'Predictors for The Nuclear Solution' An exploration of the drivers behind nuclear energy implementation through the eye of innovation theory.

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Summary

This thesis will attempt to determine the reasoning behind the lack of nuclear power implementation within the OECD countries in the period of 1990-2010. This is done in order to generate a better understanding of the subject and to potentially promote the implementation of nuclear power. To this end I will discuss 3 major categories of drivers consisting of governance, social and economic drivers. Which should, according to existing literature relate to nuclear power or innovation implementation, whilst the data collected will mainly consists of quantitative/descriptive statistics derived from the OECD, Nuclear power related organizations and election results. Some literature will be used to provide additional context for interesting and outlying data.

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Chapter 1 Introduction

According to the Dutch government there is a standing need and desire to reduce greenhouse gas emissions by 49% in order to offset the effects of climate change (Ministerie van Economische Zaken, Landbouw en Innovatie, 2020). However as of yet one of the most lifesaving, cost effective and efficient emission reducers known as nuclear power, has not been used significantly (Ministerie van Algemene Zaken, 2017; Nuclear Energy Institute, 2021; Statista, 2021). This is especially concerning as some climate experts are considering the possibility that alternatives to nuclear energy such as renewables will not be practical as the only solution within the given time frame (Böhm, 2016). This despite the technology of nuclear power having existed for some time now and being utilized effectively to reduce the usage of fossil fuels by nations such as France in order to increase energy independence (Electricité de France, z.d.). Nuclear energy is used in these nations to generate (mostly) clean energy, generate national energy independence and lower energy prices overall/stimulate local economies (Office of Nuclear Energy, 2021; Patterson, 1983). The history of nuclear power being utilized as an energy source started in 1951, with breeder reactors and then later nuclear reactors, here the number of reactors started expanding until the 70s (World Nuclear Association, 2020). After this period nuclear reactors went through a period of improvement and replacement with better variants, but their numbers did not really increase, until the 1990s with the introduction of third generation reactors and the nuclear revival (World Nuclear Association, 2020). In this period more nuclear power plants were built, this time in the form of the third-generation variant (World Nuclear Association, 2020). Regarding these generations there are 4 types, with generation one concerning experimental nuclear reactors from the 1950s until the 1965 (Goldberg & Rosner, 2011). Whilst the second generation concerns a period of 1965 until 1995 and the third concerns generators form 1995 until 2010, where the near-term deployment or third generation-plus starts (Goldberg & Rosner, 2011). Lastly, I have the future, fourth generation reactors which are reactors built from 2030 onward (Goldberg & Rosner, 2011). These generation periods are however neither all-encompassing nor does a generator of any generation have to be built in its allotted period for this generation. Since these generations encompass certain key attributes of generators such as, Safety, security, cost-effectiveness, commercialization etc, rather than their actual age (Goldberg & Rosner, 2011). Which means that it is difficult to be certain of the exact makeup of the generation types currently in existence. However, it does seem to be the case that, the last first-generation nuclear power plant known as the Wylfa Nuclear Power Station in Wales closed down in 2012 (Goldberg & Rosner, 2011). Furthermore, as of 2019: 92 reactors are 40+ years old, 200 reactors are between 30-39 years, 55 are between 20-29 years, 22 are between 10-19 years and 63 are between 0-9 years old (Gospodarczyk & Fisher, 2019). This would mean that at that time at least 292 reactors would have been from the second generation with the rest being either from the third, third plus or second generation, since these 292 would have been built before the inception of the third-generation reactor. Furthermore, as of 2016 up to a total amount of 601 nuclear reactors have been built and 400 are still operational in 31 nations (Bennett, 2019). These and other more recently completed reactors provided up to 6.6 Terawatt-hours of energy or 4.34% of the global energy supply in 2020 (Ritchie, 2020). With France being one of the most nuclear reliant nations, with up to 36.57% of its total energy being currently produced by nuclear power. Whilst the European union as a whole only derives about 11.09% of its energy form nuclear power, whilst nations such as Austria derive none of their energy from nuclear power (Ritchie, 2020). However even during and after the nuclear revival many nations still did not significantly increase their implementation, with only 6,64% of the global energy production being the result of nuclear power at its highest point in 2001, despite its relative cheapness and aforementioned advantages (DEUTCH et al., 2009; Ritchie, 2020). This begs the question as to why this innovation has not yet become the main supply of power in many nations their power policy?

