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The effect of public policy on renewable energy capacity - a panel data study

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Preface

This thesis marks an end to the two years master's programme in Change and Management at Molde University College. The thesis has been conducted during the spring of 2022 and corresponds to 30 ECTS.

Writing this thesis have been rewarding, very educational, challenging and occasionally demanding. I am grateful for my friends and family who have supported and cheered me on, especially through the demanding times.

I would like to give a special thanks to my supervisors Dag Harald Claes and Andrew Muteti Musau for sharing their professional expertise and giving very good guidance and feedback throughout the entire writing process. Quick responses and being available for questions have also been very much appreciated.

Trondheim, May 2022

Pia Kristin Østeraas

Abstract

Global warming and climate change has contributed in setting development of renewable energy on the national agenda. To promote renewable energy development public policies have been extensively used by countries worldwide. It exists numerous policy instruments to promote renewable energy development, hence assessing the effectiveness of these policy instrument on renewable energy is of great concern.

This study attempts to detect the effect of public policies on renewable energy capacity in megawatt using a longitudinal research design. A fixed effects model is applied to investigate the influence of renewable energy policies using a panel dataset covering 123 countries during the period 2001 – 2018. The study evaluates twelve specific renewable energy policy instruments. The analysis is carried out on specific renewable energy sources, solar, wind and bio, and on aggregated data, all renewable energy sources. Furthermore, the study aims to uncover if the effect of public policy differs across two subsamples; developed countries and countries in transition and developing countries.

The effect of renewable energy policy varies by policy instruments, renewable energy sources and subsample. The results indicates that targets and strategic planning, codes and standards and GHG emission allowances are the most significant policy instruments to grow renewable energy capacity. These policies are suggested to impact the risk structure of renewable energy projects, which consequently increases renewable energy capacity growth due to increased renewable energy investments. There is also evidence that the effect of renewable energy policies is more effective in countries in transition and developing countries than in developed countries.

Sammendrag

Global oppvarming og klimaendringer har bidratt til å sette vekst av fornybar energi på den nasjonale dagsorden. For å fremme vekst i fornybar energy har offentlig poltikk blitt omfattende brukt av land over hele verden. Det fins en rekke virkemidler som kan tas i brukt for å fremme vekst i fornybar energi. Å undersøke effekten av disse virkemidlene er derfor veldig relevant.

Denne masteroppgaven skal undersøke effekten av offentlige insentiver på fornybar energikapasitet i megawatt gjennom et longitudinelt forskningsdesign. For å undersøke effekten av fornybar energi virkemidler blir en fixed effects modell og et paneldatasett som dekker 123 land i perioden 2001 – 2018 brukt. Oppgaven evaluerer tolv spesifikke offentlige fornybar energi virkemidler. Analysen er utført på spesifikke energikilder, sol, vind og bio, og på alle fornybar energikildene samlet. Videre ønsker studien å finne ut om det er forskjell i effekten av offentlige fornybar energi virkemidler på to delutvalg; utviklede land og fremvoksende- og utviklingsland.

Effekten av fornybar energi insentiver varierer etter type virkemiddel, fornybar energi kilde og delutvalg. Resultatene indikerer at mål og strategisk planlegging, koder og standarder og klimagassutslippskvoter er virkemidler som har størst effekt på fornybar energikapasitet. Det er foreslått at disse virkemidlene påvirker risikostrukturen til fornybar energi prosjekter, og dermed øker fornybar energikapasiteten på grunn av økte investeringer i fornybar energi. Resultatene viser også at fornybar energi virkemidler har større effekt i fremvoksende- og utviklingsland enn i utviklede land.

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1.0 Introduction

1.1 Energy and climate change

In August 2021 the Intergovernmental Panel on Climate Change (IPCC) released its sixth assessment report on climate change. In relation to the release of the IPCC report António Guterres, Secretary-General in the UN (United Nations), stated that the evidence in the report was a 'code red for humanity' and that urgent measures must be taken to keep the 1,5-degree target limit set in the Paris Agreement alive (UN, 2021). Both the UN and most researchers are agreeing that reduced CO_2 emission is essential for slowing down and reversing global warming. A solution for reducing CO_2 emission is to switch from fossil fuel to renewable energy (Coninck et al., 2018; Kitzing et al., 2012; Marques & Fuinhas, 2012a; Popp et al., 2011; Ritchie et al., 2020; UN, n.d.). UN states that by 2030 about half of the emission must be cut, which means that between 2020 and 2030 fossil fuel production must decline about 6 percent per year to keep global warming below 1,5-degrees (UN, n.d.). This decline in fossil fuels need to be offset by alternative energy resources to meet global energy demand.

Over the past twenty years, installed renewable energy capacity [1]has steadily increased worldwide. The world has seen the share of renewable energy capacity grow from 773 576 MW in 2001 to 2 807 264 MW in 2020, see Figure 1 (IRENA, n.d.). Especially renewable energy sources such as solar and wind have experienced a significant growth in the last few years (Wüstenhagen & Menichetti, 2012). Wind energy have had a strong growth with an average of 20 percent annual global capacity growth from 2002 to 2020. From 2013

[1] Installed energy capacity is the maximum output of electricity that a generator can produce. Energy generation, on the other hand, is the actual amount of electricity that a generator can produce. For instance, in a country solar power can account for 3 percent of installed energy capacity. Under ideal conditions, the amount of energy generated form solar power could supply 3 percent of this country's energy needs. However, the actual amount of power produced is generally not equal to installed capacity due to factors such as down time or weather conditions. Energy consumption is the amount of energy consumed by end users such as companies, industry and households. Installed capacity is generally measured in megawatts (MW) or kilowatts (kW) while energy generation and energy consumption is generally measured in kilowatt-hours (kWh), megawatt-hours (MWh) or terawatt-hours (TWh) (Eurostat, 2018; US Department of Energy, 2017).

wind power capacity growth has slowed down to an annual growth below 20 percent (IRENA, n.d.).

Solar energy is the fastest growing renewable energy technology (Wüstenhagen & Menichetti, 2012), with a seventeen-time capacity increase from 2010 to 2020, and an average annual growth of 38 percent over the same time period. Global solar energy capacity was eighteen-times less than global wind power capacity in 2001, but now solar energy capacity has almost reached the same capacity levels as wind power (IRENA, n.d.).

Hydropower accounts for the largest share of global renewable energy capacity. Global hydropower capacity has had a marginal annual average growth of 2,9 percent in the past twenty years. The rest of the global renewable energy capacity comes from marine energy, geothermal energy and bioenergy (IRENA, n.d.).

Figure 1. Total installed renewable energy capacity (in MW)

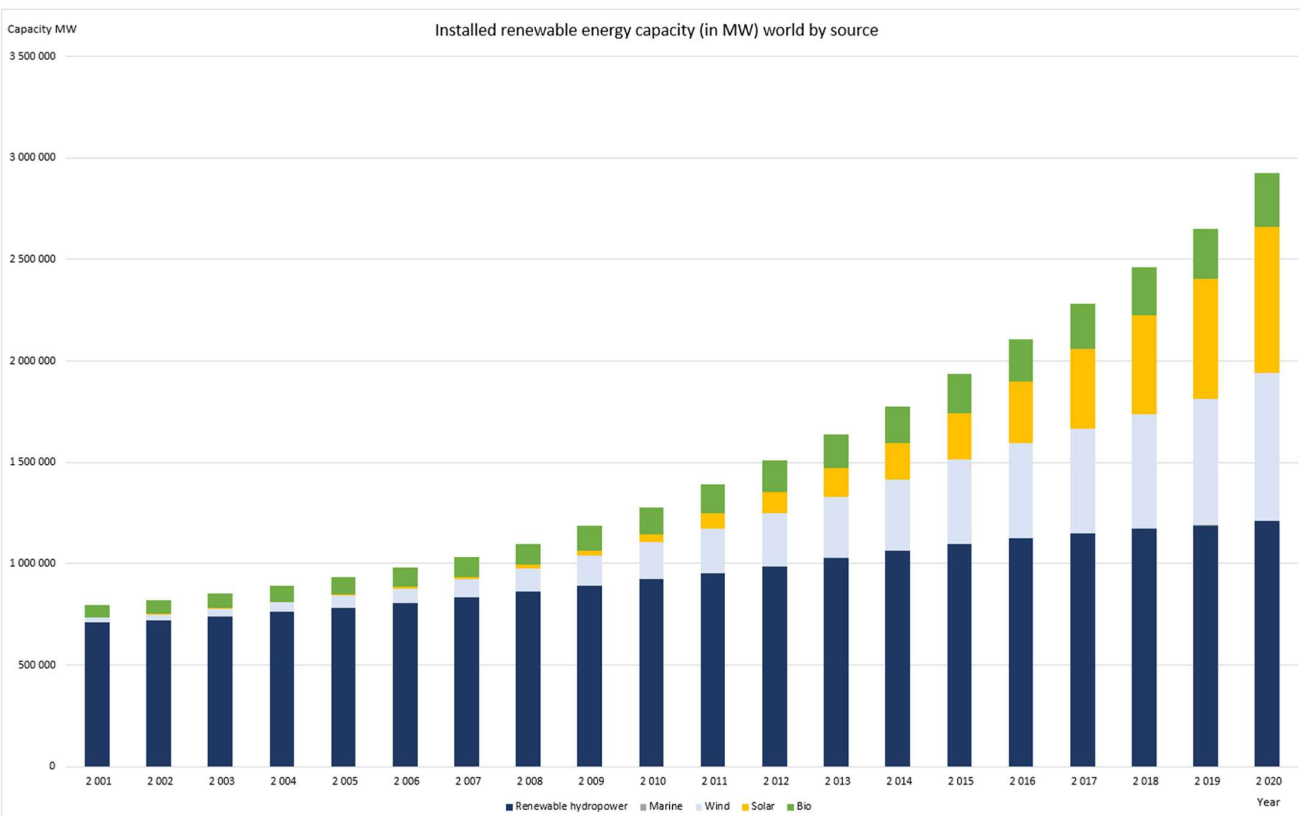


Fig. 1. Total global installed renewable energy capacity, 2001 – 2020 in megawatt (IRENA, n.d.). Renewable energy does not include large hydro.

Europe, North America and Asia, with South America not far behind, accounted for about the same share of the global renewable energy capacity up until 2012. From 2012 to 2020 Asia had an average annual growth of 13 percent while Europe, North America and South America had an average annual growth of 6 percent, 6,3 percent and 4,8 percent respectively. From 2017 Asia accounted for almost half of the renewable energy capacity in the world, hence the largest share of renewable energy capacity in the world is in Asia. Two thirds of Asia's renewable energy capacity is from China (IRENA, n.d.).

Looking at energy capacity additions, renewable energy accounted for over 50 percent of global capacity additions over the past five years, with a record of around 80 percent renewable capacity additions in 2020 (BP, 2021; Demôro et al., 2021). Fossil fuel capacity additions on the other hand is down from around 60 percent in 2012 to 20 percent in 2020. The strong growth in renewables and reduction in fossil fuel capacity additions have not made changes in global coal generation which in 2020 was unchanged from 2015 levels (BP, 2021). Also, fossil fuel production has increased per annum for decades, with minor bumps due to the financial crisis in 2007/2008 and the Covid-19 pandemic in 2019/2020 (BP, 2021; DNV, 2021). Oil, coal and gas production has grown at an average rate of 1,2 percent, 2,8 percent and 2,6 percent per year respectively from 2001 to 2020 (BP, 2021).

1.2 Investment in renewable energy

The growth in renewable energy capacity is reflected by the investments in renewable energy projects. In 2006 investment in renewable energy was amounted to about 79 billion USD. Since then, investment in renewable energy reached 282 billion USD in 2020 (Demôro et al., 2021; IRENA, 2017). However, investments in renewable energy have remained almost flat since 2015. From 2012 wind and solar technology received about 95 percent of the global financial investments in renewable energy. China accounted for a third of the total renewable energy investments (94 billion USD) in 2020. The renewable investments are highly concentrated in relatively small number of markets with China, United States and Japan representing 60 percent of the renewable energy investments in the world from 2016 to 2020 (Demôro et al., 2021).

