongly in the last few years. Part of this growth might be explained by the increasing number of active feed-in tariffs but expected to be at least as important is the strong increase of the PVSHARE in a few forefront countries as Germany (2008: 0.7%, 2011: 3.1%), Spain (2008: 0.8%, 2011: 2.8%) and Italy (2008: 0.06%, 2011: 3.6%).

	Obs.	**Mean**	**Std. Dev.**	**Minimum**	**Maximum**	**Notation**
PVSHARE	660	0.06	0.30	0.00	3.57	*% of PV in electricity-mix*
LNPVADDCAP	630	0.72	1.62	0.00	8.93	*Nat. Log yearly added PV capacity*

Table 9 Descriptive statistics dependent variables

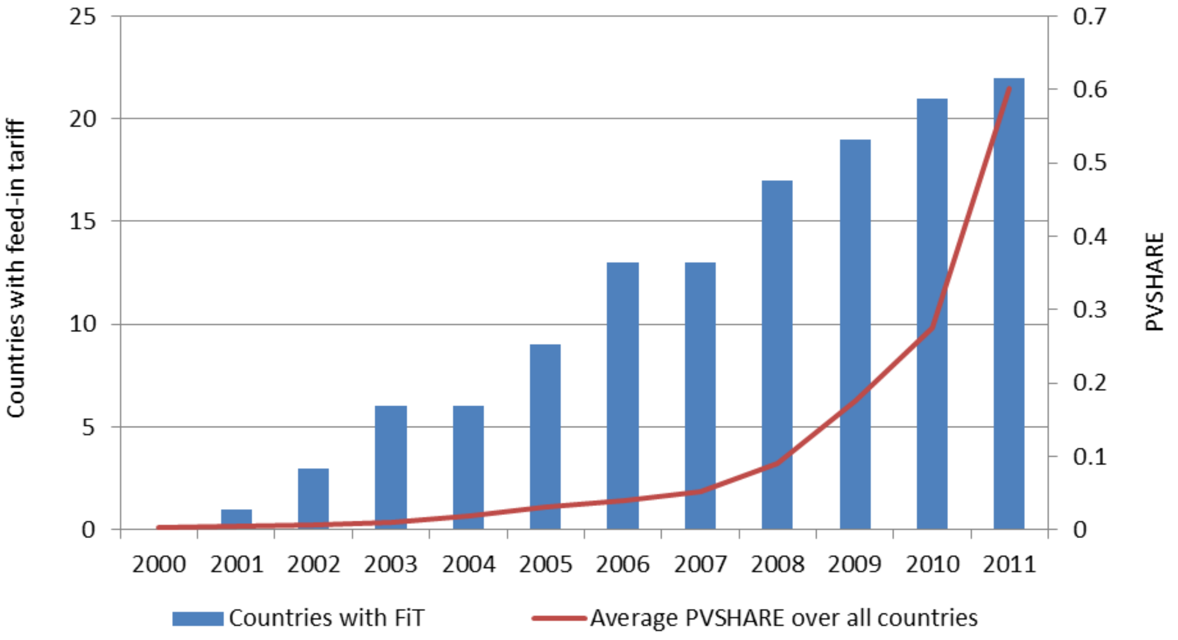


Figure 10 Average PVSHARE development + number of countries with FiT

4.2 Data feed-in tariff measurement

Measuring the impact of feed-in tariffs on the development of the PV-industry is the core of our research. At first we have generated a binary variable to measure the presence of a feed-in tariff (FITDUM), also displayed by the blue columns in Figure 10. Besides the binary variable we have composed a more sophisticated indicator that measures the strength of a feed-in tariff (FITSTRENGTH) as we have extensively elaborated in section 3.4. This is crucial to obtain data that forms a good representation of reality. The light orange dots in Figure 11 are showing all FITSTRENGTH observations through the years. The feed-in tariff policy in Germany (red line) is an exception but furthermore feed-in tariffs become on average stronger through the years. Part of this increase is of course explained by decreasing system prices which makes PV more and more attractive. But after some relatively bad feed-in tariffs more countries follow the example of Germany by implementing stronger feed-in tariffs to stimulate the development of PV. Besides the development of the feed-in tariff in Germany, which is very consistent through the years, there are also lines drawn for the development of FITSTRENGTH in Italy and Spain. The in the literature discussed Spanish peak in 2008 is made clearly visible by our indicator. Also visible is the strength increase in Italy in 2008, which seems to be strongly correlated with the increase in PVSHARE. As we have just discussed in the last paragraph, the share of PV in Italy was close to 0% in 2008 and now accounts for 3.6% of the total electricity-mix.

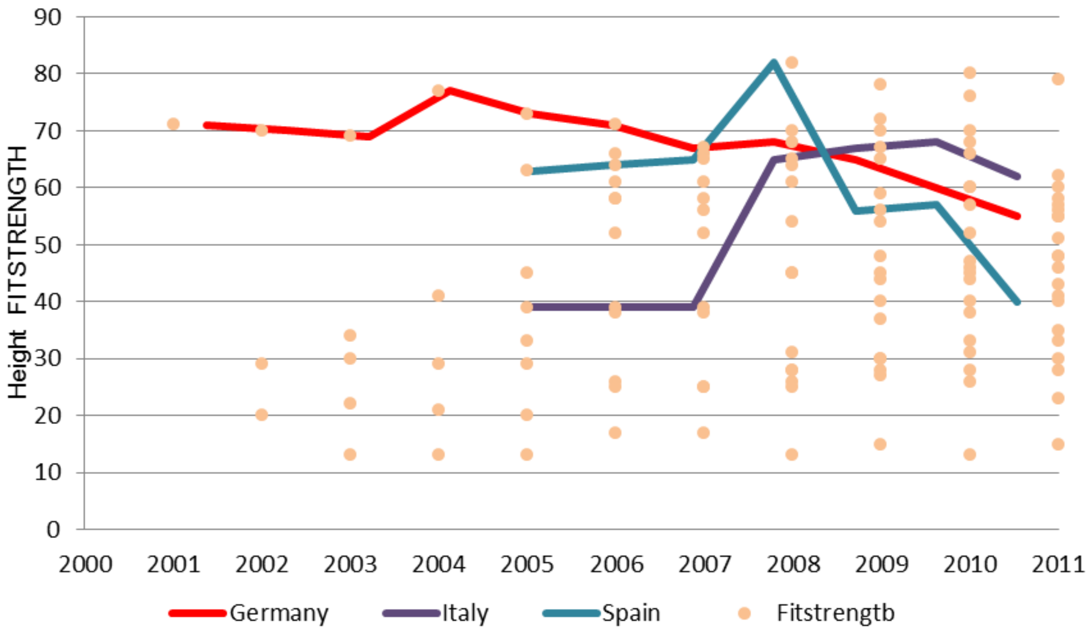


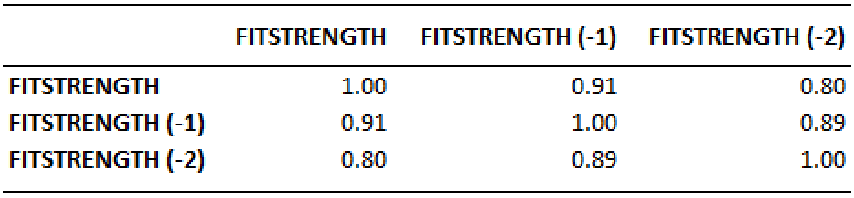
Figure 11 Overview FITSTRENGTH observations + development three countries

Descriptive statistics of both FITDUM and FITSTRENGTH are shown in Table 10 below. Furthermore included are FITSTRENGTHA en FITSTRENGTLA, binary variables respectively for higher and lower FITSTRENGTH values. These two are included to be able to test the expectation that stronger feed-in tariffs result in a disproportional stronger development of the PV-industry. While the relative proportions between valuations of the different design features are well thought-out, it is not said that it's done completely correct. Therefore we have experimented by changing the weight for the average cost of generation and thereby composed FSACG2. FITSTRENGTH2 is adjusted for this change to check whether the results improve as a consequence of this change.

	Obs.	**Mean**	**Std. Dev.**	**Minimum**	**Maximum**	**Notation**
FITDUM	660	0.20	0.40	0.00	1.00	*Binary for presence feed-in tariff*
FITSTRENGTH	660	8.46	19.38	0.00	82.00	*Feed-in tariff strength indicator*
FITSTRENGHA	660	0.11	0.31	0.00	1.00	*FITSTRENGTH >40*
FITSTRENGLA	660	0.09	0.28	0.00	1.00	*FITSTRENGTH <40*
FITSTRENGTH2	660	7.09	17.20	-3.00	77.00	*Adjusted for FSACG2*

Table 10 Descriptive statistics FiT-policy variables

A final sensitivity analysis is performed to control for the delay in visibility of the impact of FiTs on the dependent variable PVSHARE. This shortcoming of the dependent variable is explained in more detail in paragraph 3.2. We have included two sensitivity analyses for the base model first including FITSTRENGTH lagged one period and the second including FITSTRENGTH lagged both one and two periods. It is expected that this will result in a higher summed coefficient for the FITSTRENGTH variables, although correlation is causing some bias as clearly visible in the correlation diagram in table 10 below.



	FITSTRENGTH	FITSTRENGTH (-1)	FITSTRENGTH (-2)
FITSTRENGTH	1.00	0.91	0.80
FITSTRENGTH (-1)	0.91	1.00	0.89
FITSTRENGTH (-2)	0.80	0.89	1.00

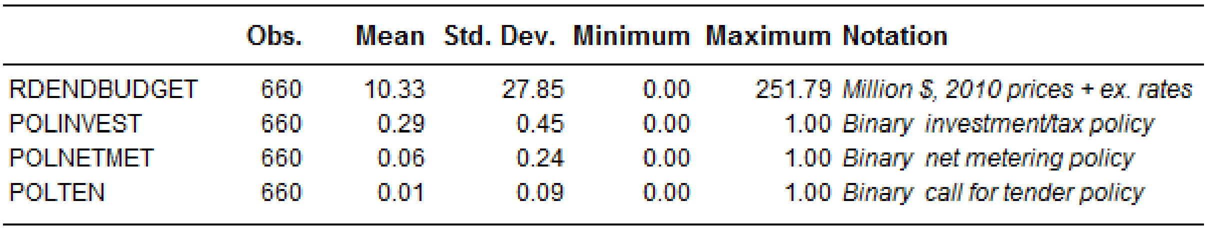
Table 11 Correlation diagram lagged FITSTRENGTH variables

When it was hard to find data for a specific country, on either a feed-in tariff or a non-FiT policy, and development of PVSHARE is zero or close to zero, we have considered it as reasonable to assume that no policy has been in place.

4.3 Data non-FiT policy variables

RDENDBUDGET data is found in the IEA Database. Data of the other non-FiT policy variables is obtained from a broad variety of sources since not one database gives a good overview of the implemented policies. A big part of our data comes from one of the few more complete databases: the IEA Policies & Measures Database. Furthermore we obtained data from windworks.org, EPIA and several governmental websites. Out of the broad range of policies that have been implemented to stimulate the development of PV we have selected only instruments with a direct and regulatory approach. We have excluded Renewable Portfolio Standards because only 2 countries have implemented this type of policy. Tradable permits on its turn are only implemented as major incentive in Belgium and therefore not measured by a separate variable. In the case of Belgium we have transformed the green certificates scheme that is in place since 2005 to a FiT-policy since this type of policy has many similarities with a FiT-policy.

We have included in total three binary variables for respectively investment and tax related policies, net metering incentives and calls for tender. The setup of these policy types differ per country and are therefore hard to measure in a more comprehensive way than a binary variable. This is a shortcoming of our research since it would be of added value to be able to



	Obs.	Mean	Std. Dev.	Minimum	Maximum	Notation
RDENDBUDGET	660	10.33	27.85	0.00	251.79	*Million $, 2010 prices + ex. rates*
POLINVEST	660	0.29	0.45	0.00	1.00	*Binary investment/tax policy*
POLNETMET	660	0.06	0.24	0.00	1.00	*Binary net metering policy*
POLTEN	660	0.01	0.09	0.00	1.00	*Binary call for tender policy*

Table 12 Descriptive statistics non-FiT policy variables

include variables that distinct the weak from the stronger policies. It is not unthinkable to assume that these non-FiT policies have had a significant contribution in some countries in our panel. To mention one: Japan implemented strong investment grants since 1994, for more than a decade Japan was world leader on cumulative installed PV capacity. Besides this shortcoming we assume that POLINVEST has a positive impact on PVSHARE. POLNETMET and POLTEN are not expected to contribute since there are only few observations. If unexpectedly one of them would have any impact it is expected to be positive as well.