Relevance

This thesis is socially relevant because it studies a better understanding of the motivation behind the implementation or lack thereof of nuclear power, which should allow for a more informed approach to the issue of climate change as well as the issue of energy independence.

This thesis also bears scientific relevance in the sense that it seeks to apply innovation predictors from multiple theories to the case of nuclear power, whereby nuclear power is a form of innovation. This research will therefore show if and how these predictors can be applied to nuclear energy. It will also seek to further support or undermine existing theoretical assumptions regarding the relationship between these predictors and innovation/ nuclear power as is relevant to the data presented.

Problem setting

As has been discussed in the introduction there is both a problem and a question regarding nuclear power. This concerns the necessity for a reduction in greenhouse gas or put more broadly, the need for a 'clean' alternative to current energy generation, for the halting of climate change. Whilst this main problem already has a potential solution in the form of nuclear power. However here I arrive at the problem/question of this research that, despite the only practical solution being on hand and even revived through technical innovation in the 1990%s. It still only provides about 4 % of the world's current energy production (Ritchie, 2020). Therefore, the proposed problem of this thesis is: *The current lack of nuclear power within the energy mix.*

Research question

The general goal of this research, therefore, can be derived from the problem definition. Which desires to understand how it is that some nations did not implement nuclear power or implemented nuclear power less, while other nations implemented nuclear energy to a far greater degree. Here there will be a focus on the macro-economic and political predictors for nuclear power implementation to discover what drives its implementation degree. With a final goal of discovering what could be done to allow nations that have not yet taken the nuclear option to implement nuclear power in a meaningful way. Since this research has a time constraint it will not look at all world nations, but only look at OECD nations over the nuclear revival period of 1990s until 2010. This period is chosen to allow for the innovation aspect of nuclear power to be more relevant due to the invention of the third-generation reactors. Whilst also not going to an earlier period, since data from before 1990's is hard to find and less relevant to the current discussion. Whilst the post 2010 public backlash to nuclear power, due to the Fukushima disaster in Japan would be a significant polluter of the data (Kang, 2019). The Fukushima disasters exclusion is necessary although only partial, as will be discussed later, due to the goal of this research. Which is to understand why there is a lack of nuclear power implementation with an eye on how to potentially change this. A unique one-time events such as, a major earthquake causing a 15-meter tall tsunami which disabled the power supply and cooling of three Fukushima Daiichi reactors (International Atomic Energy Agency, 2015; World Nuclear Association, 2022a). Leading to a nuclear accident beginning with All three cores largely melting in the first three days (International Atomic Energy Agency, 2015; World Nuclear Association, 2022a). Might although relevant to the study of how to improve nuclear reactors, not be very scientifically relevant to the study of what drives nuclear power implementation more generally, due to their incredible rarity. Furthermore, the discovery that nuclear crisis affect nuclear power implementation is neither disputed nor an overly novel subject regarding the improvement of nuclear power implementation as a policy process (Kang, 2019). Therefore, it seemed best to try and exclude its data pollution in order to get a better look at what effects nuclear power implementation in more normal times. Meanwhile the OECD was chosen due to western nations being the main implementers of climate policy regarding climate altering pollution (Andersson, 2019). Other nations with climate policies such as China have not been included due time constraint and their relatively different political and social situations (Economist Intelligence Unit, 2022). Which although enhancing representation, would also make comparisons between nations as well as the internal validity of this study more difficult. The validity concern mainly regards my later analysis of political support which requires at least comparable political/democratic systems.

These limitations have led this research to ask the following question:

Why did OECD nations in the period of 1990-2010 not implement nuclear power to a greater degree?

To answer this question, this research will make use of an auxiliary literature review as well as macro-economic and political data on 10 different OECD countries over the period of 1990 until 2010.

To answer the main question, this thesis will have to answer a few sub questions as to the drivers/processes behind nuclear power implementation. To arrive at the why of nuclear power implementation. These questions consist of the following:

1. What processes and drivers have had a significant effect on an OECD nation's decision to implementation of nuclear energy?