In 2011 renewable energy investments in developing markets exceeded investments in renewable energy in developed markets, with 52 percent in developing markets and 48 percent in developed markets. However, in 2020, during the Covid-19 pandemic, investors sought to invest in lower-risk market causing investments in developing markets to decline to 52 percent in 2020 from a peak of 63 percent in 2017. Conversely, developed markets had an increase in investments in renewable energy to 48 percent in 2020 up from 37 percent in 2017. When looking at the income levels of countries receiving renewable energy investments, lower middle income and low-income countries only accounted for 6,9 percent of the total renewable energy investment in 2020, while high-income countries and middle-income countries accounted for 53 percent and 40 percent respectively in 2020 (Demôro et al., 2021). If this becomes a trend an uneven energy transition can emerge (Eicke & Goldthau, 2021).

Implementing the necessary solutions for an energy transition means that more investment in renewable energy projects and infrastructure is needed (Coninck et al., 2018). IEA (2021b) estimates that a spending of nearly 4 trillion USD annually by 2030 is required to accelerate the necessary renewable energy deployment to meet the 1,5-degree target limit and net zero emission by 2050. Most of this flow of capital is needed in emerging markets and developing countries who is expected to move into an energy- and emission intensive phase due to urbanisation and industrialisation.

1.3 Global energy consumption and renewable energy

Over the past 40 years, global energy consumption grew at an average of 2,5 percent per year. The growth in global energy consumption by source is illustrated in Figure 2. The global energy demand is expected to continue to grow due to population growth, economic growth and improved standard of living. BP (2013) in their Energy Outlook 2030 projected that global energy demand will grow at an average of 1,6 percent per year to 2030. This growth in energy demand will vary significantly between different regions (DNV, 2021). To meet this growing global energy demand additional energy capacity needs to be installed. This means that even if the total expected growth in energy demand is met by low emission energy sources, annual emission would probably still be around current levels and global average temperature would be rising, all other things being equal (IEA, 2021b).

Figure 2. Energy consumption by source, World

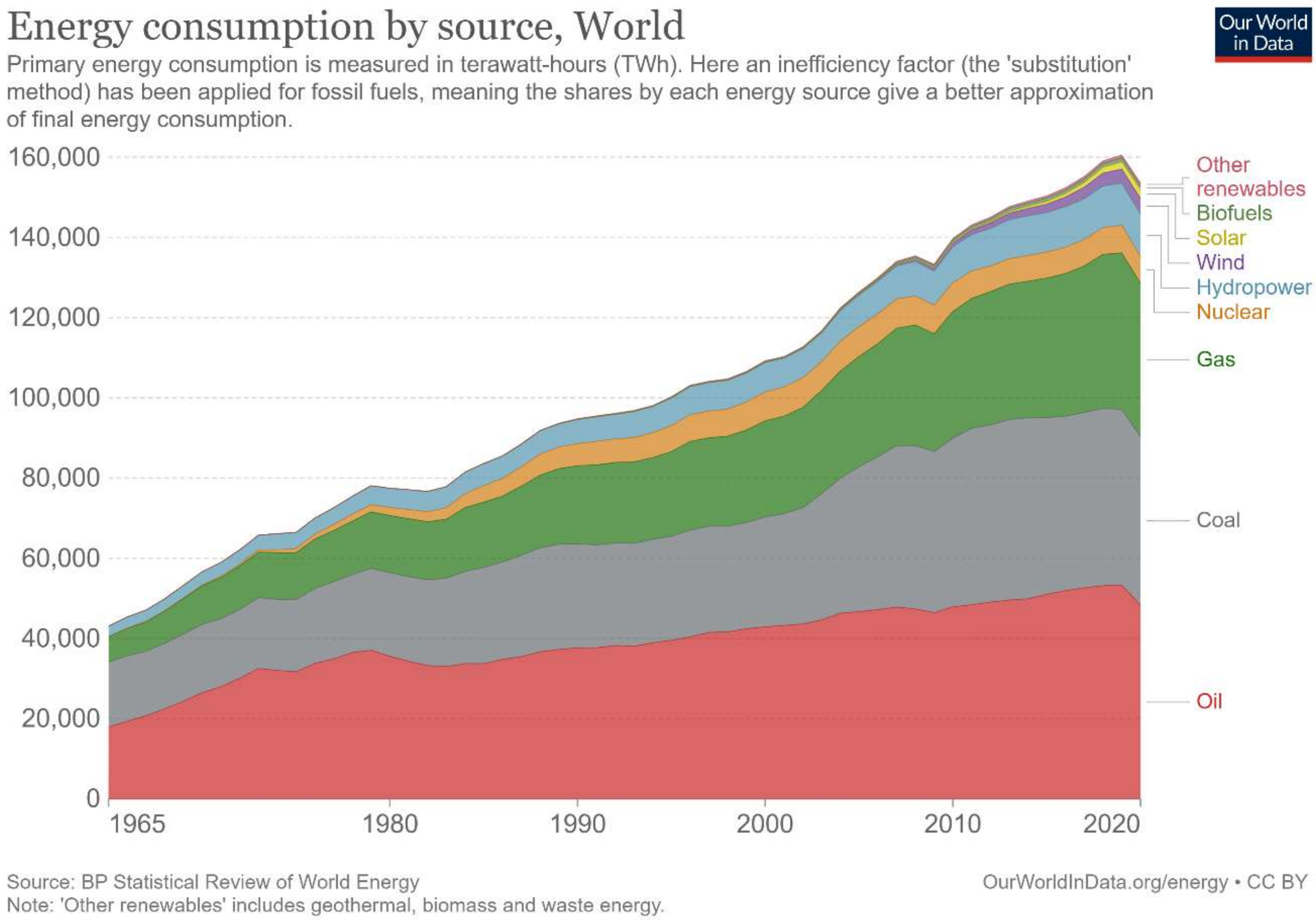


Fig. 2. Primary energy consumption in the world by source, 1965 – 2020 in terawatt-hours (Ritchie et al., 2020).

Even if renewables are expanding rapidly, renewables only accounted for 11,4 percent in the global energy mix in 2019, while non-renewables accounted for 84,3 percent and nuclear accounted for 4,3 percent. In Figure 2 it can also be seen that global energy consumption has been, and still are, dominated by oil, coal and gas (IEA, 2018; Ritchie et al., 2020).

The current pace of investment in renewables and fossil fuels in addition to the phase-out of fossil fuels can risk the energy supply falling short of what is required to maintain current energy consumption trends. This can be illustrated with an example from the electricity sector. IEA (2020a) estimated that global electricity demand would grow 5 percent in 2021 and 4 percent in 2022 while total renewable electricity generation is estimated to grow 8 percent in 2021 and 6 percent in 2022. Even with this rapid growth, IEA (2020a) state that renewable electricity generation will only be able to cover around half of the additional demand in 2021 and 2022, with fossil fuel and nuclear power covering the rest. This means that if renewables are expanding in current pace, it will still not be sufficient to meet the growth in global energy demand. Consequently, by reducing the share of fossil fuel in the global energy mix and with growth in energy demand massively and continuous investments in renewable energy are required to meet the global energy demand.

Researchers and international organisations are arguing that public policies are essential for attracting investment in renewable energy to grow renewable energy capacity (Chakraborty et al., 2021; Goldthau, 2013; IEA, 2018; Liu et al., 2019; Zhao et al., 2013). This is because policy support is contributing to lowering investment costs and risk, technological advancement and cost reduction of renewable energy (IEA, 2020b; IRENA et al., 2018). As an example, the implementation of feed-in tariff for grid-connected solar systems in 2017 have been identified as the main driver for Vietnam becoming the world's third largest market for solar energy in 2020 (Demôro et al., 2021; Do et al., 2020; IEA, 2020b; Le et al., 2022). In 2019, after the implementation of the feed-in tariff, Vietnam had a 45 times growth in total installed solar capacity compared to installed capacity in 2018. Furthermore, it is believed that the implementation of feed-in tariff has contributed to the large growth in solar power in inter alia Europe from 2008 to 2012, China from 2011 to 2016 and Japan from 2012 to 2017 (Le et al., 2022). Now that Vietnam's government is scaling back renewable energy incentives it is assumed that capacity additions will be reduced significantly (IEA, 2020b).

1.4 Research question

It is expected that public policies will play a role in increasing renewable energy capacity, however there is limited empirical evidence concerning the effectiveness of renewable energy polices and which policies are the largest driver for growth in renewable energy capacity (Marques et al., 2010; Zhao et al., 2013). This is especially the case in developing countries and countries in transition, as an overweight of the studies on public policies on renewable energy are conducted on industrialised countries (Liu et al., 2019; Polzin et al., 2015; Wall et al., 2019). This study seeks to contribute to the limited empirical knowledge by quantitatively investigating the effect of public policies on renewable energy capacity on an aggregated level and on a group level.

The following research question has been developed to guide this study:

Does public policy increase renewable energy capacity?

To address this research question, this study seeks to quantitatively assess if renewable energy policies increase renewable energy capacity. Data on developed countries, countries in transition and developing countries is included in the study.

It is expected that countries in transition and developing countries will be the primary source of economic growth, energy consumption and emissions growth in the coming decades. It is estimated that if annual investments in clean energy do not increase, energy-related emissions from mainly Asia, Africa and South America will grow by 5 billion tonnes over the next two decades. Hence, the world is indeed dependent on whether countries in transition and developing countries can successfully transition to cleaner energy systems (Demôro et al., 2021; IEA, 2021a). Following the steps of developed countries, countries in transition and developing countries have in the past decade implemented policies supporting renewable energy development and building renewable energy capacity. Developed countries are considered the pioneers of renewable energy and have long experience with policy incentives to promote renewable energy. In general, developed countries get more of their energy from low-carbon sources than the global average, and tend to have numerous and extensive policy incentives in place to promote renewable energy (IRENA et al., 2018). Developed countries are in a different part of their clean energy transition journey now than they were a decade ago when the majority of the quantitative studies on public policy effect was conducted.

Thus, studying the effect of renewable energy policy in both developing countries, countries in transition and developed countries is highly relevant.

More specifically, this thesis is a longitudinal study using data from the time period 2001 – 2018 from a variety of countries to explain the effect of policy instruments on the renewable energy capacity. Policy instruments tend to be part of a policy packages that consist of a mix of policy instruments used by public authorities to reach objectives and goals. In this study the individual policy instruments are analysed as recommended by Lester M. Salamon who state that the individual policy instruments should be analysed and not policy packages. Salamon explains this by arguing that in order to understand how policy instruments interacts in policy packages it is necessary to first understand the individual policy instruments separately. Also, understanding the individual policy instrument makes it possible to recognise characteristics and to identify the instrument. This knowledge can be applied from one policy area to another whereas knowledge about a policy package tend to be useful only for the specific case (Vabo et al., 2020). The policy instruments included in this study will be presented in chapter 2.4.

1.5 Limitation of scope

This thesis takes a quantitative approach and will remain quantitative throughout the entire study. Therefore, this study is not able to give an in-depth insight and detailed conclusions about the effectiveness of certain policy instrument on renewable energy capacity in certain countries.

1.6 Structure of the thesis

The rest of this thesis consists of five chapters and is structured as follows:

Chapter 2 presents the theoretical background by introducing and describing theoretical concepts relevant for this thesis. The methodology, data and model are explained and accounted for in chapter 3. Next, the findings from the panel data regression in this study is presented in chapter 4. In chapter 5 the findings for each policy instrument are discussed. Finally, chapter 6 summarises the study and presents the conclusion of the findings.

2.0 Theoretical background

The purpose of this section is to establish a theoretical framework and to introduce related empirical research. This thesis is based on four concepts (1) public policy, (2) energy policy, (3) policy instruments and (4) the effect of renewable energy policy instruments on renewable energy capacity. These concepts will be introduced and explained within the framework of the study. Related empirical research will be linked to the theoretical concepts.

The first subsection introduces public policy. The second subsection describes the purpose of energy policy and the factors that influences national energy policy. The focus is mainly on renewable energy policy. The third subsection explains the purpose of policy instruments and provides an overview of policy instruments that are covered in this study. The final subsection focuses on the connection between renewable energy policy instruments and renewable energy capacity including propositions which will guide the analysis and discussion of this study.

2.1 Public policy

2.1.1 What is public policy?

Public policy is public authorities' intentional action, or no action, in order to solve issues, obtain a set goal or to create value for the society (Cairney, 2019; Vabo et al., 2020). Vabo et al. (2020) break down their understanding of public policy (generally in democracies) in five parts:

(1) Public authorities are the only actor who make decisions on behalf of the citizens. This means that policies approved by organisations is not defined as public policy. However, the power of public authorities is influenced and limited by lobbying from private actors and non-governmental organisations.

(2) Public policy is an intentional action. No action from public authorities is also considered as public policy, for instance not increasing taxes for people with high income when the gap between rich and poor is increasing.