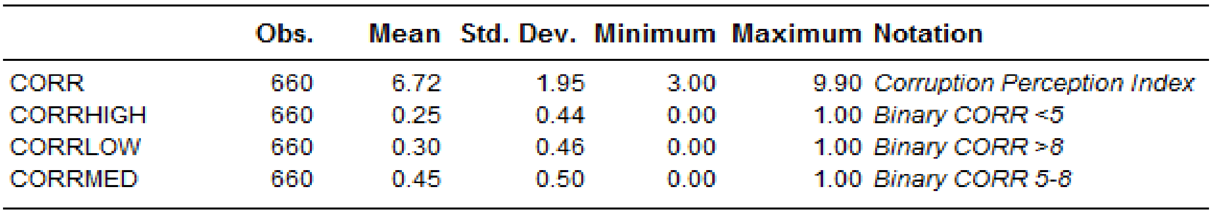
As last non-FiT policy indicator we have selected a variable that measures governments RD&D investments in PV in million US$ (RDENDBUDGET). Although some might argue that a per capita indicator is preferable we have decided not to adjust this variable. Bigger countries do indeed have more budget to invest in RD&D, that could be an argument. But besides Japan not one country invested more than US$70 million in RD&D and the average investment is only US$10 million, not a shockingly high investment. We argue that RD&D investments are complementary and besides that a reasonable investment is needed in order to make a difference. Therefore it is better to use the real investments instead of the investments per capita.

4.4 Data policy-consistency and corruption

In our methodology we already discussed the way we have composed our consistency-indicators CONSDUM and CONSAVER. Existing literature or databases do not provide any data that can be used to measure consistency. One suggestion is to use corruption as an indicator since it says something about the stability of implemented policies. But corruption is a very general and indirect indicator in that sense that it is not directly related to PV policies. Therefore we compose variables that are directly linked to the implemented feed-in tariff policy of a country. As discussed in our methodology-chapter, a limitation of variables that are directly linked to the feed-in tariff policy is that it could result in high correlation levels, which it inhibits correct coefficient estimation. The best way to measure the contribution of consistent policy to the effectiveness of a FiT is to include an interaction variable between FiTSTRENGTH and CONSAVER. But due to the correlation this is not possible. Unfortunately we have not been able to find a comparable comprehensive alternative to realize that. As an alternative we have included CONSDUM, a binary variable that measures the added value of sustainable tariffs. An interaction variable of FITSTRENGTH*CONSDUM is expected to have a stronger impact than FITSTRENGTH on its own since unsustainable and insufficient feed-in tariffs are excluded. Descriptive statistics of both CONSAVER and CONSDUM are displayed in Table 6.

Additionally we include a measure for the impact of corruption. Although this variable is not directly linked to the promotion of the PV-industry it can give us an impression about the role and impact of stable and consistent policy enactment. We have used data from Transparency International; they publish a yearly Corruption Perception Index (CPI). Although this index is an average of a variety of corruption indicators including several that are not at all related to policy-consistency, it is reasonable to assume that if a country has a low total score (which means that corruption is high) on the CPI, policy-consistency related factors are harmed as well. Our expectation is that our corruption indicator CORR is positively related to PVSHARE, in other words the lower corruption the stronger the development of the PV-industry. As a robustness check we have split the CORR sample in three binary variables that distinguishes low (CORRLOW), medium (CORRMED) and high (CORRHIGH) levels of corruption. Table 13 displays the descriptive statistics and also mentions how the binaries have been split.

One shortcoming of the Corruption Perception Index is that data is available only from 2002. The consequences for our research are limited because data on the last decade are more important since we want to measure the impact of corruption on the development of PV, which primarily took place after 2002. We have copied the value of 2002 for the years 1990-2001 to complete our dataset.



	Obs.	Mean	Std. Dev.	Minimum	Maximum	Notation
CORR	660	6.72	1.95	3.00	9.90	*Corruption Perception Index*
CORRHIGH	660	0.25	0.44	0.00	1.00	*Binary CORR <5*
CORRLOW	660	0.30	0.46	0.00	1.00	*Binary CORR >8*
CORRMED	660	0.45	0.50	0.00	1.00	*Binary CORR 5-8*

Table 13 Descriptive statistics corruption variables

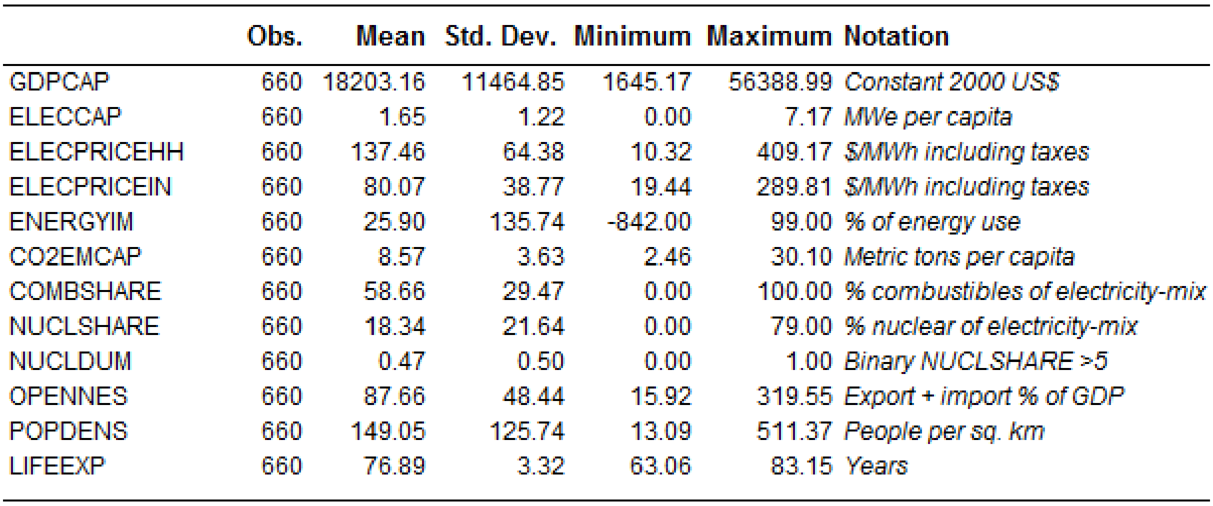
Some other variables have also missed observations. An example is the electricity price for either households or the industrial segment. Since we have data for two electricity price variables we can copy the growth rate of one if observations for the other are missing. For country-years where both variables have observations missing we used the average growth-rate of five consecutive years in the direct past or future. The same technique is used for missing observations of GDPCAP. Additionally LIFEEXP, CO2EMCAP, POPDENS, RDENDBUDGET and ELECCAP all lack observations for the year 2011. For these variables we continue the series using the past five years as reference. For ELECCAP we have manually determined the observations for 2011. Since the development of this specific variable is quite stable we assume that taking the average growth rate of the years 2006-2010 gives a realistic representation of the actual electricity generation per capita in 2011.

4.5 Data exogenous and control variables

We have included several exogenous variables as potential drivers of PV development: GDP per capita (GDPCAP), electricity generation per capita (ELECCAP), electricity price (ELECPRICEHH), imported energy (ENERGYIM), CO2 emissions per capita (CO2EMCAP) and conventional electricity shares (COMBSHARE AND NUCLSHARE). Of those GDPCAP, ELECCAP, ELECPRICEHH and ENERGYIM will be included in the base model.

COMBSHARE, NUCLSHARE and CO2EMCAP are potentially causing endogeneity bias. If PVSHARE becomes very big these variables will become very small, a negative relationship is expected. The larger the weight of non-conventional electricity sources, the lower the use of renewables will be. These three and NUCLDUM are therefore only used in sensitivity analyses.

To correctly measure the impact of wealth as a country-specific variable we have included both GDPCAP and its quadratic variant GDPCAP^2. This is also to test if this variable is in line with the Kuznets literature. One of Simon Kuznets hypothesized relationships is explained by the environmental Kuznets curve, an inverted U-shaped curve. It presumes that environmental problems get worse as a country first industrializes, but once the country reaches a certain income level, this trend reverses. From that point being richer translates into being greener according to Tierney (2009).



	Obs.	**Mean**	**Std. Dev.**	**Minimum**	**Maximum**	**Notation**
GDPCAP	660	18203.16	11464.85	1645.17	56388.99	*Constant 2000 US$*
ELECCAP	660	1.65	1.22	0.00	7.17	*MWe per capita*
ELECPRICEHH	660	137.46	64.38	10.32	409.17	*$/MWh including taxes*
ELECPRICEIN	660	80.07	38.77	19.44	289.81	*$/MWh including taxes*
ENERGYIM	660	25.90	135.74	-842.00	99.00	*% of energy use*
CO2EMCAP	660	8.57	3.63	2.46	30.10	*Metric tons per capita*
COMBSHARE	660	58.66	29.47	0.00	100.00	*% combustibles of electricity-mix*
NUCLSHARE	660	18.34	21.64	0.00	79.00	*% nuclear of electricity-mix*
NUCLDUM	660	0.47	0.50	0.00	1.00	*Binary NUCLSHARE >5*
OPENNES	660	87.66	48.44	15.92	319.55	*Export + import % of GDP*
POPDENS	660	149.05	125.74	13.09	511.37	*People per sq. km*
LIFEEXP	660	76.89	3.32	63.06	83.15	*Years*

Table 14 Descriptive statistics control variables

We will only include ELECPRICEHH as electricity price indicator. Including both ELECPRICEIN and ELECPRICEHH is causing collinearity and does not contribute to the explanatory power of the base model. The latter is less correlated with the other variables in the base model and therefore preferred. A positive relation with the development of PV is expected.

An important exogenous variable is ELECCAP. It is included as a measure for country-specific factor electricity consumption, discussed in paragraph 2.4.4.4. It is expected that higher electricity generation capacity per capita corresponds with an increasing development of PVSHARE. Electricity capacity is in most countries growing and besides of that, the bigger the electricity capacity the more capacity needs to be replaced; renewables can be a solution.

ENERGYIM is included to measure the impact on PV development of the goal of some countries to decrease their energy import dependency. It is expected that a higher import dependency corresponds with more support for PV; an increase in development.

Life expectation (LIFEEXP), population density (POPDENS) and the trade openness of a country (OPENNES) are included as control variables and are all part of the base model.

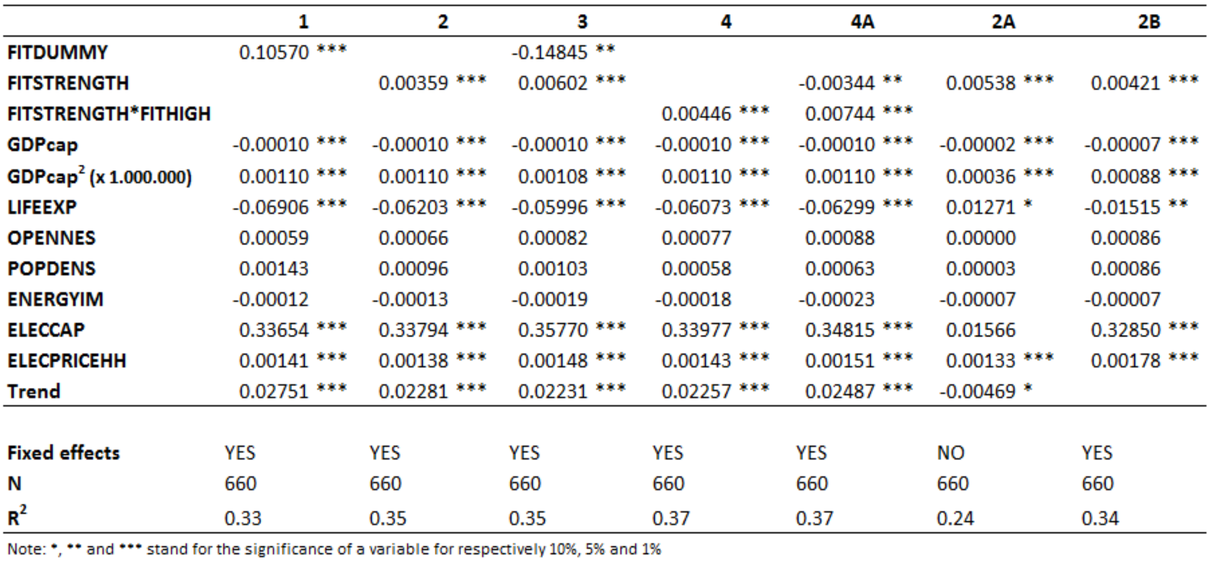
Data for CO2EMCAP, GDPCAP, LIFEEXP, POPDENS, OPENNES is obtained from the World Bank Data. ELECCAP, ENERGYIM, NUCLSHARE, COMBSHARE, ELECPRICEHH and ELECPRICEIN data is all derived from the OECD-ilibrary. Descriptive statistics of both exogenous and control variables are displayed in Table 14.

5. Results empirical study

In this chapter the results of the different models are presented and interpreted. First we will discuss the results for the base model. In the subsequent paragraphs the validity of these estimations are tested by performing a number of sensitivity tests. Besides that we analyse the impact of separate design features, non-fit policies, policy-consistency and corruption. The chapter ends with a pointwise summary of the main results.

5.1 Base model

Table 15 presents the results for the base model. It is clearly visible that in all four models at least one of the FIT variables has a significant positive impact on the development of the share of PV in a countries' electricity-mix. This is an important result; it proofs that feed-in tariff policies have been effective in the development of PV Solar.