2. What motivations drive the implementation of nuclear power in OECD nations?

To answer these questions, I will use quantitative/descriptive statistics derived from the OECD site, nuclear power related organizations and election results. Some literature will also be used to provide additional context for interesting and outlying data and improve the quality of the analysis. However due to this method using correlation data, I am limited to making statements that mainly regard association between the drives and nuclear power implementation. With causal claims being outside of the explanatory power of these descriptive statistics. So in the future, research should be focused on using the significantly associated predictors found in this research to make more practically relevant causal claims regarding the drivers of nuclear power implementation.

Chapter 2 Theory

Literature review

This thesis will look at two general groups of literature to derive a possible answer to the sub questions regarding the process drivers and motivations that are behind/effect nuclear power implementation. These literatures consist of innovation literature and nuclear/energy literature. In innovation literature I look at what current literature considers to be the motivations and drivers for innovation. This type of literature was chosen due to nuclear power, sometimes being considered as a radical innovation with a degree novelty (Markard & Truffer, 2006). The analysis of nuclear power as an innovation is further supported by the earlier mentioned new appearance of third generation reactors, during the researched period of 1990-2010(World Nuclear Association, 2020). Whilst I will look at nuclear/energy literature with a more specifically economic focus as to what is required/necessary to run a nuclear power plant. This is done in order to focus the general innovation literature used on nuclear energy specifically on nuclear power.

To this end I will consider innovation as a concept: In literature innovation it is often discussed as and even separated into, different forms or types of innovation. With the more general concept of innovation considering innovation, as a process through which new ideas, objects and practices are created, developed or reinvented (Walker et al., 2011). Whilst these new ideas, objects and practices also have to be new to the organization which adopts them (Walker et al., 2011). Others discuss innovation through the separation of radical and incremental innovations (Markard & Truffer, 2006). With incremental innovations being more of a slow but steady change of practices, whilst radical innovations seem to be more breakthrough based (Markard & Truffer, 2006). Since this thesis considers nuclear power as a whole, but only researches the period of 1990-2010 both concepts somewhat apply. With nuclear power at its inception being more of a breakthrough innovation, whilst the upgrading to 3rd generation reactors seems more of an incremental innovation. Therefore, this thesis will use a broader concept of innovation here: innovation encompasses the widespread adoption and use of a new idea, object or practice. Which in this case would concern the widespread (or lack thereof) adoption of nuclear power.

The concept of nuclear power as is relevant to this thesis will be based on how a nuclear reactor operates. In its most simplified form, a nuclear reactor releases nuclear energy in the form of heat using fissile material; this heat is used to generate steam, and the steam is used to turn power turbines which convert rotational energy into electricity, energy generated in this way will therefore be considered as nuclear power (Patterson, 1983). Fissile material here is material that can incur fission or in other words, it allows for a neutron to slam into a larger atom, forcing it to excite and split into two smaller atoms releasing energy (UNODA, n.d.; Office of Nuclear Energy, 2021a).

In the section below I found 13 theoretical drivers for nuclear power implementation. For the sake of an orderly analysis, I have subdivided the potential innovation/nuclear implementation drivers into 3 categories, governance, social and economic. Governance is mainly concerned with government-based motivation and actions. Whilst Social drives are derived from the demographics and opinions of the general public. Whilst economic drivers are derived from the financial and resources side of nuclear power.

Governance drivers

Political support

As one of the main governance-oriented drivers, political support seems to have a strong consensus regarding its importance to innovation implementation (Berry et al., 1998;Choi & Chandler, 2015;World Nuclear Association, 2021). On the one hand political support for nuclear power or rather a political actor's actions, in favor of nuclear power/innovation is considered to be a major driving force behind the implementation of nuclear power (Markard & Truffer, 2006). One of the supposed reasons for this consists of the uncertainty around investing into nuclear power. This is driven by the long period of time required to break even and is reinforced by pressure from protesters/ interest groups seeking plant shutdowns or construction delays, by pressuring both the plant itself and politicians (World Nuclear Association, 2021). This generates a risk to investors since the high investment costs and longtime spend waiting for their return, will be lost if politicians give into these pressure groups. Therefore, political support for nuclear power seems crucial for this uncertainty to be counteracted. This positive relationship is echoed by innovation literature, where a variety of political variables which are on balance in support for statutory objectives, are considered to be a key stage in implementing an innovation (Berry et al., 1998). This belief is further reinforced by some of the literature's assertions that: If the degree of political pressure is strong enough to break through the organizational inertia often found in public organizations, then this pressure will result in real innovation in the public sector (Choi & Chandler, 2015). However, there are also some risks associated with the use of political pressure for the implementation of innovations. Mainly that, innovation coming from political pressure is not voluntary and often not well planned (Choi & Chandler, 2015). Therefore, there is usually a lack of motivation to excel, which can hamper innovation (Choi & Chandler, 2015). Furthermore, the external influence of elected officials is likely to have a dampening effect on risk-taking due to accountability concerns (Wang & Feeney, 2016). This leaves politicians and their political support open to a potential failure of effect or negative effect on innovation. Which leaves the literature's consensus regarding the effect of political support on nuclear power implementation open to debate.