(3) Allocating or redistribution of resources such as distributing benefits and burdens, for example strengthening mental health care for children or increase taxes for people with high income.

(4) Identify issues and finding solutions to these issues by setting goals and implementing policy instruments. As an example, by identifying climate change as an issue the Norwegian Government have composed strategies with actions in order to reach their goal of reducing emission of greenhouse gasses with 50 to 55 percent within 2030.

(5) Public policy is interest and value based. Based on differences in interests and values there will be disagreement about what is considered as an issue and what the best policy instrument to address an issue will be. In public policies one value can come in conflict with another value which the government need to take a decision on, for example should nature conservation or renewable energy production weight more when deciding on building wind turbines. Vabo et al. (2020) are in the opinion that these decisions about which value has precedence over another value is in the core of the policy concept. Further, a question in public policies is also who benefits and who is loaded by a public policy (Vabo et al., 2020), for instance does a renewable energy policy primarily benefit the private energy players while not being socio-economic for the society, burdening the economy and placing high electricity prices on consumers (Marques & Fuinhas, 2012b).

2.1.2 Input-output model, outcome and impact

Davis Easton described public policy as an input-output model that compound of two inputs, one output and a feedback mechanism. In the model, input represent the pressure on the political system from the environment through demand and support while output is the decision on policies made by public authorities. In other words, the model illustrates how demands and support in the political system results in an output, law, actions, reform, regulations and so on, from the political system. The response from the output is then fed back into the input and again the demand and support from the input is converted into output, causing the impact-output model to go in loop.

Easton emphasised that it is not enough to study the actions in the political system, it is also necessary to study the effect of these actions. Moving beyond the input-output model comes outcome and impact. The effect, such as changes in behaviour that the action has caused, is outcome, while impact is about whether the action has obtained the expected results set in a policy instrument. As an example, within energy policy public authorities can decide to implement carbon taxes (output). Whether the carbon tax have had an effect on the society (outcome) will be questioned first. In this example is can be questioned if the carbon tax has reduced demand for fossil fuels, increased the use of clean energy sources or if there is greater use of eco-friendly transportation (public transportation, electric car, cycling). Then, whether the carbon tax have reached the expected results (impact) is questioned - are the implemented carbon tax contributing to reduce CO_2 emission?

This thesis will primarily be concerned with the impact of public renewable energy policies.

2.2 Energy policy

In energy policy authorities address challenges and issues concerning energy (Islam & Hasanuzzaman, 2020). This can for instance be to secure supply of energy, to provide energy at an affordable price and to avoid carbon lock-in (Goldthau, 2013; Hooker et al., 1981). Further, Energy policy covers a set of aspects; market, security, sustainability and development (Goldthau, 2013). Energy markets is about trading of energy and is the mechanism to make supply react to demand, the essence of energy security is to provide reliable and continuing availability of energy at a reasonable price, climate change have set sustainable energy on the agenda and development is about providing countries with access to modern energy (Goldthau, 2013; IEA, 2021b).

In the last twenty years or so decarbonisation of energy, energy efficiency and transition to clean energy has been at the centre of energy policies and the energy debates (Goldthau, 2013). Shifting the energy sector from being fossil based to being based on renewable energy sources is of political concern. This energy transition comes with high costs for nations (Chassot et al., 2014; Liu et al., 2019; Zhao et al., 2013), and traditionally the cost of fossil fuel and investment in fossil fuel have been at an advantage over renewables (Aguirre & Ibikunle, 2014). The task of energy policies would therefore be to correct for this type of disadvantage by for example reducing the risk of renewable energy investments, by subsidising renewable energy or discourage the dependence of fossil fuels by making them more expensive (Aguirre & Ibikunle, 2014; Johnstone et al., 2010; Wüstenhagen & Menichetti, 2012). Popp et al. (2011) imply that policy intervention is more necessary to encourage investments the higher the cost of the energy technology. Energy policies supporting development of renewable energy technology has already contributed to the lowering of costs of renewable energy technology, which is contributing in closing the gap between renewables and fossil fuel (Popp et al., 2011).

Renewable energy policy, which this thesis will be concerned about, have expanded worldwide, and almost all countries now have at least one renewable energy target (IRENA et al., 2018). Important factors for adopting renewable energy policies in a country is to (1) promote development and deployment of renewable energy, (2) reduce carbon emission, (3) reduce energy dependency and energy-system lock-in, and (4) compliance of international agreements (Liu et al., 2019; Marques et al., 2010; Menz & Vachon, 2006). Even with the immense focus on climate change and sustainability in the public debate, these concerns are not necessarily the main driver for national renewable energy policy. Several researchers have mentioned that energy security and reducing energy dependency is one of the most important factors for stimulating development of renewable energy use and implementing renewable energy policies (Dong, 2012; Kanellakis et al., 2013; Marques et al., 2010). Studies by Aguirre and Ibikunle (2014) and Popp et al. (2011) on the other hand report that energy security is not a main factor for development of renewable energy. It should be mentioned that the ongoing energy transition can bring risk to energy security, and it is the task of energy policy to manage such risks. For example, a change in one area, reduction in fossil fuel investment, ought to be complemented or balanced with a change elsewhere, increase in renewable energy investment (IEA, 2021b).

Energy policies adopted in countries vary from country to country depending on political context, energy market maturity and condition and the country's availability of energy resources (Kanellakis et al., 2013; Popp et al., 2011; Romano et al., 2017; Wall et al., 2019). Consequently, there is not one universal energy policy that can be pointed out as a preferred policy in all contexts (IRENA et al., 2018). Even countries considered to be fairly similar, such as Norway and Sweden, have pursued different paths in energy system transformation and production of renewable energy. Ydersbond (2014) conducted a study analysing renewable energy policies in relation to energy system transformation in Norway and Sweden identifying Norway focusing on electricity production primarily from hydropower while Sweden has persuaded developing bioenergy. Availability of resources, technological development, crises and EU membership is factors that have been influencing the energy policy in the two countries and hence led to development of different renewable energy sources in Norway and Sweden.

2.3 Factors influencing energy policy

2.3.1 External shocks

External factors such as oil crises, crises in energy supply, nuclear accidents and fluctuating energy prices affects and influences national energy policies. For example, nuclear accidents and the oil crises in 1973 and 1979 have influenced energy policies, leading counties to pursue alternative energy sources, such as wind, solar and bio, and accelerated research, innovation and development of renewable energy (Ydersbond, 2014). In the end of 2021 and in 2022, the world experienced all-time high gas prices due to increased demand and lower supply than expected. This is expected to encourage gas-consuming countries to further accelerate investments in renewable energy to become more self-reliant and to diversify their energy mix (IEA, 2022). Implementing policy instruments that promote development of renewable energy might be an answer to these external factors. Furthermore, external shocks tend to open windows of opportunity and provide legitimacy to prompt national energy policy initiatives that support renewable energy (Ydersbond, 2014).

However, renewable energy is not entirely immune against high and volatile prices and geopolitics. Renewable energy technology is dependent on critical minerals such as cobalt, copper and lithium, which are concentrated in a smaller number of countries. Trade restrictions, political instability and regulatory changes can disturb the renewable energy supply chain. Hence, renewable energy technology dependent on these critical minerals could get an increase in cost of 5 – 15 percent which can slow down the energy transition and make it more costly (IEA, 2021b).

High prices on oil and gas make production of renewable energy competitive which should favour renewables and encourage countries to switch from oil and gas to renewable energy sources. On the other hand, rising energy bills for consumers due to high oil and gas prices might cause public authorities to subsidies oil and gas to limit the negative consequences on the consumer, risking causing a reduction in funds or public incentives supporting renewable energy as public budgets are limited (IEA, 2021b).

2.3.2 Lobbying

Public policy involve power and how this power is used through implementing measurements, frameworks, incentives and regulations. It varies from nation to nation how this power is used and how strong the government intervention is in the energy market. In democratic states it is generally a practice for public authorities to involve community groups or interest groups before new policies are implemented or before changes in policies occur (Vabo et al., 2020). Whereas in autocratic states the autocratic leader has absolute power, and the influence of interest groups tend to be very limited. Nevertheless, the power and the political decision-making of public authorities is influenced and limited by lobbying from private actors, non-governmental organisations and interest groups (Vabo et al., 2020). In a study by Marques et al. (2010) analysing the motivation driving renewable energy in European countries found that lobbying by conventional energy sources (oil, coal and gas) restrain renewable energy deployment. Furthermore, Aguirre and Ibikunle (2014) and Marques and Fuinhas (2012a) reports that the power of these conventional energy sources is influencing energy policies.

2.3.3 International agreements and international organisations

By signing of the Kyoto Protocol and the Paris Agreement and the establishment of IPCC, nations are making commitments to limit global warming by reducing emission of greenhouse gasses. Hence, the agreements and global organisations are putting pressure on nations to implement energy policies that support the transition to renewables (Liu et al., 2019; Popp et al., 2011; Zhao et al., 2013). Liu et al. (2019) particularity highlight the effect the signing of the Kyoto Protocol in 2005 had on policymakers and the implementation of renewable energy policies worldwide. Furthermore, Popp et al. (2011) find that countries that have signed the Kyoto Protocol invest more in renewables. Regarding the social pressure on reducing carbon emission, Marques et al. (2010) reports that this social pressure is not a motivation in the decision process of promoting renewable energy.

It can be said that countries who are members in international organisations are more influenced by the international organisation regarding the country's energy policy than non-member countries. Marques et al. (2010) conducted a panel data study on European countries to analyse the impact renewable energy policies have on the contribution of renewable energy to the total energy supply. They found that EU membership was a significant explanation for renewable energy use. The findings in Marques et al. (2010) are confirmed in a comparative study by Ydersbond (2014). Ydersbond (2014) observes that Sweden's EU membership has somewhat contributed to Sweden's renewable energy policies being more ambitious than non-EU member Norway's energy policies.

2.3.4 Country specific factors

When designing energy policies national and local conditions should be considered (IRENA et al., 2018). Differences in natural environments can be a possible factor for why countries implement different energy policies and policy incentives. As an example, countries that are more vulnerable to natural disasters due to climate change might be more likely to implement energy policies that supports development of clean energy sources. Also, citizen acceptance and support for climate measures might be higher in countries vulnerable to climate change (IPCC, 2022; Zhao et al., 2013).

The availability of resources is generally kept in mind when deciding on policies to specifically promote renewable energy. Norway for instance have vast potentials for hydropower and wind power and South Africa have enormous solar energy resource potential. The access of abundant and affordable hydro power in Norway for example has made other renewable energy sources expensive in comparison (Ydersbond, 2014). If countries are required to make use of additional renewable energy, countries will most likely choose the most available and cost effective energy resource (Johnstone et al., 2010). Countries lacking access to abundant and cheap renewable power, tend to have more long-lasting and extensive incentives in place for various types of renewables than countries with renewable energy sources that are easily accessible (Aguirre & Ibikunle, 2014; Ydersbond, 2014). This is in order to compensate for reduced environmental conditions (Aguirre & Ibikunle, 2014).

Marques et al. (2010) found that countries with a larger proportion of energy from fossil sources have less focus on renewable energy and hence use less renewables. This finding is consistent with Romano et al. (2017) who find that when generation from fossil fuels increases, investment in renewable energy are reduced. There are numerous countries in the world with abundant solar potential such as Egypt, Algeria, Malaysia, Iran, Qatar and Saudi Arabia. However, due to the subsidisation of fossil fuel in these countries, investors and consumers are left with limited incentives to invest in solar power (Le et al., 2022; Popp et al., 2011). In 2017 the world's total energy subsidies were estimated to be 634 billion USD. Subsidies to renewables accounted for around only 20 percent, 128 billion USD, of total energy subsidies, while fossil fuels accounted for 70 percent, 447 billion USD. The EU (54%), US (14%), Japan (11%), China (9%) and India (2%) accounted for 91 percent of the total renewable energy subsidies. The rest of the world accounted for the remaining 9 percent (Taylor, 2020).

Countries with higher income can have more resources to invest in renewable energy and to implement support incentives for renewable energy. Furthermore, high-income countries can have greater capacity to be concerned about matters reaching beyond the local, for instance climate change-related issues and global environmental concerns (Aguirre & Ibikunle, 2014; Marques & Fuinhas, 2012a). For instance, the poverty issue in low-income Burundi and what is required to solve this issue is very different and greater than the poverty challenges in high-income Denmark, which would most likely limit Burundi's efforts to prioritise climate and clean energy measures (IEA, 2021b; Vabo et al., 2020). Studies shows that developed countries invest more in renewable energy and have a larger proportion of renewables in their total electricity generation than emerging and developing countries. Furthermore, developed countries also have more renewable energy policies implemented than emerging and developing countries (Popp et al., 2011; Zhao et al., 2013). Zhao et al. (2013) concludes that the number of renewable energy policies increases with the state of development.