	1	2	3	4	4A	2A	2B
FITDUMMY	0.10570 ***		-0.14845 **				
FITSTRENGTH		0.00359 ***	0.00602 ***		-0.00344 **	0.00538 ***	0.00421 ***
FITSTRENGTH*FITHIGH				0.00446 ***	0.00744 ***		
GDPcap	-0.00010 ***	-0.00010 ***	-0.00010 ***	-0.00010 ***	-0.00010 ***	-0.00002 ***	-0.00007 ***
GDPcap^2 (x 1.000.000)	0.00110 ***	0.00110 ***	0.00108 ***	0.00110 ***	0.00110 ***	0.00036 ***	0.00088 ***
LIFEEXP	-0.06906 ***	-0.06203 ***	-0.05996 ***	-0.06073 ***	-0.06299 ***	0.01271 *	-0.01515 **
OPENNES	0.00059	0.00066	0.00082	0.00077	0.00088	0.00000	0.00086
POPDENS	0.00143	0.00096	0.00103	0.00058	0.00063	0.00003	0.00086
ENERGYIM	-0.00012	-0.00013	-0.00019	-0.00018	-0.00023	-0.00007	-0.00007
ELECCAP	0.33654 ***	0.33794 ***	0.35770 ***	0.33977 ***	0.34815 ***	0.01566	0.32850 ***
ELECPRICEHH	0.00141 ***	0.00138 ***	0.00148 ***	0.00143 ***	0.00151 ***	0.00133 ***	0.00178 ***
Trend	0.02751 ***	0.02281 ***	0.02231 ***	0.02257 ***	0.02487 ***	-0.00469 *	
Fixed effects	YES	YES	YES	YES	YES	NO	YES
N	660	660	660	660	660	660	660
R^2	0.33	0.35	0.35	0.37	0.37	0.24	0.34

Note: *, ** and *** stand for the significance of a variable for respectively 10%, 5% and 1%

Table 15 Estimation results base model

In model 1 the effectiveness of the FITDUMMY variable is tested. It says that if there is a FIT in place, PVSHARE will increase with on average 0.11%. This seems to be little but it makes sense if we take into account that the maximum PVSHARE in a country during the panel period 1990-2011 is only 3,57% (Italy, 2011), moreover the average PVSHARE for the 129 observations with a feed-in tariff in place is only 0,28%.

Replacing FITDUMMY by FITSTRENGTH (model 2) results in a small but significant increase of the explanatory power. The maximum value of FITSTRENGTH is 82, so the contribution of a strong FIT to the share of PV in a country is 0.29%. Which is nearly three times more compared to the dummy variable. The average value of FITSTRENGTH is 43.27, multiplying that number with the coefficient of model 2 gives the impact of an average feed-in tariff: 0.16%. An important observation is that it is not just the presence of a FIT that is determinative, but also the strength of a FIT. A less powerful FIT corresponds with a lower increase of PVSHARE and vice versa. Model 4A underlines this statement; we add a dummy which is 1 for all values of FITSTRENGTH that are equal or higher than 40 (FITHIGH), in other words the less powerful feed-in tariffs are not taken into account in this model. As a result the effect of FITSTRENGTH is taken over by the interaction variable of FITSTRENGTH and FITHIGH. To show the exact impact of the interaction variable we only include the interaction variable in model 4. The latter model is clearer and therefore easier to compare with the base model as well; with a maximum average impact of 0.37% the coefficient is about 20% higher than in model 2. The explanatory power is even higher than of the base model; allowing us to assume that the significant relation between feed-in tariffs and PVSHARE is mainly explained by the presence of stronger feed-in tariffs.

Model 3 displays the results of a regression in which both FITDUMMY and FITSTRENGTH are included. As a consequence the coefficient of FITDUMMY turns negative but remains significant, FITSTRENGTH becomes more powerful to compensate for the negative impact of the dummy. This contrast is very likely caused by the high correlation between both variables. More important is that FITSTRENGTH takes over the effect of FITDUMMY. This is another proof that the variable FITSTRENGTH has an important added value compared to the dummy.

Table A5 in the appendix shows that the inclusion of FITDUMMY is not rejected, the performed F-test on the error sum of squares is significant. In other words model 3 has some added value to model 2. However we have decided that model 2 will be the base model for further analysis in the coming paragraphs. Model 3 is affected by correlation and therefore less easy to interpret. Additionally, FITSTRENGTH is the key-variable of this research; to be able to focus on this variable it is preferable to not include another feed-in tariff indicator.

In model 1-4 fixed cross-section effects are incorporated to control for country specific characteristics. These may influence the development of PV in a country and as a consequence also affects the impact of FITSTRENGTH. Model 2A is included to reveal the influence of the possible presence of fixed effects. According to this model it is obvious that the inclusion of fixed effects is necessary; the explanatory power of model 2A is about 30% lower. Additionally the coefficient of FITSTRENGTH has increased up to a maximum of 0.44%, which is substantially higher compared to the fixed effects models (model 1-3). This indicates that part of the growth in PVSHARE is explained by country specific characteristics instead of the strength of a FIT. But it is not said that the complete difference between 0.29%

and 0.44% is caused by fixed effects. It can be that the correction for fixed effects is too rough; as a result a too big part of the result is absorbed. The actual effect of the variable FITSTRENGTH may be somewhere in between.

We have included a time-trend to correct for autonomic developments in our analysis, like technological developments. Part of the development of the PV-industry might be caused by these autonomic developments and not by FITSTRENGTH or other variables that are included in the model; the time-trend adjusts for this potential bias. Based on model 1-4 we can conclude that the inclusion of a trend is a good decision, it has a significant positive impact. In other words, autonomic developments have its impact on the development of the PV-industry. Model 2B helps us to reveal the exact impact of the trend. It shows that FITSTRENGTH is about 15% more effective without the trend and ELECPRICEHH has even 22.5% more impact. Hence these effects are somewhat overstated; so we can conclude that the inclusion of a time-trend is relevant to optimize our model. One note has to be mentioned; similar as with the incorporation of cross-section fixed effects it can be that a too big part of the result is absorbed by the time-trend.

Summarized, the presence of a feed-in tariff has a significantly positive effect on the share of PV in the electricity-mix of an average country. Assuming that the correction for fixed effects is necessary, FITSTRENGTH has a maximum average impact of 0.29%. When we distinguish the weak from the strong feed-in tariffs, even an average impact of 0.37% can be reached. The stronger the feed-in tariff the higher the increase of a countries' PVSHARE.

Besides the role of FITSTRENGTH there are four other indicators important in the explanation of the development of the PV-industry: GDP per capita, a countries' electricity capacity per capita, the price of electricity and life expectancy.

The strong significance of the variable electricity capacity per capita is not remarkable. Besides Japan, most of the bigger electricity markets have above average levels of PV in their electricity-mix, those include Germany, Spain and Italy. It seems that larger electricity markets are more able to effectively support the development of PV (Jenner et al, 2012). This is not surprising, as investments will be higher in these markets.

We can deduce that the higher the life expectation in a country, the lower the expected share of PV. Assume that two countries have an equally high total GDP, but due to the higher life expectation in one country the total GDP needs to be divided over a bigger number of inhabitants. As a result, the country with the higher life expectations has a lower average GDP per capita. The income needs to be divided between more individuals; accordingly less money is available to invest in more expensive technologies like PV.

For GDP per capita we have included a quadratic term, this is to test if this variable is in line with the Kuznets literature, as explained in chapter 4. Both variables are significant and therefore contributing to the explanatory power of the model. Figure 12 shows a graphical representation of the relation between GDPcap and PVSHARE. Until a GDPcap around 40000$ its impact is negative, from then the relation turns increasingly less negative. In other words, according to figure 1 the wealthier a country the higher the relative investments in PV after the turning point. This relationship is robust across all models. Nevertheless only 22 observations have a GDP per capita above 40000$, 14 of these observations belong to one country with a relatively high PVSHARE, Luxembourg. The shown figure is in line with the environmental Kuznets literature, although the figure is mirrored because less environmental investments here is equal to a decrease of the graph instead of an increase in the graph drawn by Kuznets.

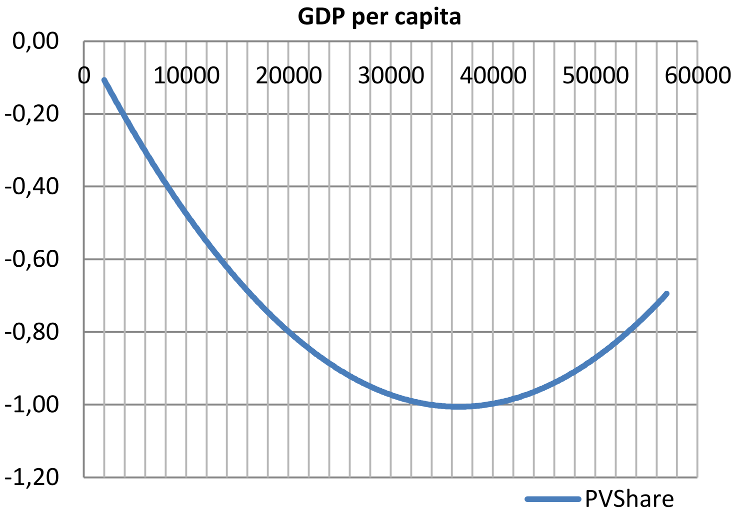


Figure 12 Relation GDP per capita to PVshare

The last robust and constant significant indicator is the price of electricity. The average impact of the household electricity price is 0.18%. A potential increase of 10$ per MWh electricity is equal to a 1$cent increase of a kWh electricity. Such an increase results on average in a 0.014% increase of a countries' PVSHARE. A seemingly small impact but the electricity price has increased on average 101$ over the last decade, which corresponds to an average increase of 0.14% of the share of PV. In some countries, like Germany, the electricity price has had an even higher impact. Over the last 10 years, the electricity price increased with 228$, which is equal to an average increase of PVSHARE of 0.31%. Summarized; as expected, the higher the electricity price the higher the share of PV in a countries' electricity mix.

5.2 Effectiveness of separate Feed-in tariff design features

As pointed out in the literature (section 2.4.3.2) a FiT can have different characteristics, known as design features. FITSTRENGTH consists of four different measures; the impact of these separate features is tested in model 5. The different design features are:

- FSTARIFFS: the average of the three FiT tariff amount categories; residential, commercial and utility scale systems
- FSDURATION: indicator for FiT contract duration
- FSACG: indicator for the average cost of generation of one solar kWh
- FSCAP: indicator that measures the presence of a cap on installed capacity

In model 5 only the design feature contract duration is of significant influence. It has a positive impact; the longer a FiTs' contract duration the more a PV-industry develops. This is in line with expectations. Nevertheless it is surprising that FSTARIFFS is not significantly contributing in model 5. However, If we leave 2011 out of the model (model 5A) the tariff amount design feature is significant. The significance of contract duration and tariff amount combined with the fact that FSACG does not significantly contribute, gives us reason to assume that it is not that important that a country has abundant solar irradiation[8]. As long as a FiT contains a beneficial tariff amount and a long enough contract duration a market will develop. These findings support the literature statement (section 2.3) that instead of intensity of the sun as main driver we can infer that PV-industry growth is more explained by financial returns. Nevertheless, by including 2011 the role of FSTARIFFS is not that important anymore. This observation can be explained using some market insights. According to our data, the average tariff amount impact decreased with about 15% compared to 2010, this presumably results from the strong decrease of PV-system prices in the last years. Several markets have become more able to develop PV-projects with lower feed-in tariffs. In other words, the tariff amount has become less important in explaining the development of PVSHARE.

We were surprised that FSACG was not significant. To analyse the impact of a higher valued FSACG, some more weight is added to this variable in model 6. This means, a lower average cost for generation of one solar kWh is valued with relatively more points compared to model 5. As a result FSACG2 turns significant. Fortunately the variable for contract duration is also still significant. The explanatory power of the model increases, which gives rise to assume that this addition has brought us closer to reality. As said it is reasonable to assume that the strong decrease of prices has its impact on the development of the PV-industry. That FSACG2 turns significant is in these circumstances not at all surprising. One note should be placed: the correlation with other design features has increased considerably, which may induce bias.