Legitimacy

Another government-oriented driver found in the literature concerns legitimacy, or rather the drive for legitimacy. Organizations supposedly innovate in search of legitimacy or rather the acceptance of their authority and as a result might not fully implement the innovation as long as this legitimacy is achieved **(**Walker et al., 2011**).** This essentially means that if an innovation is not desired or perceived as legitimate then its implementation might be limited. This view is further supported by the literature on institutional change where at the institutional level, organizations focus on their mission and establishing legitimacy within their environment (Jun & Weare, 2011). It therefore seems likely that a governments drive for legitimacy might see them implement an innovation if it is desired by the public, which in turn gives the government legitimacy. Whilst an innovation's implementation might be hampered if it is not considered to be legitimate. Here legitimacy seems to be generated by public support for a policy.

Bureaucratic competition

Bureaucratic competition is also considered to be a driver behind innovation implementation. This effect occurs via the existing power relationships within an organization, where they cause innovations to be designed, implemented and adopted in ways that support existing power relationships (Jun & Weare, 2011). Also, according to this view, resistance increases as complexity increases (Jun & Weare, 2011). This is supposedly due to innovation potentially shaking up and possibly threatening the existing power relations by introducing new sources of power and complexity which are difficult to control (Jun & Weare, 2011). Another way in which competition drives innovation is through diffusion (Walker et al., 2011). Here innovation is communicated through certain channels over time among the members of a social system (Walker et al., 2011). With one of the channels through which this can happen being competition between bureaucracy's (Walker et al., 2011). Here I can see a two-sided exception in the literature, where competition within and between bureaucracy's seems to drive and be a motivator for innovation, because of a desire to outdo one's competitors. While at the same time, this driver can be reversed in effect if Bureaucratic complexity is high enough. Since then, the potential for a power shakeup/loss amongst relevant actors such as local politicians and contractors seems to be too high to risk innovation. Since the innovation of processes might cause new actors that implement these innovations to become competitors with established interests. Due to the complexity making the controlling these innovations and their results difficult for established interests.

Centralization

Centralization or a stronger power concentration at the top of an organization, has many different aspects that are considered in the literature that are relevant to this thesis. With most nuclear specific literature that regards the two concepts, discussing how nuclear power requires some form of organizational and supply centralization (Sustainable Development Commission, 2006; Funcke & Ruppert-Winkel, 2020). Here the sheer size and complexity of the resources involved with nuclear power plant construction and operation, tend to necessitate some form of centralized control in the form of either government direction or control by large businesses with monopolistic degrees of market power (Sustainable Development Commission, 2006; Funcke & Ruppert-Winkel, 2020). Since these are the ones generally capable of gathering the resources required to build and operate nuclear power plants (Sustainable Development Commission, 2006; Funcke & Ruppert-Winkel, 2020). Meanwhile the relationship between centralization and innovation mainly discusses either social innovation such as unionization or some form of specific innovation area such as water services, which seems to hold little relevance to nuclear power (Haucap & Wey, 2004; Sharma et al., 2013). Whilst literature that discusses national centralization and innovation is generally more descriptive as to how innovation would take place in various forms of centralization, rather than showing if centralization would cause more or less innovation (Kuhlmann, 2001). It would therefore seem to be scientifically relevant, to try and see how national centralization or inversely local autonomy and nuclear power are related. Since some kind of relationship does seem to be suggested by the need for some form of centralized and sometimes government organized logistical management, regarding the construction and operation of a nuclear power plant. Furthermore, this specific relationship between national government centralization and nuclear power implementation does not seem to have been explored before. Thus, an analysis of the relationship between national/governmental centralization degree and nuclear power could provide a better future understanding of how these two concepts relate. To achieve this, I will use more generalized theory that regards both innovation (and thus the innovation aspect of nuclear power) and centralization, with the focus on how centralization effects innovation adoption, to construct my hypothesis regarding centralization. This is done since nuclear power and national centralization specific theory, as just stated, do not seem fitting for the relationship I wish to investigate regarding centralization. So generally, centralization is considered to have a negative impact on innovation adoption, although the result of empirical research are limited (Wang & Feeney, 2016). Furthermore, the complete opposite of an organic or bottom-up organization with diversity of tasks predicts more innovation adoption (Wang & Feeney, 2016). Whilst personnel rules or constraints driven by centralization are negatively associated with the implementation of innovations (Wang & Feeney, 2016). Whilst a risk-taking culture is positively associated with innovation adoption due to personnel being more willing and supportive of risk taking (Wang & Feeney, 2016). However, centralization negatively impacts risk-taking through the external influence of elected officials which has a dampening effect on risk-taking due to accountability concerns (Wang & Feeney, 2016). Therefore, centralization seems to have a negative effect on innovation implementation, which could also mean that state centralization has a negative effect on nuclear power implementation through its innovation aspect. Although the conversion from general organization theory to government or state level might make this assertion less applicable.