Public authorities are not only limited from implementing public policies by lobbying, but also from the cost of policy instruments. Developing countries are particularly vulnerable when it comes to economic downturn and public spending, and hence policy instruments might cost too much for public authorities to implement (Aguirre & Ibikunle, 2014; IEA, 2021b). For instance, the Covid-19 pandemic are causing developing countries to increase borrowings to cope with the continuing and pressing public health crisis. This is setting back efforts of public spending on policy instruments supporting renewable energy and are leaving little room for governments to kick-start investments in renewable energy (IEA, 2021b). The high costs that come with the energy transition can result in countries failing to achieve their renewable energy targets (Liu et al., 2019) due to smaller economies not being able to handle the costs of renewable energy development (Marques et al., 2010).

2.4 Policy instruments promoting renewable energy

Policy instruments is an integrated part of public policy. Public authorities adopt goals and strategies, but it is through policy instruments that public authorities enforce its power on the society. For example, without financial and fiscal incentives supporting renewable energy, investors would most likely not choose to invest in renewable energy above fossil fuel even if public authorities have decided that CO_2 emission shall be reduced. In other words, policy instruments are the element that is used to get actors to do something that they normally would not do (DNV, 2021; Vabo et al., 2020).

Mandatory injunction and prohibitory injunction and positive and negative incentives is used in policy instruments to influence. For instance, an organisation can be tempted by switching to renewable energy by a positive incentive such as tax reduction. Or an organisation can be discouraged to use energy produced from fossil fuels by a negative incentive such as carbon tax (Vabo et al., 2020).

There is a variety of policy incentives that can be implemented to promote investments in renewable energy (Liu et al., 2019), and a multiple of these policy incentives are usually implemented in a country (Kitzing et al., 2012; Popp et al., 2011). Types of renewable policy incentives that a public authority can implement to achieve their political objectives can be fiscal and financial incentives, market-based incentives, direct investments, policy support, R&D incentive programs and regulatory instruments (Kanellakis et al., 2013; Marques et al., 2010). Which policy instrument is implemented by public authorities depends on the challenge that is addressed, objectives, type of energy source and country characteristics and so forth.

In the following section all the different renewable energy policy instruments that are included in the sample of this study will be described.

2.4.1 Fiscal and financial incentives

Fiscal and financial incentives have the purpose of reducing the risk and stable the income for investors (Friebe et al., 2014; Liu et al., 2019).

Incentives such as feed-in tariffs and feed-in premium are examples of **price policies** that are used as renewable energy incentives to ensure long-term stability and cost-based compensation to renewable energy producers. Feed-in tariffs guarantee producers of renewable energy a purchasing price for electricity produced from renewable energy. Feed-in premiums guarantee producers of renewable energy a premium price, which is an addition to the market price. The price in these price policies can be guaranteed for either a predeterminant amount of production or for a specific period, hence (Kitzing et al., 2012; Marques & Fuinhas, 2012a; Zhao et al., 2013).

Grants and subsidies are financial aids provided by the governments or institutions to support the development of renewable energy. These financial aids can be in the form of loans or non-reimbursable payments. The purpose of grants and subsidies is to reduce capital cost for investors in renewable energy projects or to reduce costs for consumers (Kitzing et al., 2012; Zhao et al., 2013).

Tax incentives are designed to reduce tax burden on renewable energy companies and renewable energy investments (Liu et al., 2019; Wall et al., 2019). The aim is to encourage renewable energy production by reducing tax burden (Zhao et al., 2013). Taxes can for example either be income tax reliefs, electricity tax reliefs, reduced valued added tax or carbon taxes which encourage reduction of carbon emission by making emissions more expensive (Popp et al., 2011). Carbon taxes is not specifically considered in this analysis.

2.4.2 Market-based incentives

Market-based incentive are policies that seek to use market-based tools to reduce greenhouse gas emission. Examples of market-based incentives are **GHG (greenhouse gas) emission allowances** and **green certificates**. GHG emission allowances focus on solving the issue of greenhouse gas emissions by striving to reduce CO_2 emission (Liu et al., 2019). For instance, in EU, including EEA-EFTA states, the EU emission Trading System is operating. The aim of the EU emission trading system is to reduce greenhouse gas emission cost-effectively by setting a cap on the total amount of greenhouse gasses companies can emit. Emission allowances can be traded between emitters if the total number of allowances issued are not enough or if an emitter have extra allowances. Over time the annual cap on greenhouse gasses emission are reduced (European Commission, n.d).

Green certificates are a tool that track and verify electricity generated from renewable energy sources. The green certificates can also be traded between companies and countries to meet renewable energy obligations (Wall et al., 2019; Zhao et al., 2013).

2.4.3 Direct investments

Direct investments are incentives with the objective of reducing capital costs of renewable energy investments (Liu et al., 2019).

Funds to sub-national governments are federal money from central government provided to municipalities or local or regional authorities to fund renewable energy projects (Polzin et al., 2015).

Investment in infrastructure is investment in assets that are necessary to facilitate the flow of renewable energy such as electric power transmission line and providing grid access (Polzin et al., 2015).

2.4.4 Policy support

Policy support seeks to promote renewable capacity inside a country by defining strategies and specific plans and targets (Liu et al., 2019). Under the group policy support is **institutional creation**, for instance implementation of an energy agency, and **targets and strategic planning** (Polzin et al., 2015). Targets and strategic planning can be long-term energy strategies with a clear vision that specify the percentage of total energy production that are expected to come from renewable energy inside a country (Kitzing et al., 2012; Marques & Fuinhas, 2012a; Polzin et al., 2015; Wall et al., 2019). Targets should be supported by dedicated policies and measures (IRENA et al., 2018).

2.4.5 Regulatory instruments

Regulatory instrument is regulations that a country or state has implemented to promote renewable energy or to reach renewable energy targets (Menz & Vachon, 2006; Wall et al., 2019).

Codes and standards are a set of guidelines and requirements that governments and authorities use to encourage the transition to clean energy sources and hence achieve renewable energy objectives (ISO, n.d.).

Obligation schemes like for instance renewable portfolio standards are a regulatory instrument where electricity supply companies are obliged to produce a specific amount of their electricity from renewable energy sources (Menz & Vachon, 2006; Wall et al., 2019).

Regulations is mandatory rules and laws on renewable energy set by governments and authorities in a country or state.

2.5 Renewable energy capacity and the role of public policy

Currently the world does not have enough renewable energy capacity and production to replace fossil fuel. Wüstenhagen and Menichetti (2012) writes that today's investment in renewable energy provides an insight into tomorrow's installed renewable energy capacity. Hence, substantial investments in renewables are needed to grow renewable energy capacity (Goldthau, 2013; Wüstenhagen & Menichetti, 2012). Since financial resources of governments are limited involvement of private investments in renewable energy is needed to transit from fossil-fuel to renewable energy (DNV, 2021; Polzin et al., 2015).

There seems to be general consensus among researchers that investment in renewable energy is driven by policy (Marques & Fuinhas, 2012a; Marques et al., 2010; Popp et al., 2011; Wüstenhagen & Menichetti, 2012). The purpose of renewable energy policies is among other things to reduce investment risk, overcoming market barriers and to provide a secure and fair environment for renewable energy investors (Dong, 2012). The outcome of renewable energy policies instruments is to influence actors to invest in renewable energy, and the desired impact is growth in renewable energy capacity and reduced greenhouse gas emission. It can be assumed that an absence of policies to promote renewable energy leads to a lack of capital allocated into renewable energy projects and less renewable energy capacity additions (Chassot et al., 2014). How public policies can attract investment in renewable energy to grow renewable energy capacity therefore becomes an important question (Goldthau, 2013).

If a renewable energy policy is successful, or not, relies on its design (IRENA et al., 2018). Countries that have experienced good policy results is countries with a stable, reliable and well-designed policy framework for renewable energy support (Dong, 2012). For example, Germany implemented an Electricity Feed-In Law in 1991 which were modified and replaced by the Renewable Energy Sources Act in 2000. Due to the long-term security for investors these policies provided and by adapting policies in line with changes in the market, Germany is now one of the top countries in the world for solar power capacity additions (Le et al., 2022). Conversely, poorly designed policies, unclear agreements and discontinuity of policies can lead to volatile periods for energy markets and uncertainty and confusion amongst investors which then can result in underinvestment and constrain renewable energy capacity expansion (IEA, 2021b; IRENA et al., 2018; Marques & Fuinhas, 2012a; Romano et al., 2017). Italy for instance experienced chaos and trouble for solar energy development in 2006-2013 due to weak policy management, several changes in the feed-in tariff scheme and confusion in the transition between feed-in tariff schemes (Le et al., 2022).

In previous studies, researchers have found that a single-focused approach to solving energy problems might fail to meet the desired outcomes set by policy makers. To find solutions to energy challenges through the use of policies, a policy mix is recommended in order to meet the desired outcomes (Goldthau, 2013; Liu et al., 2019; Polzin et al., 2015). Liu et al. (2019) found that GHG emission allowances and green certificates alone did not have significant effect on renewable energy capacity, however market-based instruments as a group had a strong effect on renewable energy capacity, which imply a synergy effect. Similar with marked-based instruments, Liu et al. (2019) find that the policy support group that consists of institutional creation and strategic planning is more significant than the strategic planning incentive alone. This illustrates that renewable energy policies are enhancing each other. However, Zhao et al. (2013) observe that policies only enhance each other if they are complementary polices. If policies are overlapping or uncoordinated a decreasing policy effect might be observed. As a consequence, Zhao et al. (2013) point out that policymakers ought to take consideration to policy interactions when designing a renewable policy mix. Well-designed renewable energy policies have proved countries to receive economic and environmental benefits (Dong, 2012). It still does not exist a final answer to what the optimal policy mix should be (Goldthau, 2013; Polzin et al., 2015), as the optimal policy mix would allegedly depend on country context, technological development and market barriers for instance (Johnstone et al., 2010; Kanellakis et al., 2013). Knowledge about the effect of renewable energy policies can help policy makers take informed decisions about implementing effective policy instruments and to compose an optimal policy mix (Wüstenhagen & Menichetti, 2012).

In summary this subsection expects that renewable energy capacity is affected by renewable energy policy instruments. This leads to the following proposition:

Renewable energy policy instruments lead to a positive influence on renewable energy capacity.

Developed countries, countries in transition and developing countries are generally in very different stages of their renewable energy development and economic development. High-income economies and to a certain degree upper-middle-income economies have mature renewable energy markets where investment risk is perceived as lower than in lower-middle-income economies and low-income economies, who is more or less in the starting block of renewable energy development (Demôro et al., 2020). This leads to the second proposition:

The effect of renewable energy policy instruments on renewable energy capacity are more significant in countries in transition and developing countries than in developed countries.

3.0 Methodology

This section describes the methodology used to address the research question in this study. First, the research design is presented. Then the data sample and data collection are described. Last the panel data regression model is explained.

3.1 Research design

The research question of this study attempts to find out if public polices increase renewable energy capacity in megawatts (MW). The study covers a variety of developed countries, developing countries and countries in transition throughout the time period from 2001 – 2018. In order to investigate the effect of public policies on renewable energy capacity on the country level and over the selected time periods, a longitudinal research design is required (Johnstone et al., 2010; Polzin et al., 2015; Popp et al., 2011). A panel data regression is conducted covering 123 countries throughout the time period from 2001 - 2018. The time frame is selected due to the availability of data. From approximately the year 2000 several countries begun focusing on development of renewable energy and implementing policies to stimulate development of renewable energy (Liu et al., 2019). Hence, 2001 is set as the starting year. The countries are also selected according to the availability of data. All countries in the World Economic Situation and Prospects (WESP), UN country classification are included in the sample. WESP classifies all countries in the world in three categories; developed countries, countries in transition and developing countries. If a country has implemented at least one renewable energy policy, it is included in the sample. Countries with zero renewable energy policies for the selected time period is removed from the sample.