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[8] As explained in section 3.4, FSACG is mainly driven by the level of solar irradiation

	BASE 2	5	5A	6	7
FITDUMMY					
FITSTRENGTH	0.00359 ***				
FITSTRENGTH2					0.00489 ***
FSTARIFFS		0.00170	0.00410 **	-0.00413	
FSDURATION		0.01796 ***	0.00956 ***	0.01325 ***	
FSACG		0.00698	0.00155		
FSACG2				0.02811 ***	
FSCAP		-0.00075	-0.00320	0.00414	
GDPcap	-0.00010 ***	-0.00009 ***	-0.00005 ***	-0.00006 ***	-0.00009 ***
GDPcap^2 (x 1.000.000)	0.00110 ***	0.00099 ***	0.00075 ***	0.00071 ***	0.00107 ***
LIFEEXP	-0.06203 ***	-0.04818 ***	-0.01942 *	-0.04676 ***	-0.05813 ***
OPENNES	0.00066	0.00099	0.00021	0.00120	0.00073
POPDENS	0.00096	0.00044	-0.00053	-0.00129	0.00058
ENERGYIM	-0.00013	-0.00013	0.00013	0.00010	-0.00013
ELECCAP	0.33794 ***	0.33086 ***	0.18263 ***	0.27695 ***	0.33561 ***
ELECPRICEHH	0.00138 ***	0.00152 ***	0.00071 ***	0.00090 ***	0.00134 ***
Trend	0.02281 ***	0.01372	0.00761	0.01393 **	0.02026 ***
Fixed effects	YES	YES	YES	YES	YES
N	660	660	630	660	660
R^2	0.35	0.37	0.40	0.43	0.36

Note: *, ** and *** stand for the significance of a variable for respectively 10%, 5% and 1%

Table 16 Effectiveness of feed-in tariff design features

To control for the impact of this change on the combined variable we have composed FITSTRENGTH2, which now includes FSACG2 instead of FSACG. The impact of FITSTRENGTH2 is higher but needs to be adjusted slightly downwards due to the lower level of the mean (Table 10). The robustness of the base model is not affected. All together it is encouraging that the adjustment in ACG has contributed in reaching the best possible approximation of the reality.

To conclude this paragraph: contract duration is the most important contributor to the significant impact of FITSTRENGTH. Furthermore, it is crucial that rewards for the different design features are well balanced. More weight on one design feature will take over the effect of other design features. We have some evidence that tariffs and costs might influence the development of PV. Whatever the weights are, the combined variable FITSTRENGTH remains robust.

5.3 Role of non-FiT policy instruments

In model 8-10 we analyse the role of non-FiT policy instruments on the development of the PV-industry (see Table 15). In model 8 the four different non-FiT policy dummy variables are added to our base model. The result clearly shows that all four variables are insignificant. At the same time, the results for FITSTRENGTH are still comparable and therefore robust. The insignificance of the non-FiT policies is not that remarkable. POLNETMET and POLTENDER consist of only a few observations. Besides that, the dummies for net metering policies, calls for tender and investment or tax grants have one shortcoming: the difference in strength of one policy compared to another is not captured. Although not optimally measured, based on the results of model 8 it can be stated that we have no evidence that any of the non-FiT policy has individually contributed to the development of the PV-industry.

When adding interaction variables in model 9 some changes appear. Part of the impact of FITSTRENGTH is taken over by its interaction variable with RDENDBUDGET. On itself not surprising, this shows that stronger FiTs in combination with higher governmental RD&D investments results in higher PV shares. To give an example, if we take the level of the interaction variable for the year 2008 in Germany the impact sums up to 68 (strength of FiT) * 69 (RD&D investments) * 0.00004 (coefficient) = 0.19% + the level of FITSTRENGTH (0.00193*68) = 0.32%. So the estimated impact of the combined FiT and RD&D policies is higher compared to the impact of FITSTRENGTH just on its own in the base model, 0.24% (68*0.00359). Still this measurement is biased downwards by one dominating cross-section, Japan. Leaving Japan out of the model would cause a strong increase in significance and power of the interaction variable (model 9A). The impact for the observation Germany 2008 would increase from 0.32% to 0.52%, completely explained just by the interaction variable. Japan is a country with, compared to all other countries, extremely high RD&D investments. The PV-industry is relatively large in Japan but accounts for only a fraction of the electricity-mix, it’s PVSHARE in 2010 is less than 0.4%. Accordingly Japan’s electricity capacity is by far the largest of our panel.

The net metering policy dummy POLNETMET is of negative impact on the development of the PV-industry in both model 9 and 10. As said, only a few countries have implemented a net metering policy for PV applications. The outcome could therefore be biased such that it happens to be that net metering incentives are mostly implemented in countries with a relatively low share of PV. As a consequence a negative relation exists.

Model 10 leaves out FITSTRENGTH. The impact of the interaction variable with RD&D investments remains of comparable impact. The earlier considered impact of FITSTRENGTH in model 9 is taken over by the interaction variable FITSTRENGTH*POLINVEST. Although its impact is only marginally higher than the impact of FITSTRENGTH in model 9, it can be assumed that a FiT combined with an investment or tax grant might have added value. Alternatively it can just be the case that feed-in tariffs with more impact are more often accompanied with a complementary investment or tax grant. In that situation the growth of the industry is not explained by the presence of the investment of tax grant but by the fact that a more effective FiT is in place.

	BASE 2	8	9	9A	10
FITSTRENGTH	0.00359 ***	0.00368 ***	0.00193 *	0.00174	
POLINVEST		-0.00023	-0.01175	0.01595	-0.02708
POLNETMET		-0.06347	-0.11404 *	-0.11667 *	-0.12887 *
POLTENDER		-0.15599	-0.14247	-0.09872	-0.16885
RDENDBUDGET		0.00054	-0.00009	-0.00014	-0.00020
FITSTRENGTH*POLINVEST			0.00092	-0.00051	0.00251 **
FITSTRENGTH*POLNETMET			0.00213	0.00217	0.00240
FITSTRENGTH*POLTENDER			-0.00062	-0.00318	0.00018
FITSTRENGTH*RDENDBUDGET			0.00004 *	0.00011 ***	0.00004 *
GDPcap	-0.00010 ***	-0.00010 ***	-0.00009 ***	-0.00009 ***	-0.00009 ***
GDPcap^2 (x 1.000.000)	0.00110 ***	0.00108 ***	0.00101 ***	0.00105 ***	0.00100 ***
LIFEEXP	-0.06203 ***	-0.06506 ***	-0.06435 ***	-0.06547 ***	-0.06772 ***
OPENNES	0.00066	0.00067	0.00066	0.00048	0.00065
POPDENS	0.00096	0.00156	0.00176	0.00196	0.00208
ENERGYIM	-0.00013	-0.00024	-0.00024	-0.00027	-0.00024
ELECCAP	0.33794 ***	0.33726 ***	0.34319 ***	0.34384 ***	0.35356 ***
ELECPRICEHH	0.00138 ***	0.00146 ***	0.00146 ***	0.00153 ***	0.00150 ***
Trend	0.02281 ***	0.02323 ***	0.02244 ***	0.02303 ***	0.02456 ***
Fixed effects	YES	YES	YES	YES	YES
N	660	660	660	638	660
R^2	0.35	0.35	0.36	0.37	0.36

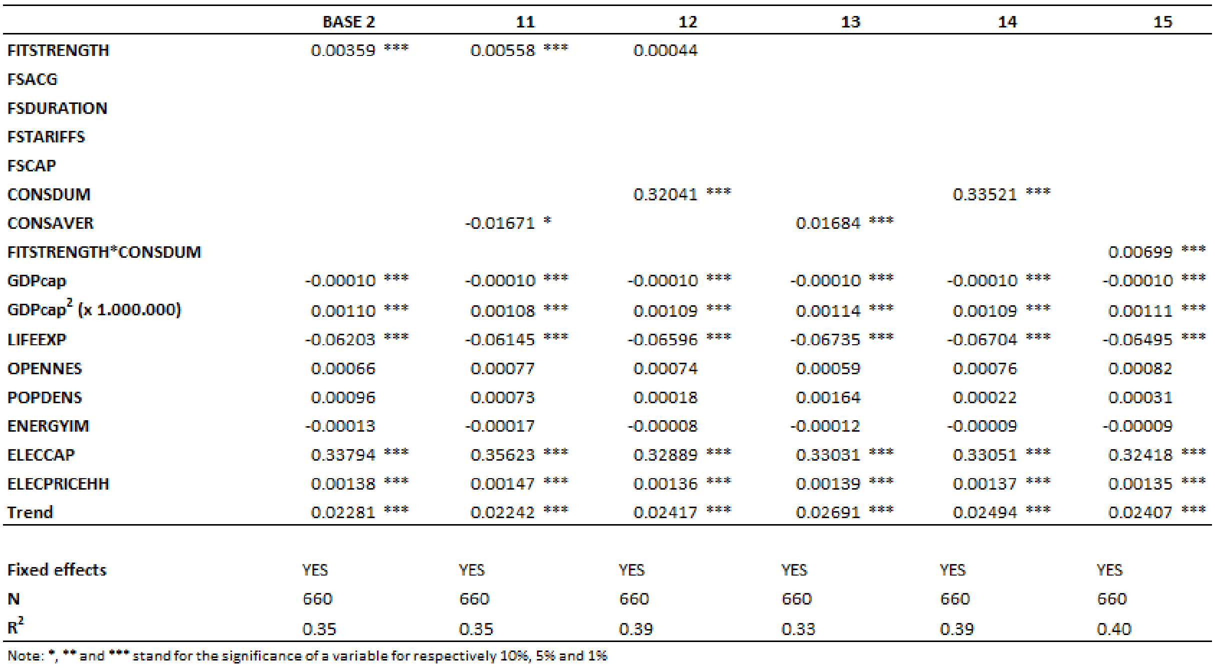
Note: *, ** and *** stand for the significance of a variable for respectively 10%, 5% and 1%

Table 17 Effectiveness of non-FiT policy instruments

The main finding of this section is that countries with a combined policy of RD&D investments and a feed-in tariff might experience stronger growth of its PV-industry than countries with a feed-in tariff as the only policy incentive. Some models show evidence that the higher the investments in RD&D the more effective the deployment of the PV-sector. Non-FiT policies do not contribute individually, although this might result from data problems. More in depth research on the individual effectiveness of non-FiT policies can be helpful to further underpin this statement.

5.4 Policy-consistency

In this section we include policy-consistency indicators to determine the contribution of consistent policy enactment to the effectiveness of a feed-in tariff. One important note is that the composed consistency indicator CONSAVER is unfortunately strongly correlated with the main FiT strength indicators. This is clearly visible in the correlation-matrix in the appendix (Table A4) but is also discernible from Table 18. The main reason is that CONSAVER by definition only has observations for the years in which a FiT was in place. Besides that, the separate measures that together compose CONSAVER are based on the sustainability, past and future of a feed-in tariff and therefore correlated with FITSTRENGTH. This is a limitation of our attempt to include policy-consistency in our effectiveness analysis.



	BASE 2	11	12	13	14	15
FITSTRENGTH	0.00359 ***	0.00558 ***	0.00044			
FSACG						
FSDURATION						
FSTARIFFS						
FSCAP						
CONSDUM			0.32041 ***		0.33521 ***	
CONSAVER		-0.01671 *		0.01684 ***		
FITSTRENGTH*CONSDUM						0.00699 ***
GDPcap	-0.00010 ***	-0.00010 ***	-0.00010 ***	-0.00010 ***	-0.00010 ***	-0.00010 ***
$GDPcap^2$ (x 1.000.000)	0.00110 ***	0.00108 ***	0.00109 ***	0.00114 ***	0.00109 ***	0.00111 ***
LIFEEXP	-0.06203 ***	-0.06145 ***	-0.06596 ***	-0.06735 ***	-0.06704 ***	-0.06495 ***
OPENNES	0.00066	0.00077	0.00074	0.00059	0.00076	0.00082
POPDENS	0.00096	0.00073	0.00018	0.00164	0.00022	0.00031
ENERGYIM	-0.00013	-0.00017	-0.00008	-0.00012	-0.00009	-0.00009
ELECCAP	0.33794 ***	0.35623 ***	0.32889 ***	0.33031 ***	0.33051 ***	0.32418 ***
ELECPRICEHH	0.00138 ***	0.00147 ***	0.00136 ***	0.00139 ***	0.00137 ***	0.00135 ***
Trend	0.02281 ***	0.02242 ***	0.02417 ***	0.02691 ***	0.02494 ***	0.02407 ***
Fixed effects	YES	YES	YES	YES	YES	YES
N	660	660	660	660	660	660
R^2	0.35	0.35	0.39	0.33	0.39	0.40

Note: *, ** and *** stand for the significance of a variable for respectively 10%, 5% and 1%

Table 18 Analysing the role of Policy-consistency

CONSAVER initially is negatively significant in the shadow of FITSTRENGTH (model 11), but leaving the latter out of the model (13) turns the sign positive. The impact, however, is relatively low (maximum impact is 10.5*0.01684= 0.177%). It is hard to draw right conclusions from these results. As an alternative we have replaced CONSAVER by CONSDUM, a binary variable that measures the effect of sustainable feed-in tariffs and is much less correlated with FITSTRENGTH. Insufficiently low and unsustainably high feed-in tariffs are excluded. As a result the effect of FITSTRENGTH is completely taken over by the consistency dummy, the average contribution of a sustainable feed-in tariff is now 0.34% (model 14) which is more than twice the average contribution of the FITSTRENGTH indicator, 0.15%. Model 15 underlines this finding. The coefficient for the interaction variable FITSTRENGTH*CONSDUM has a significant higher level than we have observed in the past sections. Taking the average value of all FITSTRENGTH observations that coincide with CONSDUM (51) and multiplying that value with the coefficient we find that the average impact of a sustainable feed-in tariff on the development of PVSHARE in a country is about 0.36%. In section 1 we found that the maximum impact of the strongest feed-in tariff was 0.37%. Model 15 shows that the strongest (still sustainable) feed in tariff can have a maximum impact of 0.45% (65*0.00699). As a consequence, the earlier made conclusion should be modified as follows: a sustainable feed-in tariff has a bigger impact on the development of a PV-industry than a very strong but unsustainable feed-in tariff.

Nevertheless one critical note needs to be placed: as we have seen in our data-chapter, the biggest increase of PVSHARE occurred in 2011, a year with on average more feed-in tariffs with strength in the range 35-65 (Figure 11). However PVSHARE has the shortcoming that it displays growth with a certain time-delay so that this growth might be coincidentally explained by somewhat lower feed-in tariffs but actually result from 2010's stronger feed-in tariffs.

Further research is desirable to measure the added value of other policy-consistency measures; mainly to get an eye on the impact of the presence of feed-in tariffs in the past or future. The above proven added value of one consistency-indicator is hopefully a motivation for others to consider doing more extensive research on the role of policy-consistency.

5.5 Impact of CO2 emissions and non-conventional electricity shares

	BASE 2	16	17	18	19	20
FITSTRENGTH	0.00359 ***	0.00361 ***	0.00358 ***	0.00357 ***	0.00331 ***	0.00205 ***
CO2EMCAP		0.00255				
NUCLDUM			0.04335			
NUCLSHARE					-0.01705 ***	-0.00833 ***
COMBSHARE				-0.00095		-0.00162 **
GDPcap	-0.00010 ***	-0.00010 ***	-0.00010 ***	-0.00010 ***	-0.00010 ***	-0.00011 ***
GDPcap^2 (x 1.000.000)	0.00110 ***	0.00111 ***	0.00110 ***	0.00114 ***	0.00113 ***	0.00129 ***
LIFEEXP	-0.06203 ***	-0.06318 ***	-0.06224 ***	-0.05943 ***	-0.06063 ***	-0.04796 **
OPENNES	0.00066	0.00071	0.00064	0.00062	0.00094	0.00084
POPDENS	0.00096	0.00102	0.00097	0.00096	0.00066	0.00062
ENERGYIM	-0.00013	-0.00015	-0.00013	-0.00008	-0.00040	-0.00020
ELECCAP	0.33794 ***	0.33679 ***	0.33782 ***	0.33907 ***	0.30744 ***	0.30728 ***
ELECPRICEHH	0.00138 ***	0.00139 ***	0.00139 ***	0.00136 ***	0.00159 ***	0.00152 ***
Trend	0.02281 ***	0.02307 ***	0.02293 ***	0.02236 ***	0.02271 ***	0.02055 ***
Fixed effects	YES	YES	YES	YES	YES	YES
N	660	660	660	660	660	660
R^2	0.35	0.35	0.35	0.35	0.37	0.38

Note: *, ** and *** stand for the significance of a variable for respectively 10%, 5% and 1%

Table 19 Impact analysis for CO2 emissions and Combustible and Nuclear share

Not every government implements favourable policies to stimulate renewable energy sources. One reason for a lack of support can be the strong presence of specific non-conventional electricity sources. Besides that there can be environment related aspects like the emission of greenhouse gases that have its influence on the development of PV solar. In this section we will take both factors into account.

Model 16 includes a variable for CO_2 emissions per capita. It turns out that it has no impact on a countries' PVSHARE. This finding is in contrast with the negative and statistically significant relationship that has been found by Marques et al (2010). Their result could be a consequence of endogeneity. If the share of PV in a country increases significantly, CO_2

emissions will decrease accordingly. For this reason, CO_2 emissions are not included in the base model.

Based on model 17-20, we find a negative and significant relationship between the share of nuclear energy in a countries' electricity-mix and its development of PV. This finding is interpretable in two ways, it can be either a consequence of the stronger position of the conventional-electricity lobby, or alternatively the larger nuclear share reduces the wholesale price of electricity which affects PV's competitive position. The latter argument is used by Jenner et al (2012) to explain this relation in their paper.

In contrast, the share of combustible fuels (coal, oil and natural gas) has no relationship with our dependent variable PVSHARE. Although its sign is negative as expected, the coefficient is insignificant. An exception is model 20, here both COMBSHARE and NUCLSHARE are significant. Surprisingly the coefficient of FITSTRENGTH is affected; it is hard to draw conclusions from this model since high correlation exists between NUCLSHARE and COMBSHARE.

Summarized, the main finding of this section is the significant negative impact that the share of nuclear electricity generation has on the development of PV. The higher a countries' nuclear electricity usage, the lower the perspective for the PV-industry to develop.

5.6 Does corruption inhibit PV development?

This section of the empirical study addresses the role of corruption. The most common idea is that corruption hinders the development of the PV-industry. However, model 21 shows the opposite effect[9]. Higher corruption stimulates the development of the PV-industry. To check if this interpretation is correct, we have substituted the corruption indicator by three dummy variables; CORRLOW for below average corruption levels, CORRMED for medium corruption levels and CORRHIGH for above average levels of corruption. The results are in line with our earlier result, it turns out that feed-in tariffs in countries with relative high levels of corruption are more effective than in countries with low levels of corruption. If we make a quick analysis on the relation between countries which are in the top 10 of worldwide PV markets and their corruption ranking we find that it is not at all a very remarkable finding. Czech Republic, Greece, Spain, Italy, Belgium and France all have above average levels of corruption. It can be a coincidence that countries with higher levels of corruption do stimulate PV more than others. It could be a coincidence, but there seems reason to assume that there is a positive relation between solar irradiation and corruption. Mainly the countries with low

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[9] An important note to interpret the coefficients in Table 20 correctly is that the higher the level of CORR, the lower a countries' corruption.

levels of solar irradiation and also no real development of the PV-industry have low corruption levels (Sweden, Finland, Denmark, Netherlands, Ireland, UK). Summarized we find empirical proof that corruption does not hinder the development of the PV-industry, countries with above average corruption are more effective in the promotion of PV. It should be kept in mind, however, that there are countries in the world that have far more corruption than countries in our data set. It could be the case that if corruption is very high, it would hinder the development of PV.

	BASE 2	**21**	**22**	**23**	**24**
FITSTRENGTH	0.00359 ***	0.00388 ***	0.00358 ***	0.00305 ***	0.00408 ***
CORR		-0.13036 ***			
FITSTRENGTH*CORRLOW					-0.00385 **
FITSTRENGTH*CORRMED			0.00001		
FITSTRENGTH*CORRHIGH				0.00230 *	
GDPcap	-0.00010 ***	-0.00010 ***	-0.00010 ***	-0.00009 ***	-0.00009 ***
GDPcap^2 (x 1.000.000)	0.00110 ***	0.00111 ***	0.00110 ***	0.00105 ***	0.00107 ***
LIFEEXP	-0.06203 ***	-0.06149 ***	-0.06203 ***	-0.05939 ***	-0.05464 ***
OPENNES	0.00066	0.00068	0.00066	0.00066	0.00080
POPDENS	0.00096	0.00096	0.00096	0.00111	0.00132
ENERGYIM	-0.00013	-0.00014	-0.00013	-0.00012	-0.00016
ELECCAP	0.33794 ***	0.33930 ***	0.33797 ***	0.32833 ***	0.33093 ***
ELECPRICEHH	0.00138 ***	0.00140 ***	0.00139 ***	0.00135 ***	0.00137 ***
Trend	0.02281 ***	0.02270 ***	0.02280 ***	0.02134 ***	0.02006 ***
Fixed effects	YES	YES	YES	YES	YES
N	660	660	660	660	660
R^2	0.35	0.37	0.35	0.35	0.36

Note: *, ** and *** stand for the significance of a variable for respectively 10%, 5% and 1%

Table 20 Measuring the effect of corruption

5.7 Natural logarithm of PV added capacity as dependent variable

As a sensitivity analysis we replace PVSHARE as dependent variable by LNPVADDCAP, the natural logarithm of PV added capacity. This dependent variable is also used by Jenner (2012) and Jenner et al (2012). Table 21 shows the outcome. Due to the fact that the dependent variable is replaced, the coefficients of the different explanatory variables are not comparable with our base model. Nevertheless we can compare the sign and significance. Fortunately FITSTRENGTH is still strongly significant and of positive impact on the development of yearly added PV capacity. This is important since this result proofs that our FITSTRENGTH indicator is robust. This underlines our conclusion that the presence of feed-in tariffs has contributed to the development of the PV-industry. The most surprising change of table 13 is that the relation of PV-industry development with the electricity price turned negative. It is hard to explain this specific result. Besides that coefficients of OPENNES and POPDENS are now significant as well. All together our model seems to explain a remarkably high percentage of the development in LNPVADDCAP. It is hard to draw further conclusions from this outcome; most important is that we still find a comparably strong relation between the dependent variable and our FITSTRENGTH indicator.

	Base 2	LNPVADDCAP
FITSTRENGTH	0.00359 ***	0.05139 ***
GDPcap	-0.00010 ***	-0.00023 ***
GDPcap^2 (x 1.000.000)	0.00110 ***	0.00255 ***
LIFEEXP	-0.06203 ***	-0.19110 ***
OPENNES	0.00066	-0.00595 **
POPDENS	0.00096	0.00901 **
ENERGYIM	-0.00013	0.00247
ELECCAP	0.33794 ***	0.57383 ***
ELECPRICEHH	0.00138 ***	-0.00232 **
Trend	0.02281 ***	0.12273 ***
Fixed effects	YES	YES
N	660	630
R^2	0.35	0.79

Note: *, ** and *** stand for the significance of a variable for respectively 10%, 5% and 1%

Table 21 Replacing the dependent variable

5.8 The value of including lagged FiT measures

As discussed in paragraph 3.2, a shortcoming of using PV's share of electricity generation as dependent variable is that the effect of a feed-in tariff in one year might be only partly observable in that year. To control for this delayed effect of FITSTRENGTH on PVSHARE we perform a last sensitivity analysis by including lagged FITSTRENGTH variables. Table 20 shows the results. In model 25 only FITSTRENGTH (-1) is included, not surprisingly correlation is harming the coefficients of the two FiT variables such that it is hard to measure the actual source of the positive relation. However the sum of the two coefficients is with 0.00561 more than 50% higher than the coefficient of FITSTRENGTH in our base model. In model 26 we add the lagged FITSTRENGTH variable of two years ago. Surprisingly is that the impact of FITSTRENGTH(-1) is for a big part taken over by FITSTRENGTH(-2). But we have to keep in mind that as a consequence of correlation it is hard to distinguish the three effects. Nevertheless, the summed effect of the three variables has become even higher with 0.00785 which can be translated to a maximum average impact of 0.64%.

Most important is that the effect of FITSTRENGTH remains robust. However, if we assume that it this correction is needed, the maximum impact might be even higher than we have measured so far.

	Base 2	25	26
FITSTRENGTH	0.00359 ***	-0.00484 ***	-0.00436 ***
FITSTRENGTH (-1)		0.01045 ***	0.00284 *
FITSTRENGTH (-2)			0.00937 ***
GDPcap	-0.00010 ***	-0.00010 ***	-0.00009 ***
GDPcap^2 (x 1.000.000)	0.00110 ***	0.00110 ***	0.00107 ***
LIFEEXP	-0.06203 ***	-0.06362 ***	-0.06763 ***
OPENNES	0.00066	0.00075	0.00077
POPDENS	0.00096	0.00083	0.00091
ENERGYIM	-0.00013	-0.00015	-0.00014
ELECCAP	0.33794 ***	0.31516 ***	0.30029 ***
ELECPRICEHH	0.00138 ***	0.00113 ***	0.00093 ***
Trend	0.02281 ***	0.02385 ***	0.02478 ***
Fixed effects	YES	YES	YES
N	660	630	600
R^2	0.35	0.43	0.48

Note: *, ** and *** stand for the significance of a variable for respectively 10%, 5% and 1%

Table 22 Results including lagged FITSTRENGTH variable

5.9 Main conclusions from empirical study

The main conclusions from our empirical study are:

- There exists a strong positive relation between the presence of a feed-in tariff and the development of a countries' share of PV in the electricity-mix. The average impact can reach up to 0.45%.
- Assuming that there is a need to correct for bias in the FITSTRENGTH coefficient as a consequence of delayed impact on PVSHARE, the effect can even reach up to 0.64%.
- A sustainable feed-in tariff has a bigger impact on the development of a PV-industry than a very strong but unsustainable feed-in tariff.
- From the different FiT design features, contract duration is the most important contributor to the significant impact of FITSTRENGTH.
- The higher the investments in RD&D the more effective the deployment of the PV-sector.
- Countries with a combined policy of RD&D investments and a feed-in tariff experience stronger PV-industry growth than countries with solely a feed-in tariff as policy incentive.
- The higher a countries' electricity price the higher the share of PV in the electricity mix.
- Although the general impact of GDP per capita is negative we can conclude that from a level of 40,000 euro per inhabitant the wealthier a country is the higher the relative investments in PV are.
- Larger electricity markets are more able to effectively support the development of PV.
- The higher a countries' nuclear electricity usage, the lower the perspective for the PV-industry to develop.
- Feed-in tariffs in countries with relative high levels of corruption are more effective in promoting PV development than countries with low levels of corruption.
- Replacing the dependent variable PVSHARE by the natural logarithm of PV added capacity does not harm our earlier drawn conclusions; FITSTRENGTH here remains strongly related to the dependent variable.