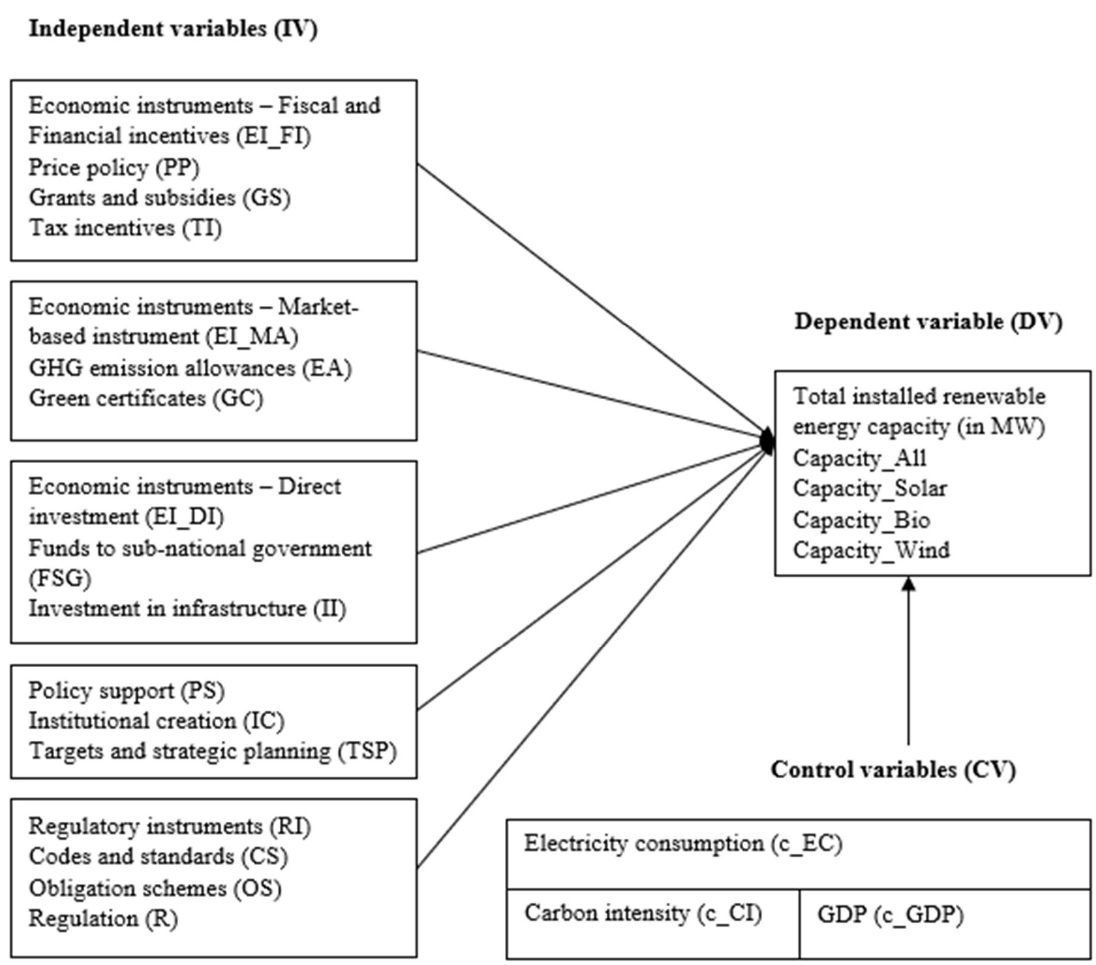
With panel data it is possible to difference the dependent variable across time for the same cross-sections. This makes panel data able to control for country specific effects, or individual heterogeneity (Baltagi, 2005; Wooldridge & Wooldridge, 2020). Hence according to Wooldridge and Wooldridge (2020), panel datasets are useful for policy analysis. The dataset in this study contains observations of different country groups across time. Since the dataset in this study fulfils the requirements of panel data and the focus of this study is to analyse the effect of public policies, panel data regression should be suitable for the purpose.

This study extends previous studies (Liu et al., 2019; Polzin et al., 2015) in one way; it includes developed countries which remain scarce because the existing studies mainly focus on countries on the EU level or across OECD countries.

3.2 Data and model

This study will investigate the effect of renewable energy policies on renewable energy capacity (in MW). The framework for the panel data regression is illustrated in Figure 3. The dataset covers 123 countries for 18 years, 2001 to 2018. The total amount of countries and time series generated 2,172 observations.

Figure 3. Framework of panel data regression.



3.2.1 Dependent variable

The dependent variable is measured as installed renewable energy capacity in MW in a certain country and year. Given the differences of the energy sources, such as level of maturity and cost structures, it is to be expected that the effect of policy instruments will vary by energy source. For example, wind power might require different policy incentives to encourage development than solar power (Johnstone et al., 2010). To capture the effect of policy instruments across energy source, the installed capacity data were structured according to four sources: all renewable energy, wind energy, solar energy and bioenergy. The 'all renewable energy source' consists of solar energy, wind energy, renewable hydropower, bioenergy, geothermal energy and marine energy.

The data of the renewable energy capacity is collected from the International Renewable Agency (IRENA) database. The IRENA database contains statistics on inter alia energy capacity, power generation, renewable energy patents evolution, climate change and public investments in energy technology at the country level (IRENA, n.d.). Installed renewable energy capacity represent an indicator of the spur of renewable energy (Liu et al., 2019; Polzin et al., 2015; Popp et al., 2011).

3.2.2 Independent variable

The public policy variable, main independent variable, is drawn from the IEA/IRENA Renewable Energy Policies and Measures Database. The IEA/IRENA database has information on policies in countries from 1948 and onwards. The policies in the IEA/IRENA database contains information about the title of the policy, scope of the policy, country, year the policy went into force, status of the policy (planned, in force or ended), policy type (e.g. grants, feed-in tariffs, tax incentives), topics (e.g. renewable energy, energy efficiency) and technologies (e.g. solar, wind, bio, geothermal) (IEA, n.d.).

According to several scholars' public policies are relevant to explain development in renewable energy globally and regionally (Aguirre & Ibikunle, 2014; Liu et al., 2019; Marques & Fuinhas, 2012a, 2012b; Marques et al., 2010; Polzin et al., 2015; Zhao et al., 2013). The public policies are measured by counting the number of active policies in a country per year (Johnstone et al., 2010; Liu et al., 2019; Polzin et al., 2015). These policy counts have been termed ‘accumulated number of renewable energy policies and measures’ by previous studies (Aguirre & Ibikunle, 2014; Liu et al., 2019; Marques & Fuinhas, 2012a; Polzin et al., 2015).

The policy data were also structured by one aggregated group and three sources: all renewable energy (aggregated), wind energy, solar energy and bioenergy. In addition, the policies were categorised in five aggregated and twelve specific policy instruments:

- Fiscal and financial incentives which includes three specific policy instruments: (1) Price policy, (2) Grants and subsidies and (3) Tax incentives.

- Market-based instruments which includes two specific policy instruments: (1) GHG emission allowances and (2) Green certificates.

- Direct investment which includes two specific policy instruments: (1) Funds to sub-national government and (2) investments in infrastructure.

- Policy support which includes two specific policy instruments: (1) Institutional creation and (2) targets and strategic planning.

- Regulatory instruments which include three specific policy instruments: (1) Codes and standards, (2) Obligation schemes and (3) Regulation.

Collecting accurate data from a large number of countries and over long periods can be challenging. The data from the IEA/IRENA Renewable Energy Policies and Measures Database are not exhaustive and might not be up to date for all countries. The policies had to be categorised manually across five aggregated and twelve specific policy instruments. Thus, errors are possible when collecting the policy data: irrelevant policies can have been included, relevant policies can have been excluded and policies can have been placed in the wrong policy instrument. These types of errors are minimised because all policies in the IEA/IRENA Renewable Energy Policies and Measures Database contains information, as described above, in order to identify the policy. To handle the challenge with accurate data from a large number of countries and long periods, Zhao et al. (2013) created dummy variables for the policy variable in their study, where the dummy variable takes the value of 1 when a policy is implemented and 0 prior to implementation. The dummy variables only measure if a country have implemented a renewable energy policy or not (controlling for their presence), and not the effect or intensity of the renewable energy policy, which this study is considered with. Besides, one can assume that collecting accurate data is less scarce due to the more recent time period of this thesis contra the time period used in previous studies.

3.2.3 Control variables

A selection of control variables is included in the model to rule out alternative explanations that might drive renewable energy capacity additions. Following previous quantitively studies analysing the effect of public renewable energy policies, the following control variables are included in the regression model: carbon intensity (Liu et al., 2019; Marques & Fuinhas, 2012a; Polzin et al., 2015; Zhao et al., 2013), GDP (Aguirre & Ibikunle, 2014; Liu et al., 2019; Marques et al., 2010; Polzin et al., 2015; Zhao et al., 2013) and total electricity consumption per capita (Johnstone et al., 2010; Liu et al., 2019; Marques et al., 2010; Polzin et al., 2015; Zhao et al., 2013). The control variables are drawn from the World Bank DataBank (carbon intensity and GDP) and Our World in Data (electricity consumption).

Carbon intensity is measured by CO_2 emission in kg per purchasing power parity (PPP) in USD of GDP. Carbon intensity shows how much CO_2 a country emits per dollar of GDP. It is possible that a country brings out more incentives towards development of renewable energy the greater the carbon intensity (Popp et al., 2011; Zhao et al., 2013). The variable can be an indicator of environmental concerns since it may be expected that environmental concern drive development of renewable energy (Aguirre & Ibikunle, 2014).

To control for a country's income, GDP in USD is included in the regression model. It can be assumed that the economic standing in a country will influence renewable energy capacity. For example, higher income countries can have the ability to invest more in renewable energy since they can afford the cost of developing renewable energy (Aguirre & Ibikunle, 2014; Romano et al., 2017; Zhao et al., 2013).

Electricity consumption is measured by electricity consumption (in kWh) per capita. The variable is used to account for differences in energy needs and consumption (Marques et al., 2010; Polzin et al., 2015). Johnstone et al. (2010) believe that growing electricity consumption should increase incentives aimed at promoting development in renewable energy.

3.2.4 Lag structure

In longitudinal studies policies can be expected to have a direct or delayed impact on the dependent variable. Often policies are announced before being set active, which can give investors time to have their projects ready when the policy goes into effect. This can allow for an immediate effect on renewable energy capacity. On the other hand, the time needed to construct solar parks or wind farms and get access to the grid can delay the investment process and policy effectiveness (Polzin et al., 2015). Panel data allows us to account for the delayed impact by including a lag procedure in the regression model (Wooldridge & Wooldridge, 2020).

A lag procedure of zero to three years is added to the dependent variable (Liu et al., 2019; Polzin et al., 2015; Wall et al., 2019).

3.3 Panel data regression

A benefit of using panel data models is that it can control for possible time-invariant unobserved heterogeneity. This is in comparison to time-series and cross-section studies who do not control for this unobserved heterogeneity and risk obtaining biased results (Baltagi, 2005; Tsionas & Tsionas, 2019). There are three possible technique that can be used in this study to analyse panel data: Pooled OLS, fixed effects and random effects.

Pooled OLS is a basic OLS (Ordinary Least Squared) that ignores time and individual characteristics; that is, it treats the observations as one large cross-section (Wooldridge & Wooldridge, 2020). In general, Pooled OLS is not a suitable method except if the time-invariant variables capture individual heterogeneity (Musau, n.d.). The fixed effects model asses the relationship between the independent variable and the dependent variables within an entity, where each entity has its own individual characteristics that may influence the independent variable. Fixed effects assumes that something within the individual could bias or influence the independent or outcome variable that should be controlled for, for example the political system of a country may have some effect on GDP. Time-invariant differences between the individuals is controlled for in the fixed effects model (Torres-Reyna, 2007). This means that fixed effects are consistent even in the presence of time-invariant country effects that are correlated with the regressor. Liu et al. (2019) and Torres-Reyna (2007) point out that one limitation with the fixed effects model when addressing panel data is that it cannot be used to examine time-invariant causes of the dependent variable. Unlike fixed effects model, the random effects model assumes that the variation across entities is random and uncorrelated with the independent variables (Torres-Reyna, 2007; Wooldridge & Wooldridge, 2020). Individual characteristics that could influence the independent variables thus needs to be specified in random effects. This can be an issue because a relevant variable can be left out of the model causing omitted-variable bias. Random effects allow for time-invariant variables to take part as independent variable, which is an advantage of random effects (Torres-Reyna, 2007).

Random effects are generally preferred to pooled OLS and fixed effects are usually always more convincing than random effects for policy analysis using aggregated data (Wooldridge & Wooldridge, 2020). Due to this, fixed effect model is selected to be used in this study.