6. Conclusion

6.1 Main conclusions

The main question addressed in this thesis is whether feed-in tariff policies have been effective in the development of PV Solar, explicitly taking into account structure and consistency of feed-in tariff policies.

Combining several existing studies gives a good overview of potential influences on the growth that the PV-industry has experienced in the last two decades. These drivers can be categorized in four groups: political factors, technology and scale effects, policy instruments and country-specific factors. Focusing on policy instruments there are a few econometric studies that asses the effectiveness of feed-in tariffs in developing the PV-industry from which Jenner et al (2012) is the most notable. A general shortcoming of the existing literature is that both FiT-structure and policy-consistency are not taken into account in an empirical or quantitative way. This paper tends to fill that gap.

Two new indicators are composed: one to get an eye on the role of consistency of feed-in tariffs (CONSAVER). The other is formed to perform a rigorous analysis on the effectiveness of FiTs (FITSTRENGTH); it is based on six separate design features to be able to analyse the relative impact of these features on PV development as well.

A feed-in tariff is considered to effectively support the development of the PV-industry if PV gains share in the electricity-mix of a country. So the share of PV in the electricity-mix of a country is selected as dependent variable. Panel data is gathered over the period 1990-2011. A macro-level approach is chosen for 30 OECD countries. The pooled least squares method is used for the empirical analysis. We control for heterogeneity and omitted variable bias by applying cross-section fixed effects. Additionally, a country-specific linear and non-linear time-trend is included to correct for autonomous technological developments.

We find a strong positive relation between the presence of a feed-in tariff and the development of a countries' share of PV in the electricity-mix. This conclusion is robust as comparable results are found in many different sensitivity analyses. The average impact can reach up to 0.45%. However, if we assume that there is a need to correct for bias in the coefficient of FITSTRENGTH as a consequence of delayed impact on PVSHARE, the effect may reach up to an average of 0.64%. The most important contributing FiT design feature in this relation is contract duration.

Since the composed consistency indicator cannot be included in interaction with the FiT strength indicator due to collinearity bias, we replace CONSAVER by a binary variable that measures the sustainability of a feed-in tariff (CONSDUM). It turns out that a sustainable feed-in tariff has a bigger impact on the development of a PV-industry than a very strong but unsustainable feed-in tariff.

Furthermore we find some evidence for a positive relation between PV development and governmental RD&D investments. Additionally, countries with a combined policy of RD&D investments and a feed-in tariff experience stronger development than countries with solely a feed-in tariff as policy incentive. We found no evidence that calls for tender, investment and tax incentives and net metering policies have contributed to the development of the PV-industry.

Other drivers that are found to have a positive effect are electricity price, electricity capacity per capita and corruption. The latter is a surprise; corruption is expected to have a negative impact but it turns out that the PV-industry is more effective developed in countries with higher levels of corruption. However, this could be a result based on coincidence. Countries with a higher share of nuclear electricity experience as expected lower PV-industry growth.

The wealth-indicator GDP per capita has an impact that is in line with the Kuznets literature. Developing countries do not invest in PV unto a certain point in their industrialisation, but once a country reaches a certain income level, this trend reverses. The wealthier a country is the higher the relative investments in PV from this point on.

Our results are generally in line with the existing literature. A contribution is made by composing the FiT strength indicator, composed of six separate design feature, which resulted to be effective in developing the PV-industry. Additional important findings are the role of contract duration and policy-sustainability.

6.2 Limitations

The existing literature lacks analyses of individual FiT design features. This paper fills this gap, but not without obstacles. A shortcoming of the chosen approach is that it is hard to determine the relative proportions between the impact of one design feature compared to the other. The chosen proportions are based on personal calculations and knowledge; it can be considered as an educated guess although the given proportions remain somewhat subjective.

Part of the goal of this research was to perform a detailed analysis on the contribution of policy consistency to the effectiveness of feed-in tariffs. But we have not been able to address the role of consistency adequately. Mainly caused by correlation issues between our consistency and feed-in tariff indicator. As a consequence the coefficient of the interaction variable to measure the added value of consistent policy enactment to the effectiveness of a FiT is affected by collinearity bias.

A shortcoming of using PV’s share of electricity generation as dependent variable is that the effect of a feed-in tariff in one year might be only partly observable in that year. Generation starts from the moment that the project is completed, which can be late in the year so that the effect is only fully observable in the year after. As a consequence the coefficients of our FiT-measures might be biased. Our sensitivity analysis with a lagged FITSTRENGTH variable deals with part of this shortcoming. Still uncertain is the actual impact of FITSTRENGTH, it might be somewhere in between.

For three of the four non-FiT policies we have included binary variables. These binary variables have one shortcoming: the differences in strength of these policies are not captured.

The last limitation of this paper is related to the availability of data. Several variables lacked data for the year 2011. A consequence of including 2011 in our empirical study is that some variables have been manually extended and therefore may deviate from reality; this could have caused bias to our results.

6.3 Suggestions for further research

While this paper is a first step in the right direction, more research is needed on the role of policy-consistency. More empirical proof is needed to test whether governments can save money by implementing less strong but consistent policies. Additionally it can be assumed that policy instruments that have been in place in the past may produce after-effects in consecutive years without policies. It can be relevant to take these effects into account to make a complete policy cost-benefit analysis.

It can be helpful for governments to understand better what the optimal structure of a policy is. More research to the relative impact of each design features can contribute. Additionally there is a lack of research to the cost effectiveness of implemented feed-in tariffs. The benefits of feed-in tariffs are clear, but what is the actual cost of these policies? More transparency about this is required to complete the cost-benefit analysis.

At last, where this paper contributes by analysing the effectiveness of feed-in tariffs more rigorous research is needed on the effectiveness of other not-FiT policies. Subsequently the same detailed analyses have to be expanded to other renewable technologies.

7. References

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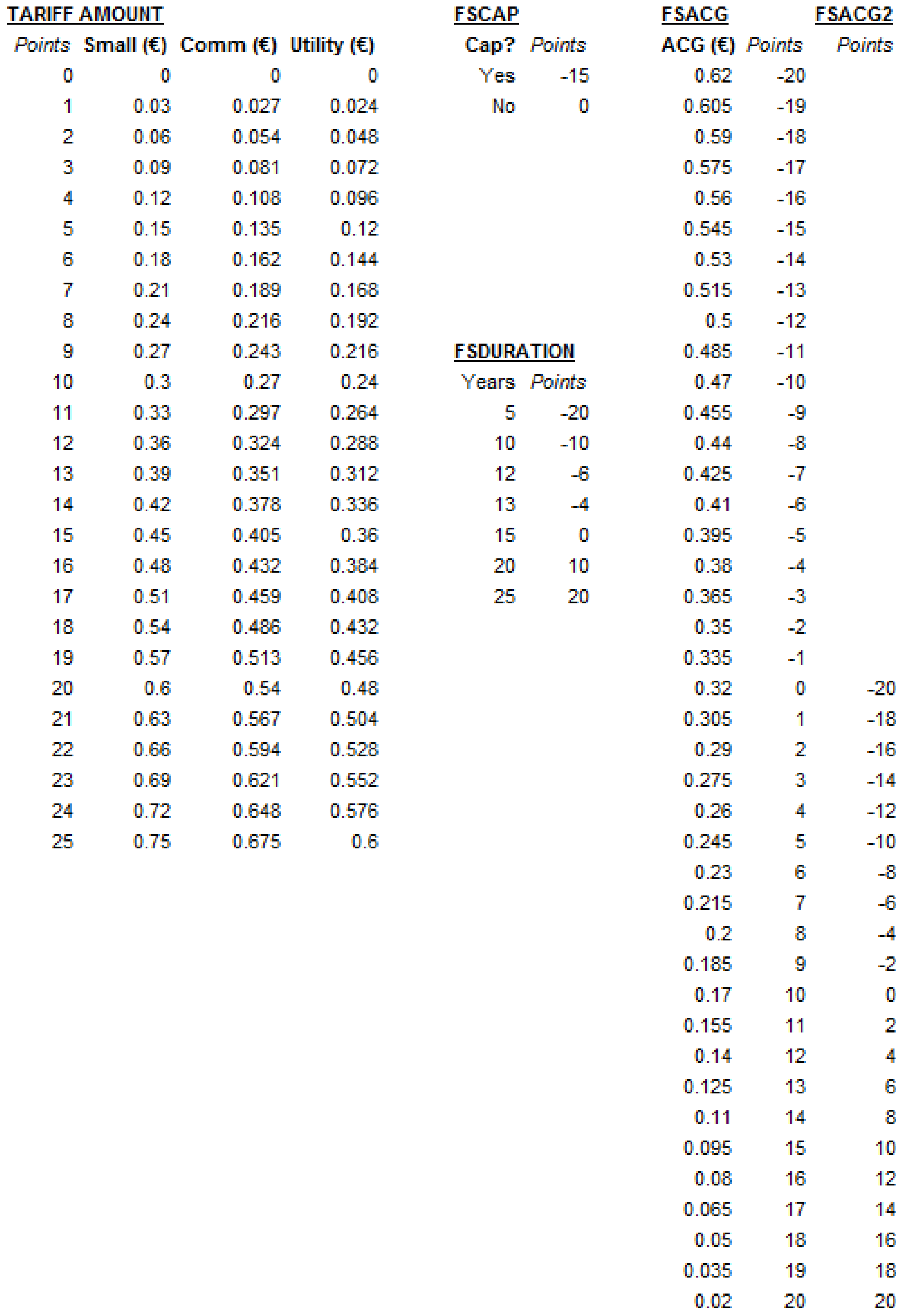
8. Appendix



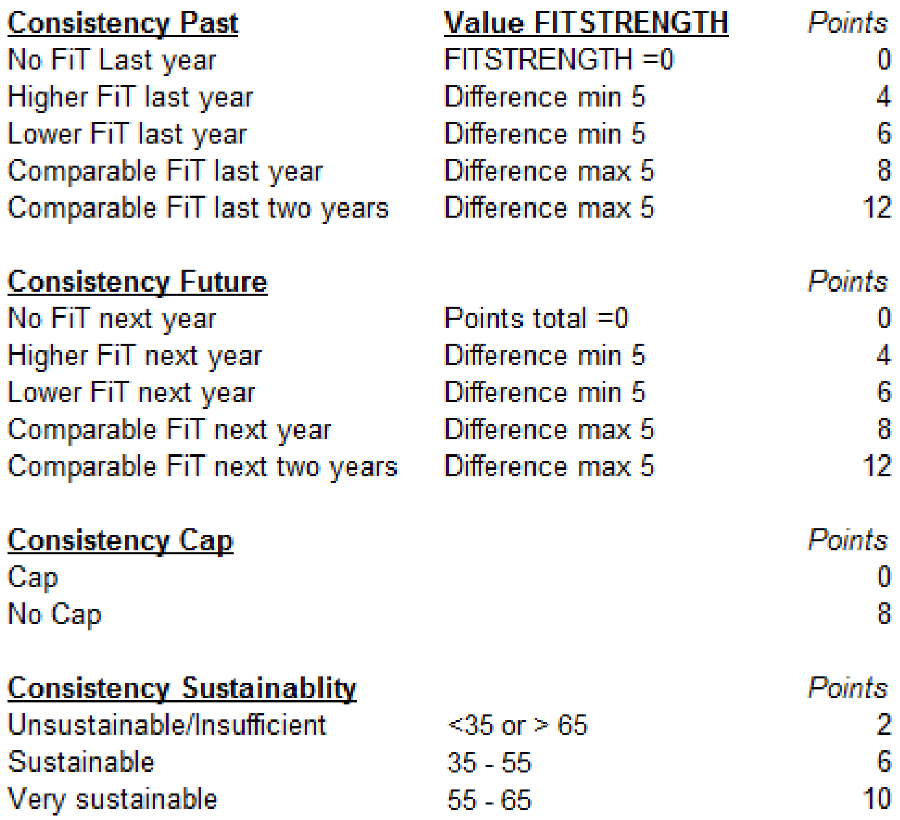
TARIFF AMOUNT			
Points	**Small (€)**	**Comm (€)**	**Utility (€)**
0	0	0	0
1	0.03	0.027	0.024
2	0.06	0.054	0.048
3	0.09	0.081	0.072
4	0.12	0.108	0.096
5	0.15	0.135	0.12
6	0.18	0.162	0.144
7	0.21	0.189	0.168
8	0.24	0.216	0.192
9	0.27	0.243	0.216
10	0.3	0.27	0.24
11	0.33	0.297	0.264
12	0.36	0.324	0.288
13	0.39	0.351	0.312
14	0.42	0.378	0.336
15	0.45	0.405	0.36
16	0.48	0.432	0.384
17	0.51	0.459	0.408
18	0.54	0.486	0.432
19	0.57	0.513	0.456
20	0.6	0.54	0.48
21	0.63	0.567	0.504
22	0.66	0.594	0.528
23	0.69	0.621	0.552
24	0.72	0.648	0.576
25	0.75	0.675	0.6

FSCAP	
Cap?	*Points*
Yes	-15
No	0

FSDURATION	
Years	*Points*
5	-20
10	-10
12	-6
13	-4
15	0
20	10
25	20

FSACG		FSACG2
ACG (€)	*Points*	*Points*
0.62	-20	
0.605	-19	
0.59	-18	
0.575	-17	
0.56	-16	
0.545	-15	
0.53	-14	
0.515	-13	
0.5	-12	
0.485	-11	
0.47	-10	
0.455	-9	
0.44	-8	
0.425	-7	
0.41	-6	
0.395	-5	
0.38	-4	
0.365	-3	
0.35	-2	
0.335	-1	
0.32	0	-20
0.305	1	-18
0.29	2	-16
0.275	3	-14
0.26	4	-12
0.245	5	-10
0.23	6	-8
0.215	7	-6
0.2	8	-4
0.185	9	-2
0.17	10	0
0.155	11	2
0.14	12	4
0.125	13	6
0.11	14	8
0.095	15	10
0.08	16	12
0.065	17	14
0.05	18	16
0.035	19	18
0.02	20	20

Table A1 Detailed overview of points assigning per FiT measure



Consistency Past	Value FITSTRENGTH	Points
No FiT Last year	FITSTRENGTH =0	0
Higher FiT last year	Difference min 5	4
Lower FiT last year	Difference min 5	6
Comparable FiT last year	Difference max 5	8
Comparable FiT last two years	Difference max 5	12

Consistency Future		Points
No FiT next year	Points total =0	0
Higher FiT next year	Difference min 5	4
Lower FiT next year	Difference min 5	6
Comparable FiT next year	Difference max 5	8
Comparable FiT next two years	Difference max 5	12

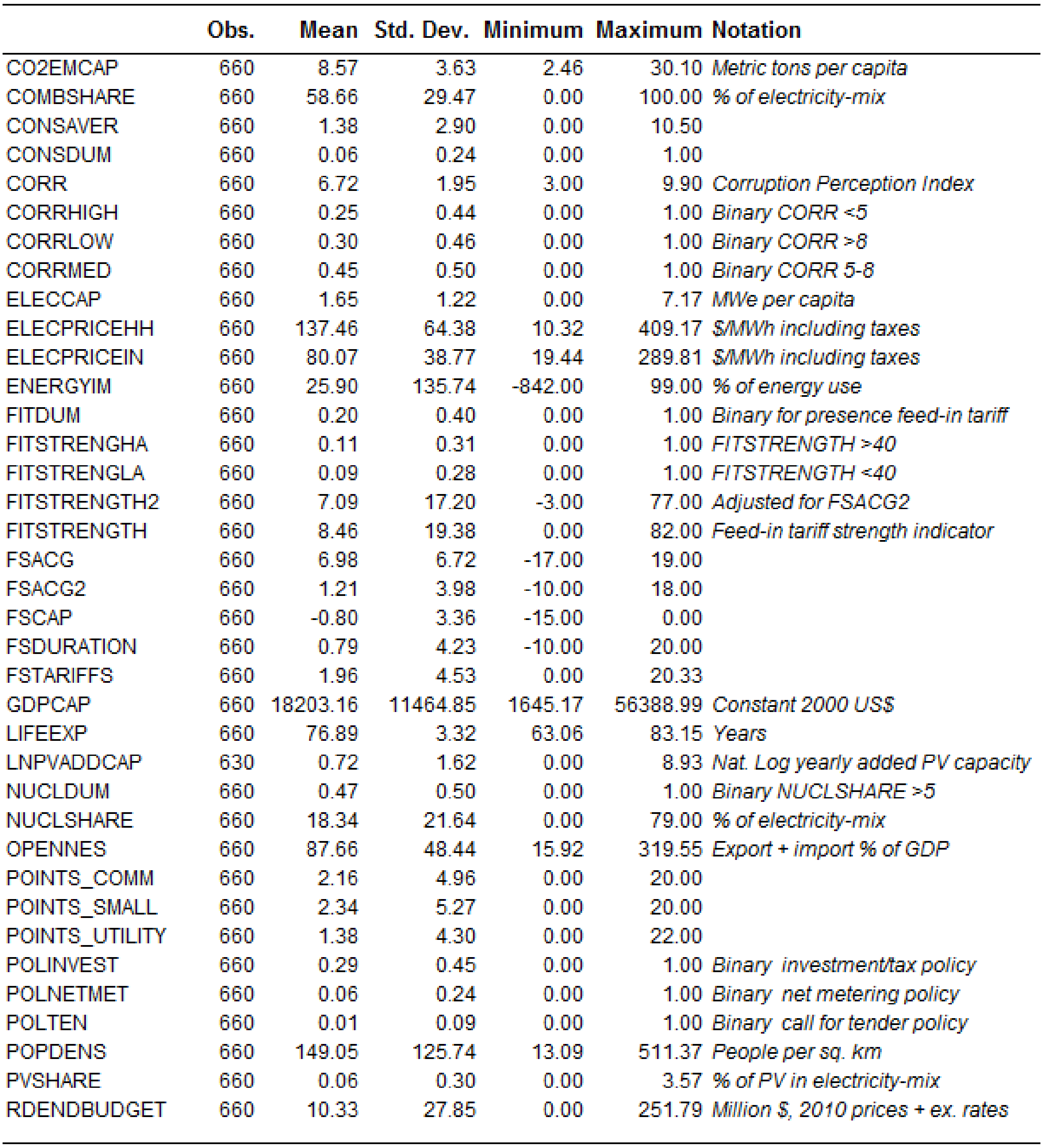
Consistency Cap		Points
Cap		0
No Cap		8

Consistency Sustainablity		Points
Unsustainable/Insufficient	<35 or > 65	2
Sustainable	35 - 55	6
Very sustainable	55 - 65	10