To deal with heteroskedasticity and autocorrelation robust/clustered standard errors are used in the fixed effects model (Stock & Watson, 2008). The xtreg command in Stata is used. All regressions control for country and year fixed effects.

The analysis in this study proceeds as follow:

1. Data is structured to meet the requirement of panel data, and the quality and nature of the data were examined.
2. Control variables were log transformed due to large numbers.

3. Standard errors are corrected for heteroskedasticity and autocorrelation by using the xtreg command and by clustering countries.
4. The regression was run on all renewable energy, solar energy, bioenergy and wind energy
5. A lag procedure of one to three years is added to the dependent variable.
6. The regression analysis is repeated but with a subsample of developed countries and countries in transition and developing countries separately.
7. The results are analysed on aggregated level and on sectoral level.
8. The results on developed countries and countries in transition and developing countries is compared.

Econometric model with fixed effects:

$$Y_{it} = \sum_{i} \alpha_i + \sum_{t} \mu_t + \beta(X_{it}) + \gamma(C_{it}) + \varepsilon_{it}$$

where Y_{it} is the total installed renewable energy capacity (in MW) in country i and year t $(i = 1, \cdots, N-1; t = 1, \cdots, T-1)$, X is a vector of independent variables representing renewable energy policy measures, C is a vector of control variables, the indicators α_i are country fixed effects controlling for time-invariant factors associated with each individual country, the indicators μ_t are year fixed country effects controlling for country-invariant factors associated with each year and ε_{it} is the stochastic error term. Following Polzin et al. (2015) lags l of one to three years is included in the regression for the analysis of time-dependent phenomenon.

3.4 Reliability and validity

Reliability and validity considerations are included throughout the methodology chapter (chapter 3) and in the results chapter (Chapter 4).

4.0 Results

The aim of this study is to discover the influence of different policy instruments on the installed capacity of renewable energy and to further look into the differences of policy influence in developed countries and countries in transition and developing countries. Table 1 presents the panel data analysis results for all 123 countries, in Table 2 data for developed countries is presented and in Table 3 the data for countries in transition and developing countries is presented. The results show positive and negative effects of the regression on renewable energy capacity. The results are reported based on a time lag of 3 years.

The results show no statistically significant relationship between price policy, mainly consisting of feed-in tariffs and feed-in premiums, and renewable energy capacity, which is an unexpected result. The coefficient of grants and subsidies is only statistically significant for bioenergy with a lag of three years and only for wind energy immediately. Tax incentives has a positive effect on bioenergy capacity immediately and a positive effect on wind energy capacity with a lag of three years.

GHG emission allowances show a strong statistically significant result at the 1% level for wind energy and all renewable energy. Also, GHG emission allowances demonstrates a significant result at the 1% level for solar energy capacity immediately. Green certificates show no statistically significant effect.

Funds to sub-national government have a negative effect on all renewable energy capacity and solar energy capacity. Investment in infrastructure and institutional creation show no statistically significant effect. The parameter measuring the effect of targets and strategic planning has a strong positive effect on renewable energy capacity.

Table 1. Fixed effects regression results. Data for all 123 countries with 3 years lag.

Independent variables	Fixed effects							
	Multiple RE		Solar		Bio		Wind	
	Coeff.	*t*	Coeff.	*t*	Coeff.	*t*	Coeff.	*t*
EI_FI_PP	-153.8	(-0.26)	412.0	(1.18)	50.40	(0.98)	-828.3	(-1.58)
EI_FI_GS	-14.55	(-0.04)	94.77	(0.56)	79.53**	(2.12)	267.2	(1.17)
EI_FI_TI	-11.39	(-0.01)	-98.80	(-0.23)	171.7	(1.43)	641.3**	(2.41)
EI_MI_EA	8276.4***	(3.36)	599.1	(0.96)	169.8	(1.17)	5867.1***	(2.82)
EI_MI_GC	-1534.8	(-0.40)	-693.4	(-0.62)	9.693	(0.04)	158.3	(0.08)
EI_DI_FSG	-4929.5**	(-2.31)	-654.4*	(-1.95)	-47.92	(-0.24)	-1217.6	(-1.17)
EI_DI_II	500.9	(0.38)	-458.6	(-0.99)	59.51	(0.46)	211.8	(0.38)
PS_IC	221.8	(0.08)	-324.1	(-0.69)	-151.4	(-1.11)	-986.8	(-0.82)
PS_TSP	4534.5***	(3.00)	392.9**	(2.26)	100.6**	(2.00)	1489.6***	(2.96)
RI_CS	3125.5***	(3.21)	652.9**	(2.41)	102.6*	(1.82)	2201.3***	(3.03)
RI_OS	-2463.1*	(-1.86)	-128.6	(-0.28)	-51.84	(-0.27)	869.5	(1.64)
RI_R	-971.7	(-1.43)	95.75	(0.60)	-151.4	(-1.62)	-430.7	(-1.18)
Control variables								
c_CI	62.68	(0.35)	-56.16	(-1.40)	-23.82	(-1.43)	-34.20	(-0.41)
c_GDP	55.68	(0.48)	-25.65	(-0.79)	-2.789	(-0.30)	-18.82	(-0.36)
c_EC	39.44	(0.19)	-52.97	(-1.13)	-1.512	(-0.14)	-26.64	(-0.17)
Observations	1812		1812		1737		1812	
Countries	123		123		118		123	
R-squared	0.940		0.521		0.888		0.780	

Dependent variable in all models is 3 period lag capacity in megawatts. All models control for country and year fixed effects. *t* statistics in parentheses. Standard errors are clustered at the country level. The "Multipe RE" category includes all renewable energy sources, i.e., solar, wind, bio, geothermal, hydro and marine. ***, **, * denote significance at the 1, 5, and 10 percent levels, respectively. xtreg command was used.

The results suggests that codes and standards is significant for renewable energy capacity, with its effect most noticeable for wind energy and all renewable energy. Obligation schemes shows a negative effect on all renewable energy. Lastly, the results for regulation indicate an immediate negative effect for bioenergy capacity, while after three years no statistically significant effect is shown for bioenergy.

The control variables, carbon intensity, GDP and total electricity consumption per capita, included in the regression analysis are not statistically significant.

In the next part, shown in Table 2 and Table 3, the regression analysis is repeated but with data on developed countries and countries in transition and developing countries separately.

Price policy is significantly present for only solar energy with a lag of three years and only for all renewable energy immediately in developed countries. Developed countries have a negative and statistically significant effect between green certificates and bioenergy capacity and all renewable energy capacity with a lag of three years and no statistically significant effect immediately. Also, investments in infrastructure shows a negative effect on renewable energy capacity in developed countries. For this policy instrument the negative effect is for solar energy and all renewable energy. Funds to sub-national government and regulations demonstrates a negative effect on bioenergy capacity only immediately. Target and strategic planning have a positive effect on wind energy capacity. Similarly, codes and standards only affect wind energy specifically as well as renewable energy capacity in multiple renewable energy.

The regression analysis finds five policy instruments that have no effect on renewable energy capacity in developed countries – grants and subsidies, tax incentives, GHG emission schemes, institutional creation and codes and standards. For countries in transition and developing countries four policy instruments have no effect on renewable energy capacity – price policy, green certificates, funds to sub-national government and institutional creation.

The control variables, carbon intensity, GDP and total electricity consumption per capita, included in the regression analysis are not statistically significant in both country groups.

The results for grants and subsidies for countries in transition and developing countries demonstrates a strong statistically significant effect immediately for bioenergy, wind energy and all renewable energy. This effect is removed with a lag of three years except for bioenergy who still demonstrates a statistically significant effect, however, the effect is diminished from 1% level to 5% level. Tax incentives shows an effect on bioenergy capacity. This effect also diminishes with a lag of three years.

Investment in infrastructure shows a positive and significant impact on only solar energy capacity. On the contrary to the results on targets and strategic planning in developed countries, target and strategic planning has a strong positive effect on renewable energy capacity in countries in transition and developing countries. Further the results demonstrates that codes and standards have a positive significant effect on renewable energy capacity except for bioenergy capacity where the results show no significant effect.

For countries in transition and developing countries the results on obligation schemes suggests a negative effect on all renewable energy capacity and the results on regulation show a negative effect on bioenergy capacity.

From the analysis of the estimation results, it can be observed that public renewable energy policies have more impact on renewable energy capacity in countries in transition and developing countries than developed countries. This results confirms the observations in Romano et al. (2017) who shows that developing countries appear to make better use of energy policies than developed countries.

Table 2. Fixed effects regression results. Results for developed countries with 3 years lag.

Independent variables	Fixed effects							
	Multiple RE		Solar		Bio		Wind	
	Coeff.	*t*	Coeff.	*t*	Coeff.	*t*	Coeff.	*t*
EI_FI_PP	1663.3	(1.64)	1099.3*	(1.86)	71.17	(1.01)	3.257	(0.01)
EI_FI_GS	742.0	(1.32)	64.36	(0.37)	2.293	(0.05)	-53.02	(-0.22)
EI_FI_TI	-1891.2	(-0.96)	1173.5	(0.83)	-93.09	(-0.42)	1091.2	(0.94)
EI_MI_EA	3306.4	(1.03)	-1317.3	(-1.19)	-35.17	(-0.13)	3286.2	(1.19)
EI_MI_GC	-3323.0*	(-1.93)	-1274.6	(-1.17)	-358.7**	(-2.55)	-1129.7	(-1.23)
EI_DI_FSG	-4528.9	(-1.60)	-506.0	(-1.04)	-301.0	(-0.88)	-2077.8	(-1.44)
EI_DI_II	-2924.1*	(-1.74)	-2529.4*	(-2.01)	7.080	(0.03)	1277.6	(0.59)
PS_IC	3460.3	(0.73)	492.3	(0.41)	-131.5	(-0.83)	2371.9	(1.60)
PS_TPS	472.4	(0.72)	532.9	(0.89)	47.21	(0.38)	920.9*	(1.90)
RI_CS	1565.6***	(3.09)	885.6	(1.10)	121.9	(1.44)	1592.7***	(3.62)
RI_OS	1426.2	(1.61)	-803.3	(-1.24)	155.0	(1.09)	949.3	(1.31)
RI_R	-74.71	(-0.13)	-339.6	(-0.72)	-96.37	(-1.65)	-160.5	(-0.33)
Control variables								
c_CI	193.0	(1.02)	-11.89	(-0.12)	-6.947	(-0.55)	-210.6	(-1.38)
c_GDP	221.6	(0.67)	101.5	(0.68)	36.61	(1.01)	187.2	(1.21)
c_EC	-242.5	(-0.92)	-118.2	(-1.04)	11.47	(0.51)	-299.3	(-0.99)
Observations	525		525		495		525	
Countries	35		35		33		35	
R-squared	0.947		0.583		0.932		0.784	

Dependent variable in all models is 3 period lag capacity in megawatts. All models control for country and year fixed effects. *t* statistics in parentheses. Standard errors are clustered at the country level. The "Multipe RE" category includes all renewable energy sources, i.e., solar, wind, bio, geothermal, hydro and marine. ***, **, * denote significance at the 1, 5, and 10 percent levels, respectively. xtreg command was used.

Table 3. Fixed effects regression results. Results for countries in transition and developing countries with 3 years lag.