Table A2 Detailed overview of points assigning per consistency measure

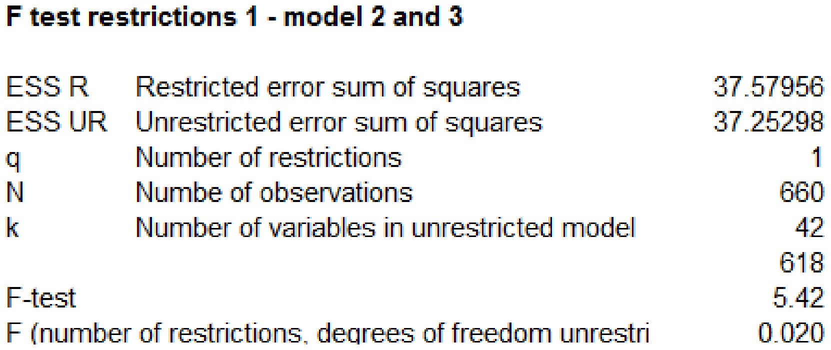
	CO2EMCAP	COMPSHARE	CONSAVER	CONSDUM	CORR	CORRHIGH	CORRLOW	CORRMED	ELECPCAP11	ELECPRICEHH	ELECPRICEIN	ENERGYIM	FITDUM	FITSTRENGHA	FITSTRENGLA	FITSTRENGT2	FITSTRENGTH	FSACG	FSACG2	FSCAP	FSDURATION	FSTARIFFS	GDPCAP	LIFEEXP	LNPVADDCAP	NUCLDUM	NUCLSHARE	OPENNESS	POINTS_COMM	POINTS_SMALL	POINTS_UTILITY	POLINVEST	POLNETMET	POLTEN	POPDENS	PVSHARE	RDENDBUDGET
CO2EMCAP	1.00	0.21	0.09	0.03	-0.12	0.13	-0.06	0.00	0.22	0.10	-0.03	0.04	0.07	0.03	0.07	0.01	0.03	-0.25	-0.05	0.05	-0.06	0.03	0.44	0.12	0.03	-0.06	-0.13	0.62	0.02	0.01	0.06	0.21	0.04	-0.06	0.23	0.10	0.06
COMPSHARE	0.21	1.00	0.05	0.03	-0.05	-0.01	-0.03	0.14	-0.42	0.05	0.13	0.32	0.05	-0.01	0.08	-0.01	0.00	0.15	0.03	-0.03	0.01	-0.01	-0.29	-0.24	0.03	-0.41	-0.55	0.04	-0.01	-0.02	0.01	0.08	0.14	0.04	0.25	0.02	0.01
CONSAVER	0.09	0.05	1.00	0.44	-0.05	0.01	-0.13	0.14	0.00	0.39	0.41	0.10	0.97	0.74	0.56	0.85	0.90	0.38	0.46	-0.33	0.37	0.88	0.04	0.27	0.59	0.07	0.06	0.16	0.88	0.89	0.69	0.35	0.18	0.10	0.13	0.35	0.12
CONSDUM	0.03	0.03	0.44	1.00	-0.07	0.07	-0.04	-0.04	0.01	0.10	0.13	0.07	0.47	0.67	-0.06	0.51	0.50	0.26	0.54	-0.40	0.37	0.48	0.03	0.19	0.29	0.05	0.01	0.07	0.51	0.50	0.32	0.17	-0.05	0.08	0.12	0.34	-0.01
CORR	-0.12	-0.05	-0.05	-0.07	1.00	-0.78	0.67	0.07	0.28	0.19	-0.09	0.14	-0.04	-0.05	-0.01	-0.06	-0.05	-0.05	-0.09	-0.06	0.00	-0.03	0.22	0.33	0.06	0.18	0.16	-0.22	-0.05	-0.04	0.00	0.09	0.12	-0.03	0.21	-0.05	0.13
CORRHIGH	0.13	-0.01	0.01	0.07	-0.78	1.00	-0.29	-0.46	-0.11	-0.14	0.03	-0.24	0.00	0.01	-0.01	0.02	0.01	0.00	0.07	0.08	0.00	-0.02	-0.04	-0.19	-0.10	-0.23	-0.26	0.17	0.00	0.00	-0.06	-0.04	-0.08	-0.04	-0.20	0.02	-0.18
CORRLOW	-0.06	-0.03	-0.13	-0.04	0.67	-0.29	1.00	-0.46	0.26	0.03	-0.16	-0.02	-0.10	-0.12	-0.02	-0.14	-0.14	-0.08	-0.07	-0.03	-0.03	-0.14	0.11	0.08	-0.12	0.03	0.02	-0.09	-0.14	-0.12	-0.14	-0.01	0.15	-0.04	0.08	-0.09	-0.10
CORRMED	0.00	0.14	0.14	-0.04	0.07	-0.46	-0.46	1.00	-0.20	0.20	0.12	0.21	0.12	0.10	0.06	0.13	0.13	0.09	0.01	-0.03	0.06	0.14	-0.03	0.14	0.22	-0.02	0.05	-0.06	0.12	0.11	0.16	0.10	-0.02	0.05	0.07	0.09	0.27
ELECPCAP11	0.22	-0.42	0.00	0.01	0.28	-0.11	0.26	-0.20	1.00	0.09	-0.10	-0.04	0.00	0.00	0.01	-0.01	-0.01	-0.02	0.02	-0.01	0.00	-0.01	0.37	0.40	0.00	-0.01	0.01	0.09	-0.01	0.00	-0.01	0.04	0.01	0.00	-0.22	0.06	-0.01
ELECPRICEHH	0.10	0.05	0.39	0.10	0.19	-0.14	0.03	0.20	0.09	1.00	0.76	0.14	0.39	0.28	0.25	0.37	0.38	0.31	0.28	-0.14	0.21	0.36	0.49	0.55	0.44	0.02	0.03	0.08	0.36	0.37	0.26	0.35	0.45	0.05	0.25	0.32	0.32
ELECPRICEIN	-0.03	0.13	0.41	0.13	-0.09	0.03	-0.16	0.12	-0.10	0.76	1.00	0.24	0.43	0.29	0.28	0.41	0.41	0.42	0.38	-0.18	0.18	0.40	0.21	0.33	0.47	0.03	-0.01	0.04	0.41	0.42	0.26	0.32	0.34	0.11	0.23	0.26	0.34
ENERGYIM	0.04	0.32	0.10	0.07	0.14	-0.24	-0.02	0.21	-0.04	0.14	0.24	1.00	0.11	0.09	0.05	0.10	0.11	0.21	0.07	-0.07	0.05	0.11	-0.23	-0.06	0.12	0.19	0.18	0.10	0.11	0.12	0.07	0.16	0.01	0.03	0.24	0.07	0.08
FITDUM	0.07	0.05	0.97	0.47	-0.04	0.00	-0.10	0.12	0.00	0.39	0.43	0.11	1.00	0.69	0.65	0.82	0.88	0.40	0.53	-0.48	0.36	0.88	0.05	0.29	0.57	0.06	0.05	0.17	0.89	0.90	0.65	0.33	0.19	0.12	0.15	0.35	0.10
FITSTRENGHA	0.03	-0.01	0.74	0.67	-0.05	0.01	-0.12	0.10	0.00	0.28	0.29	0.09	0.69	1.00	-0.09	0.93	0.91	0.31	0.51	-0.33	0.71	0.87	0.07	0.29	0.66	0.18	0.14	0.05	0.82	0.79	0.83	0.32	0.11	0.11	0.15	0.43	0.11
FITSTRENGLA	0.07	0.08	0.56	-0.06	-0.01	-0.01	-0.02	0.06	0.01	0.25	0.28	0.05	0.65	-0.09	1.00	0.16	0.26	0.23	0.20	-0.32	-0.25	0.30	-0.01	0.09	0.09	-0.11	-0.08	0.19	0.36	0.42	0.02	0.11	0.14	0.05	0.05	0.03	0.02
FITSTRENGT2	0.01	-0.01	0.85	0.51	-0.06	0.02	-0.14	0.13	-0.01	0.37	0.41	0.10	0.82	0.93	0.16	1.00	0.99	0.37	0.59	-0.36	0.68	0.95	0.06	0.32	0.74	0.17	0.13	0.04	0.92	0.90	0.86	0.36	0.18	0.14	0.15	0.46	0.14
FITSTRENGTH	0.03	0.00	0.90	0.50	-0.05	0.01	-0.14	0.13	-0.01	0.38	0.41	0.11	0.88	0.91	0.26	0.99	1.00	0.37	0.54	-0.38	0.64	0.97	0.06	0.32	0.72	0.16	0.12	0.07	0.94	0.92	0.86	0.37	0.18	0.13	0.15	0.44	0.14
FSACG	-0.25	0.15	0.38	0.26	-0.05	0.00	-0.08	0.09	-0.02	0.31	0.42	0.21	0.40	0.31	0.23	0.37	0.37	1.00	0.39	-0.24	0.20	0.35	-0.07	0.33	0.34	-0.08	-0.09	0.00	0.36	0.37	0.25	0.24	0.14	0.10	0.09	0.22	0.09
FSACG2	-0.05	0.03	0.46	0.54	-0.09	0.07	-0.07	0.01	0.02	0.28	0.38	0.07	0.53	0.51	0.20	0.59	0.54	0.39	1.00	-0.45	0.40	0.47	0.04	0.26	0.49	0.00	-0.01	0.01	0.47	0.52	0.31	0.12	0.10	0.16	0.09	0.43	0.07
FSCAP	0.05	-0.03	-0.33	-0.40	-0.06	0.08	-0.03	-0.03	-0.01	-0.14	-0.18	-0.07	-0.48	-0.33	-0.32	-0.36	-0.38	-0.24	-0.45	1.00	-0.35	-0.46	-0.06	-0.24	-0.34	0.01	0.05	0.01	-0.49	-0.52	-0.27	-0.12	-0.14	-0.17	-0.19	-0.23	-0.02
FSDURATION	-0.06	0.01	0.37	0.37	0.00	0.00	-0.03	0.06	0.00	0.21	0.18	0.05	0.36	0.71	-0.25	0.68	0.64	0.20	0.40	-0.35	1.00	0.52	0.08	0.25	0.53	0.15	0.10	-0.09	0.47	0.42	0.58	0.13	0.20	0.14	0.12	0.41	0.06
FSTARIFFS	0.03	-0.01	0.88	0.48	-0.03	-0.02	-0.14	0.14	-0.01	0.36	0.40	0.11	0.88	0.87	0.30	0.95	0.97	0.35	0.47	-0.46	0.52	1.00	0.05	0.31	0.70	0.16	0.12	0.07	0.98	0.96	0.86	0.39	0.16	0.13	0.17	0.39	0.14
GDPCAP	0.44	-0.29	0.04	0.03	0.22	-0.04	0.11	-0.03	0.37	0.49	0.21	-0.23	0.05	0.07	-0.01	0.06	0.06	-0.07	0.04	-0.06	0.08	0.05	1.00	0.68	0.24	0.06	0.04	0.23	0.05	0.07	0.02	0.34	0.16	0.02	0.23	0.15	0.36
LIFEEXP	0.12	-0.24	0.27	0.19	0.33	-0.19	0.08	0.14	0.40	0.55	0.33	-0.06	0.29	0.29	0.09	0.32	0.32	0.33	0.26	-0.24	0.25	0.31	0.68	1.00	0.42	0.11	0.10	-0.05	0.31	0.33	0.23	0.45	0.19	0.11	0.24	0.22	0.34
LNPVADDCAP	0.03	0.03	0.59	0.29	0.06	-0.10	-0.12	0.22	0.00	0.44	0.47	0.12	0.57	0.66	0.09	0.74	0.72	0.34	0.49	-0.34	0.53	0.70	0.24	0.42	1.00	0.23	0.11	-0.13	0.65	0.64	0.68	0.49	0.13	0.11	0.33	0.54	0.58
NUCLDUM	-0.06	-0.41	0.07	0.05	0.18	-0.23	0.03	-0.02	-0.01	0.02	0.03	0.19	0.06	0.18	-0.11	0.17	0.16	-0.08	0.00	0.01	0.15	0.16	0.06	0.11	0.23	1.00	0.87	-0.06	0.12	0.09	0.24	0.15	-0.12	-0.04	0.23	0.09	0.25
NUCLSHARE	-0.13	-0.55	0.06	0.01	0.16	-0.26	0.02	0.05	0.01	0.03	-0.01	0.18	0.05	0.14	-0.08	0.13	0.12	-0.09	-0.01	0.05	0.10	0.12	0.04	0.10	0.11	0.87	1.00	0.00	0.09	0.08	0.17	0.10	-0.06	0.00	0.19	0.00	0.14
OPENNESS	0.62	0.04	0.16	0.07	-0.22	0.17	-0.09	-0.06	0.09	0.08	0.04	0.10	0.17	0.05	0.19	0.04	0.07	0.00	0.01	0.01	-0.09	0.07	0.23	-0.05	-0.13	-0.06	0.00	1.00	0.08	0.07	0.03	0.01	0.07	-0.04	0.05	0.09	-0.26
POINTS_COMM	0.02	-0.01	0.88	0.51	-0.05	0.00	-0.14	0.12	-0.01	0.36	0.41	0.11	0.89	0.82	0.36	0.92	0.94	0.36	0.47	-0.49	0.47	0.98	0.05	0.31	0.65	0.12	0.09	0.08	1.00	0.97	0.75	0.38	0.15	0.13	0.14	0.36	0.10
POINTS_SMALL	0.01	-0.02	0.89	0.50	-0.04	0.00	-0.12	0.11	0.00	0.37	0.42	0.12	0.90	0.79	0.42	0.90	0.92	0.37	0.52	-0.52	0.42	0.96	0.07	0.33	0.64	0.09	0.08	0.07	0.97	1.00	0.70	0.41	0.15	0.14	0.15	0.34	0.13
POINTS_UTILITY	0.06	0.01	0.69	0.32	0.00	-0.06	-0.14	0.16	-0.01	0.26	0.26	0.07	0.65	0.83	0.02	0.86	0.86	0.25	0.31	-0.27	0.58	0.86	0.02	0.23	0.68	0.24	0.17	0.03	0.75	0.70	1.00	0.30	0.15	0.10	0.19	0.39	0.16
POLINVEST	0.21	0.08	0.35	0.17	0.09	-0.04	-0.01	0.10	0.04	0.35	0.32	0.16	0.33	0.32	0.11	0.36	0.37	0.24	0.12	-0.12	0.13	0.39	0.34	0.45	0.49	0.15	0.10	0.01	0.38	0.41	0.30	1.00	0.19	0.04	0.32	0.17	0.43
POLNETMET	0.04	0.14	0.18	-0.05	0.12	-0.08	0.15	-0.02	0.01	0.45	0.34	0.01	0.19	0.11	0.14	0.18	0.18	0.14	0.10	-0.14	0.20	0.16	0.16	0.19	0.13	-0.12	-0.06	0.07	0.15	0.15	0.15	0.19	1.00	0.06	0.20	0.03	0.03
POLTEN	-0.06	0.04	0.10	0.08	-0.03	-0.04	-0.04	0.05	0.00	0.05	0.11	0.03	0.12	0.11	0.05	0.14	0.13	0.10	0.16	-0.17	0.14	0.13	0.02	0.11	0.11	-0.04	0.00	-0.04	0.13	0.14	0.10	0.04	0.06	1.00	0.06	-0.01	0.03
POPDENS	0.23	0.25	0.13	0.12	0.21	-0.20	0.08	0.07	-0.22	0.25	0.23	0.24	0.15	0.15	0.05	0.15	0.15	0.09	0.09	-0.19	0.12	0.17	0.23	0.24	0.33	0.23	0.19	0.05	0.14	0.15	0.19	0.32	0.20	0.06	1.00	0.08	0.39
PVSHARE	0.10	0.02	0.35	0.34	-0.05	0.02	-0.09	0.09	0.06	0.32	0.26	0.07	0.35	0.43	0.03	0.46	0.44	0.22	0.43	-0.23	0.41	0.39	0.15	0.22	0.54	0.09	0.00	0.09	0.36	0.34	0.39	0.17	0.03	-0.01	0.08	1.00	0.17
RDENDBUDGET	0.06	0.01	0.12	-0.01	0.13	-0.18	-0.10	0.27	-0.01	0.32	0.34	0.08	0.10	0.11	0.02	0.14	0.14	0.09	0.07	-0.02	0.06	0.14	0.36	0.34	0.58	0.25	0.14	-0.26	0.10	0.13	0.16	0.43	0.03	0.03	0.39	0.17	1.00

Table A3 Correlation Diagram



	Obs.	Mean	Std. Dev.	Minimum	Maximum	Notation
CO2EMCAP	660	8.57	3.63	2.46	30.10	*Metric tons per capita*
COMBSHARE	660	58.66	29.47	0.00	100.00	*% of electricity-mix*
CONSAVER	660	1.38	2.90	0.00	10.50	
CONSDUM	660	0.06	0.24	0.00	1.00	
CORR	660	6.72	1.95	3.00	9.90	*Corruption Perception Index*
CORRHIGH	660	0.25	0.44	0.00	1.00	*Binary CORR <5*
CORRLOW	660	0.30	0.46	0.00	1.00	*Binary CORR >8*
CORRMED	660	0.45	0.50	0.00	1.00	*Binary CORR 5-8*
ELECCAP	660	1.65	1.22	0.00	7.17	*MWe per capita*
ELECPRICEHH	660	137.46	64.38	10.32	409.17	*$/MWh including taxes*
ELECPRICEIN	660	80.07	38.77	19.44	289.81	*$/MWh including taxes*
ENERGYIM	660	25.90	135.74	-842.00	99.00	*% of energy use*
FITDUM	660	0.20	0.40	0.00	1.00	*Binary for presence feed-in tariff*
FITSTRENGHA	660	0.11	0.31	0.00	1.00	*FITSTRENGTH >40*
FITSTRENGLA	660	0.09	0.28	0.00	1.00	*FITSTRENGTH <40*
FITSTRENGTH2	660	7.09	17.20	-3.00	77.00	*Adjusted for FSACG2*
FITSTRENGTH	660	8.46	19.38	0.00	82.00	*Feed-in tariff strength indicator*
FSACG	660	6.98	6.72	-17.00	19.00	
FSACG2	660	1.21	3.98	-10.00	18.00	
FSCAP	660	-0.80	3.36	-15.00	0.00	
FSDURATION	660	0.79	4.23	-10.00	20.00	
FSTARIFFS	660	1.96	4.53	0.00	20.33	
GDPCAP	660	18203.16	11464.85	1645.17	56388.99	*Constant 2000 US$*
LIFEEXP	660	76.89	3.32	63.06	83.15	*Years*
LNPVADDCAP	630	0.72	1.62	0.00	8.93	*Nat. Log yearly added PV capacity*
NUCLDUM	660	0.47	0.50	0.00	1.00	*Binary NUCLSHARE >5*
NUCLSHARE	660	18.34	21.64	0.00	79.00	*% of electricity-mix*
OPENNES	660	87.66	48.44	15.92	319.55	*Export + import % of GDP*
POINTS_COMM	660	2.16	4.96	0.00	20.00	
POINTS_SMALL	660	2.34	5.27	0.00	20.00	
POINTS_UTILITY	660	1.38	4.30	0.00	22.00	
POLINVEST	660	0.29	0.45	0.00	1.00	*Binary investment/tax policy*
POLNETMET	660	0.06	0.24	0.00	1.00	*Binary net metering policy*
POLTEN	660	0.01	0.09	0.00	1.00	*Binary call for tender policy*
POPDENS	660	149.05	125.74	13.09	511.37	*People per sq. km*
PVSHARE	660	0.06	0.30	0.00	3.57	*% of PV in electricity-mix*
RDENDBUDGET	660	10.33	27.85	0.00	251.79	*Million $, 2010 prices + ex. rates*

Table A4 Total overview descriptive statistics of used variables



F test restrictions 1 - model 2 and 3

ESS R	Restricted error sum of squares	37.57956
ESS UR	Unrestricted error sum of squares	37.25298
q	Number of restrictions	1
N	Numbe of observations	660
k	Number of variables in unrestricted model	42
		618
F-test		5.42
F (number of restrictions, degrees of freedom unrestri		0.020

Table A5 Restriction F-test model 2 vs. 3