Independent variables	Fixed effects							
	Multiple RE		Solar		Bio		Wind	
	Coeff.	*t*	Coeff.	*t*	Coeff.	*t*	Coeff.	*t*
EI_FI_PP	-502.9	(-0.61)	-80.21	(-0.93)	11.92	(0.19)	-946.8	(-1.61)
EI_FI_GS	701.8	(1.06)	-249.6	(-1.07)	245.5**	(2.56)	649.3	(1.61)
EI_FI_TI	-648.1	(-0.31)	-288.9	(-0.85)	273.6*	(1.85)	271.8	(0.90)
EI_MI_EA	29051.2*	(1.69)	2803.7*	(1.92)	103.0	(0.22)	16404.0**	(2.62)
EI_MI_GC	138.7	(0.02)	1295.2	(0.77)	508.3	(1.19)	2268.1	(0.83)
EI_DI_FSG	-3131.3	(-0.91)	-185.0	(-0.50)	-57.97	(-0.24)	95.56	(0.12)
EI_DI_II	-615.7	(-0.34)	242.7**	(2.09)	-3.161	(-0.02)	-812.1	(-1.22)
PS_IC	-4476.1	(-1.41)	-374.7	(-1.23)	-258.0	(-1.30)	-2545.0	(-1.39)
PS_TSP	4543.8**	(2.61)	275.5**	(2.47)	101.3***	(2.91)	1280.6***	(2.71)
RI_CS	2750.2**	(2.24)	410.6*	(1.84)	23.69	(0.31)	1683.8*	(1.78)
RI_OS	-3130.1*	(-1.76)	645.1	(1.22)	-327.5	(-0.76)	2238.7	(1.31)
RI_R	-1257.0	(-1.44)	24.16	(0.14)	-241.5*	(-1.70)	-566.5	(-1.49)
Control variables								
c_CI	153.7	(0.98)	13.98	(0.72)	-25.91	(-1.18)	42.54	(0.67)
c_GDP	74.95	(0.64)	2.899	(0.26)	-11.69	(-0.97)	21.91	(0.50)
c_EC	108.5	(0.50)	8.637	(0.38)	-1.802	(-0.16)	12.16	(0.20)
Observations	1287		1287		1242		1287	
Countries	88		88		85		88	
R-squared	0.955		0.599		0.831		0.835	

Dependent variable in all models is 3 period lag capacity in megawatts. All models control for country and year fixed effects. *t* statistics in parentheses. Standard errors are clustered at the country level. The "Multipe RE" category includes all renewable energy sources, i.e., solar, wind, bio, geothermal, hydro and marine. ***, **, * denote significance at the 1, 5, and 10 percent levels, respectively. xtreg command was used.

5.0 Discussion

5.1 Fiscal and financial incentives

The class “Fiscal and financial incentives” includes the policy incentives price policy (PP), grants and subsidies (GS) and tax incentives (TI). It should be noted that the price policy incentive includes primarily feed-in tariffs and feed-in premium. Feed-in tariffs has been one of the most widely used incentive to promote development of renewable energy (Marques & Fuinhas, 2012a).

The effect of fiscal and financial incentives differs when analysing the results from the specific sectors and specific policy instruments. Liu et al. (2019), Polzin et al. (2015), Zhao et al. (2013) and others highlight the strong effectiveness of feed-tariffs in promoting renewable energy capacity. Thus, one unexpected finding is that price policies are not statically significant in promoting renewable energy capacity across all renewable energy sources. However, the findings in this study is similar to the findings in a study by Aguirre and Ibikunle (2014), who report that feed-in tariffs is not a statistically significant factor influencing renewable energy growth on a country level. Moreover, Romano et al. (2017) state that feed-in tariffs seems to have lost some of its driving force in the industry over time and that the promotion effect now has foregone. When conducting the panel analysis with only developed countries price policies are significant on stimulating deployment in the solar sector in the long-term and across multiple renewable energy sectors in the short term. The positive and significant effect of price policy on solar confirms the findings in Johnstone et al. (2010), who shows that feed-in tariffs affect innovation of solar power. Wall et al. (2019) conducted a study to find out which policy instruments attract foreign direct investments in renewable energy across OECD countries and non-OECD countries. They find that feed-in tariffs had a greater effect on OECD countries than large middle-income non-OECD countries. This can indicate that the contradicting aggregated results is due to the inclusion of low-income countries in the sample in this study whereas previous studies seldom include low-income countries in their sample. Furthermore, it can be that developing countries has yet to exhibit effects of the price policies implemented (Romano et al., 2017).

Second, the aggregated results show that grants and subsidies is significant for bioenergy. For the countries in transition and developing countries grants and subsidies have an immediate effect on wind and multiple renewable energy in addition to biomass, but the results do not show an effect on wind and multiple renewable energy in the long term. This demonstrate that grants and subsidies prove to be effective as a short time measure and confirms the findings in Polzin et al. (2015). The results were not statistically significant for developed countries. This finding contributes to confirm earlier work who observe that grants and subsidies is effective in the diffusion stages to ease fiscal constraints (Liu et al., 2019; Polzin et al., 2015). A possible explanation for the different results among the two subsamples is that investors perceive the risk as lower in countries that have longer experience with renewable energy and longer history with renewable energy policies. As a result, these countries might have less need for development finance such as grants and subsidies than countries that are in their beginning of their renewable energy development (Demôro et al., 2020; Romano et al., 2017).

Last, the evidence for the effectiveness of tax incentives is provided. According to the results this type of incentive does promote renewable energy capacity in the wind sector. Previous studies have revealed mixed evidence on the effect of tax incentives on renewable energy. Both Liu et al. (2019) and Johnstone et al. (2010) found that tax incentives had no significant effect in promoting renewable energy, while Polzin et al. (2015) and Wall et al. (2019) on the other hand found a significant effect of tax incentives on investments in renewable energy. Zhao et al. (2013) found that tax incentives have a positive effect on electricity generation only from biomass and waste sources. Kanellakis et al. (2013) reviewed renewable energy policies in Europe and state that tax instruments are powerful when implemented in combination with other policy instruments. A reason for the ambivalent results of tax instruments is that tax incentives tend to depend upon public finance which investors regards as an uncertain factor since they might not be as long-term as incentives without a direct link to public finance (Johnstone et al., 2010). Incentives that depend on public finance can abruptly be withdrawn with a change in administration (Aguirre & Ibikunle, 2014; Johnstone et al., 2010). The Production Tax Credit for wind power in the United States (US) and the tax incentives in the Netherlands is good examples that tax instruments can create uncertainty. A boom-bust cycle in investments in wind technology in the US, which also were believed to damage the industry prospects, occurred because the Production Tax had a pattern of repeated expiration and short-term renewal (Aguirre & Ibikunle, 2014; Liu et al., 2019). In the Netherlands the substantial investments in renewables have been hindered because the tax incentives have been applied in a ‘stop-and-go’ manner, thus failing to reduce market uncertainty (Gan et al., 2007).

5.2 Market-based instruments

This analysis furthermore report evidence for the market-based instruments GHG emission allowances and green certificates.

For GHG emission allowances results on multiple renewable energy as well as results from wind sector shows a strong positive influence on renewable energy capacity at 1 percent significant level. Market-based systems have been mentioned to be the preferred instrument for investors, especially if they are less dependent on policy changes (Polzin et al., 2015). Liu et al. (2019) conducted a panel data analysis to assess the effect of renewable energy policy in 29 countries for the period 2000 – 2015, finding that market-based instruments as a whole has a strong effect on renewable energy capacity, while GHG emission allowances and green certificates alone did not have a significant effect. Liu et al. (2019) argues that this indicates that a combination of policies has a synergy effect and that the combination of the two policies is one of the most effective incentives to promote renewable energy. Wall et al. (2019) also find that emission trading schemes and renewable energy certificates were not significant for attracting foreign direct investment at the aggregated level. At the sector level, emission trading schemes had a positive association only with solar. Furthermore, Wall et al. (2019) found that emission trading schemes had a positive and significant effect on foreign direct investment in renewables in large middle-income non-OECD countries. In the case of countries in transition and developing countries in this study, GHG emission allowances indicate a positive and statistically significance on renewable energy capacity for multiple renewable energy, solar and wind. This results is in accordance with evidence by Wall et al. (2019) mentioned above. Conversely, GHG emission allowances are not significant for promoting renewable energy capacity in developed countries.

On the aggregated level green certificates show no statistical significance on renewable energy capacity. For developed countries, green certificates show a negative effect on bioenergy. This research confirms findings in existing research that also show no impact of green certificates on support of renewable energy (Liu et al., 2019; Marques & Fuinhas, 2012a; Polzin et al., 2015; Wall et al., 2019) and a negative effect on biomass (Wall et al., 2019).

5.3 Direct investments

Direct investments include funds to sub-national government and investments in infrastructure. Funds to sub-national government seem to have a negative effect on multiple renewable energy and solar. Polzin et al. (2015), who reports similar results as this study on the effect of funds to sub-national governments, argue that a possible explanation for the negative effect on solar energy capacity is a result of investors ignoring subsidies on a local level.

Investments in infrastructure demonstrates to have no effect on renewable energy capacity on an aggregated level. This finding is in accordance with both Liu et al. (2019) and Polzin et al. (2015) who report that direct investments is ineffective in growing renewable energy capacity. However, previous literature highlights that infrastructure have an effect on renewable energy capacity since a lack of energy infrastructure is a bottleneck for the expansion of renewable energy (IEA, 2021b; Steinbach, 2013). On the sectoral level, investment in infrastructure is significantly present in solar in both subsamples, although with a positive effect on countries in transition and developing countries and a negative effect on developed countries. Many developing countries lag far behind on grid infrastructure, in contrast to many developed countries, and are currently in an ongoing process of expanding grid infrastructure (Bos et al., 2018). Also, countries in transition and developing countries have the largest share of solar power capacity and an enormous solar potential (IRENA, n.d.). This can be possible explanations for the different results among the two subsamples.

5.4 Policy support

The study also provides evidence for policy support which includes institutional creation and targets and strategic planning. From the evidence institutional creation appears to be ineffective in promoting renewable energy capacity. This result confirms the findings reported Liu et al. (2019), while Polzin et al. (2015) reports mixed results demonstrating that institutional creation had a positive effect in the biomass sector and a negative effect in the solar sector. On the other hand, targets and strategic planning demonstrate a positive and statistically significant effect on renewable energy capacity in all sectors. The reason for this positive and significant effects is suggested in previous research to be due to the long-term time frame and the clear visions strategic policies tend to have (Dong, 2012; Liu et al., 2019; Polzin et al., 2015). Targets and strategic planning also shows a political will of developing renewables (Marques & Fuinhas, 2012a). The findings in this study support the empirical evidence that strategies to include renewables in the energy mix and long-term commitment in policies plays a strong role in an effective policy mix. When analysing results from the subsamples targets and strategic planning have a strong positive coefficient across all sources for countries in transition and developing countries. For developed countries targets and strategic planning is only significant for wind. Capital can be up to seven-times more expensive in developing countries than in developed countries (IEA, 2021b). And, if countries rank low on political stability, effectiveness of governing bodies and rule of law, targets and strategic plans that establishes a reliable framework with a clear vision and long-term policy objectives can thus act as an opposite pole. If targets and strategic planning are accompanied by specific renewable energy policies, it can have a great effect on renewable energy capacity. Chile and India are example of countries that have managed to make the country attractive to renewable energy investors and hence grow their renewable energy capacity by setting ambitious renewable energy targets and establish a policy framework (Demôro et al., 2020; IEA, 2021a).

Finally, Liu et al. (2019) and Marques and Fuinhas (2012a) assessed policy support on an aggregated level (the combination of institutional creation and strategic planning), finding that policy support has an effect and are significant in promoting renewable energy capacity. Liu et al. (2019) argue that institutional creation might promote the effect of strategic planning since the results indicates that the aggregated policy group demonstrated more significance than strategic planning alone. To summarise, long-term vision in policies through targets and strategic planning in combination with institutional creation appear to strongly support the renewable energy investment environment.

5.5 Regulatory instruments

The class of regulatory instruments includes codes and standards, obligation schemes and regulations.

Codes and standards demonstrate a positive and statistically significant effect in promoting renewable energy for multiple renewable energy and on the source level. In developing countries codes and standards have a positive association with promotion of renewable energy capacity in the wind sector and multiple renewable energy. This result supports the study conducted on OECD countries by Polzin et al. (2015) who found that codes and standards attract renewable energy investors. The results in this study can furthermore be confirmed for a sample of countries beyond OECD countries except for the bioenergy sector where codes and standards demonstrated no effect on countries in transition and developing countries. Similar to targets and strategic planning, codes and standards are mostly long-term incentives. Renewable energy instruments with a timeframe of five to ten years are suggested to be necessary for an incentive to be a positive reinforcement for actors to invest. Shorter timeframes for an incentive tend to be related with policy uncertainty (Aguirre & Ibikunle, 2014; Liu et al., 2019).

This study finds that obligation schemes have a negative effect on multiple renewable energy capacity and no effect on the subsources. Quotas in obligation schemes can generally be met by any renewable energy source, which can explain no effect on the subsources (Dong, 2012). Other empirical results finds that obligations tend to be effective in promoting investment in renewable energy. According to Wall et al. (2019) obligations attract foreign direct investment in renewable energy on the aggregated level, but not on the sectoral level. Furthermore, Menz and Vachon (2006) finds that obligations are effective in promoting wind power development in the United States, and similar Johnstone et al. (2010) reports that obligations have a positive effect on patenting of wind power. The results in this study is in accordance with Carley (2009) and Marques and Fuinhas (2012a) who find no significant evidence that obligations increase renewable energy generation.

Last, the results in this study indicate that regulations have an immediate negative effect on bioenergy capacity. With a lag of three years, regulations are not statistically significant on bioenergy capacity except for countries in transition and developing countries who with a lag of three years still indicate a negative effect on bioenergy capacity. Regulations have no effect on stimulating renewable energy capacity for multiple renewable energy. This results confirms the evidence by Liu et al. (2019) and Marques and Fuinhas (2012a), who report that regulatory instruments are not significant in promoting renewable energy capacity.

6.0 Conclusion

This study has investigated the effect of renewable energy policies on renewable energy capacity (in MW). Panel data regression have been applied to 123 countries for the period 2001 – 2018 to address the research question. First, all countries were analysed together. Then, the sample were divided into two subsamples, developed countries and countries in transition and developing countries, to investigate the difference between the two subsamples.

This analysis demonstrates that the effectiveness of renewable energy policy varies by policy instruments, renewable energy source and subsample.

Within this framework, targets and strategic planning, codes and standards and GHG emission allowances are policy incentives with the most effect on renewable energy capacity. Only targets and strategic planning and codes and standards are found to have a positive and statistically significant effect on renewable energy capacity for all types of renewable energy sources considered in this study. Reasons why targets and strategic planning and codes and standards have a strong positive effect on renewable energy capacity is because these policy instruments tend to be long-term, stable and reliable support mechanisms which impact the investment risk of renewable energy projects. GHG emission allowances is a market-based incentive that tend to be less dependent on public budgets, this is argued to be a factor for the positive effect on renewable energy capacity.

Price policy, green certificates, institutional creation and investment in infrastructure were found to have no effect on renewable energy capacity for all types of renewable energy sources considered in this study. Especially the finding for price policy in this study is an unexpected results as previous research have found price polies, such as feed-in tariffs, to have a significant effect on promoting renewable energy.

This study reveals that renewable energy polices have more impact on renewable energy capacity in countries in transition and developing countries than in developed countries. Developed countries, countries in transition and developing countries are in different stages of their renewable energy development. It is argued that renewable energy policies are more effective in countries in transition and developing countries because these countries tend to be in the starting block of renewable energy development and are thus in greater need of support policies to develop renewable energy capacity.

There are several limitations regarding this study. First, this study does not allow for statements concerning synergy effects among specific policies as this study assessed specific policies. Second, the quantitative design does not allow for in-depth analysis and conclusions to be drawn. In addition, this study cannot analyse the effectiveness of a certain policy in one country compared to another. Last, the sample does not cover the most recent data on renewable energy capacity (2019 and onwards). Several incidents occurred after 2018 that can impact renewable energy capacity: (1) Covid-19 pandemic, (2) Russia's invasion of Ukraine, (3) high gas, oil and electricity prices and (4) vulnerability of renewable energy due to issues with input factors limiting renewable energy production, for example windless air harming wind energy production.

Possibilities for further research are to: (1) comparatively assess the effectiveness and intensity of policy instruments in certain developed countries with developing countries and (2) extend the timeframe to include more recent years.

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Appendix A

Appendix A1: Country selection and definition

Countries are classified in three categories after the World Economic Situation and Prospects (WESP) annex by Department of Economic and Social Affairs of the United Nations Secretariat (UN/DESA). The three categories are: developed countries, countries in transition and developing countries, and reflect the economic country conditions (World Economic Situation and Prospects, 2014).

Developed countries is defined as "countries that are highly industrialised and highly efficient, and whose people enjoy a high quality of life" (Wild & Wild, 2020, p. 130).

Countries in transition is defined as countries with "an economy that is in the process for change from a centrally planned (socialist) economy to a market economy" (Gurkov, 2015, p. 1).

Developing countries is defined as countries "with the poorest infrastructures and lowest personal incomes. (…) They might show potential of becoming newly industrialised countries, but typically lack the necessary resources and skills to do so" (Wild & Wild, 2020, p. 131).

Table A1. Country selection

Developed countries	Countries in Transition	Developing countries
Australia	Albania	Algeria
Austria	Azerbaijan	Angola
Belgium	Belarus	Argentina
Bulgaria	Bosnia and Herzegovina	Armenia
Canada	Georgia	Bangladesh
Croatia	Kazakhstan	Bolivia
Cyprus	Kyrgyzstan	Botswana
Czechia	Montenegro	Brazil
Denmark	Russia	Brunei Darussalam
Estonia	Serbia	Burkina Faso
Finland	Tajikistan	Burundi
France	Ukraine	Chile
Germany	Uzbekistan	China
Greece		Colombia
Hungary		Costa Rica

Ireland	Djibouti
Italy	Dominican Republic
Japan	Ecuador
Latvia	Egypt
Lithuania	El Salvador
Luxembourg	Ethiopia
Malta	Ghana
Netherlands	Guatemala
New Zealand	Guyana
Norway	Honduras
Poland	India
Portugal	Indonesia
Romania	Iran
Slovakia	Iraq
Slovenia	Israel
Spain	Jamaica
Sweden	Jordan
Switzerland	Kenya
United Kingdom	Kuwait
United States of America	Lebanon
	Lesotho
	Libya
	Madagascar
	Malawi
	Malaysia
	Mali
	Mauritius
	Mexico
	Morocco
	Mozambique
	Myanmar
	Namibia
	Nepal
	Nicaragua
	Nigeria
	Oman
	Pakistan
	Panama
	Paraguay
	Peru
	Philippines
	Rwanda
	Saudi Arabia
	Senegal
	Singapore
	South Africa
	South Korea
	South Sudan
	Tanzania
	Thailand
	Tunisia
	Turkey
	Uganda
	United Arab Emirates
	Uruguay
	Venezuela
	Vietnam
	Yemen
	Zambia
	Zimbabwe

Appendix A2: Data definition, sources and descriptive statistics

Appendix A3: Summary of results

Table A2. Data definition, sources and descriptive statistics.

Category	Variable	Definition	Source	Obs.	Mean	Std. dev.	Min	Max
Dependent variables	Capacity_ALL	Total installed renewable energy capacity in MW (sources: solar, wind, bio, geothermal, hydro and marine)	IRENA database	2,125	10661.3	36710.5 3	.01	695488.2
	Capacity_Solar	Total installed solar power capacity in MW	IRENA database	1,647	1216.72	7356.66	.01	175286.9
	Capacity_Bio	Total installed bioenergy capacity in MW	IRENA database	1,643	724.23	1832.80	.03	14818.79
	Capacity_Wind	Total installed wind power capacity in MW	IRENA database	1,300	2996.73	12234.2	.01	184664.9
Independent variables								
Economic instruments – Fiscal and Financial incentives (EI_FI)	EI_FI_PP	Number of active price policies	IEA/IRENA Renewable Energy Policies and Measures Database	4,524	1.77	1.20	1	6
	EI_FI_GS	Number of active grants and subsidies	IEA/IRENA Renewable Energy Policies and Measures Database	6,672	2.84	2.85	1	22
	EI_FI_TI	Number of active tax incentives	IEA/IRENA Renewable Energy Policies and Measures Database	5,502	1.7	1.20	1	10
Economic instruments – Market-based instruments (EI_MA)	EI_MA_EA	Number of active GHG emission allowances	IEA/IRENA Renewable Energy Policies and Measures Database	2,694	1.01	.11	1	2
	EI_MA_GC	Number of active green certificates	IEA/IRENA Renewable Energy Policies and Measures Database	912	1.42	.66	1	3
Economic instruments – Direct investments (EI_DI)	EI_DI_FSG	Number of active funds to sub-national government	IEA/IRENA Renewable Energy Policies and Measures Database	540	1.38	.64	1	4
	EI_DI_II	Number of active investments in infrastructure	IEA/IRENA Renewable Energy Policies and Measures Database	2,676	1.38	.95	1	8
Policy support (PS)	PS_IC	Number of institutional creations	IEA/IRENA Renewable Energy Policies and Measures Database	1,800	1.18	.39	1	3
	PS_TSP	Number of targets and strategic planning	IEA/IRENA Renewable Energy Policies and Measures Database	7,638	2.52	2.75	1	37
Regulatory instruments (RI)	RI_CS	Number of codes and standards	IEA/IRENA Renewable Energy Policies and Measures Database	5,640	2.55	2.86	1	24

	RI_OS	Number of obligation schemes	IEA/IRENA Renewable Energy Policies and Measures Database	3,204	1.48	.89	1	5
	RI_R	Number of regulations	IEA/IRENA Renewable Energy Policies and Measures Database	5,076	2.02	1.60	1	11
Control variables	c_CI	Logarithm of carbon intensity – kg per PPP in USD of GDP	World Bank DataBank	2,172	36.86	1.29	29.76	38.63
	c_GDP	Logarithm of GDP in USD	World Bank DataBank	2,200	36.76	2.26	24.00	38.63
	c_EC	Logarithm of electricity consumption in kWh per capita	Our World in Data	2,199	15.93	1.76	6.65	18.99

Table A3. Summary of statistics.

Independent variables	Overview											
	All countries				Developed countries				Countries in transition and developing countries			
	Multiple RE	Solar	Bio	Wind	Multiple RE	Solar	Bio	Wind	Multiple RE	Solar	Bio	Wind
EI_FI_PP	- (NS)	+ (NS)	+ (NS)	- (NS)	+ (NS)	+ (*)	+ (NS)	+ (NS)	- (NS)	- (NS)	+ (NS)	- (NS)
EI_FI_GS	- (NS)	+ (NS)	+ (**)	+ (NS)	+ (NS)	+ (NS)	+ (NS)	- (NS)	+ (NS)	- (NS)	+ (**)	+ (NS)
EI_FI_TI	- (NS)	- (NS)	+ (NS)	+ (**)	- (NS)	+ (NS)	- (NS)	+ (NS)	- (NS)	- (NS)	+ (*)	+ (NS)
EI_MI_EA	+ (***)	+ (NS)	+ (NS)	+ (***)	+ (NS)	- (NS)	- (NS)	+ (NS)	+ (*)	+ (*)	+ (NS)	+ (**)
EI MI_GC	- (NS)	- (NS)	+ (NS)	+ (NS)	- (*)	- (NS)	- (**)	- (NS)	+ (NS)	+ (NS)	+ (NS)	+ (NS)
EI_DI_FSG	- (**)	- (*)	- (NS)	- (NS)	- (NS)	- (NS)	- (NS)	- (NS)	- (NS)	- (NS)	- (NS)	+ (NS)
EI_DI_II	+ (NS)	- (NS)	+ (NS)	+ (NS)	- (*)	- (*)	+ (NS)	+ (NS)	- (NS)	+ (**)	- (NS)	- (NS)
PS_IC	+ (NS)	- (NS)	- (NS)	- (NS)	+ (NS)	+ (NS)	- (NS)	+ (NS)	- (NS)	- (NS)	- (NS)	- (NS)
PS_TSP	+ (***)	+ (**)	+ (**)	+ (***)	+ (NS)	+ (NS)	+ (NS)	+ (*)	+ (**)	+ (**)	+ (***)	+ (***)
RI_CS	+ (***)	+ (**)	+ (*)	+ (***)	+ (***)	+ (NS)	+ (NS)	+ (***)	+ (**)	+ (*)	+ (NS)	+ (*)
RI_OS	- (*)	- (NS)	- (NS)	+ (NS)	+ (NS)	- (NS)	+ (NS)	+ (NS)	- (*)	+ (NS)	- (NS)	+ (NS)
RI_R	- (NS)	+ (NS)	- (NS)	- (NS)	- (NS)	- (NS)	- (NS)	- (NS)	- (NS)	+ (NS)	- (*)	- (NS)
Control variables												
c_CI	+ (NS)	- (NS)	- (NS)	- (NS)	+ (NS)	- (NS)	- (NS)	- (NS)	+ (NS)	+ (NS)	- (NS)	+ (NS)
c_GDP	+ (NS)	- (NS)	- (NS)	- (NS)	+ (NS)	+ (NS)	+ (NS)	+ (NS)	+ (NS)	+ (NS)	- (NS)	+ (NS)
c_EC	+ (NS)	- (NS)	- (NS)	- (NS)	- (NS)	- (NS)	+ (NS)	- (NS)	+ (NS)	+ (NS)	- (NS)	+ (NS)

NS refers to “not statistically significant”. *** significance at 1% significance levels. ** Significance at 5% significance levels. * Significance at 10% significance levels. + means positive sign. – means negative sign.