Social Drivers

Public acceptance

Public support/acceptance of nuclear power seems to be major driver behind nuclear power/innovation implementation. It is also the general view of experts around nuclear power that public acceptance/support is very important to nuclear power implementation (DEUTCH et al., 2009) The literature has discussed several different mechanisms surrounding public acceptance of nuclear power. Firstly, diffusion is also a relevant effect here, regarding the information path of diffusion known as public pressure, which drives innovation through citizens desires for a supposedly beneficial innovation, resulting in citizen pressure to implement this innovation (Walker et al., 2011). This effect is further reinforced by the government's response to environmental demands, whereby elected officials may seek political support and implement popular programs for the purpose of achieving public support, or otherwise said, legitimacy (Jun & Weare, 2011). Therefore, it seems that public acceptance is crucial for nuclear power implementation. It is also important to discuss what variables, affect public acceptance and generate a (mostly negative) desire for nuclear adoption. These consist of several concerns and factors such as, general safety concerns for a plant's surroundings, education, nuclear disasters and the waste issue concerning the uncertainty regarding the effects and ability of nuclear plants to store their waste (Toth & Rogner, 2006). This negative perception is reinforced by nuclear power's severe stigmatization amongst the public due to media action. (Toth & Rogner, 2006). Whilst a small driver for nuclear acceptance also seems to be trust in government (Ramana, 2011). The literature therefore seems to consider public acceptance as a main driver behind nuclear power implementation. This generally occurs through a politicians' desire for popular/legitimate policy that will win them political support. However, the literature also considers nuclear to be highly unpopular on one side whilst highly beneficial and thus supposedly supported on the other side, as seen in the introduction and other parts of this thesis. Therefore, the size and effect of public support/opposition to nuclear power seems to be uncertain.

I will now go into further detail regarding some of the just mentioned theoretical drivers of public support, as public acceptance seems to be very important to nuclear power implementation. This is done with an eye on developing a well-rounded view of how public acceptance and its drivers affects nuclear power implementation.

I will first discuss the crisis effect, despite attempts having been made to exclude the occurrence of nuclear disasters/the crisis effect, from the data set due to validity concerns. Since it is a major driver behind the implementation of nuclear power as it is found in the literature. Furthermore, it seems that the Fukushima disaster has led to a reinforcement of the negative perception of nuclear power (Ramana, 2011). Whereby significant parts of the public actively campaign to end nuclear power around its occurrence (Ramana, 2011). Fukushima is not the only disaster that has had such an effect, with both Chernobyl and three-mile island being the subject of a disproportionate amount of negative media coverage (Office of Nuclear Energy, 2021). This focus on nuclear disasters has led to significant levels of fear surrounding nuclear power which get reawakened whenever a new disaster occurs (Office of Nuclear Energy, 2021). An example of this effect is that some nations such as Germany temporarily or permanently stopped nuclear power projects and reevaluated old projects right after the Fukushima disaster due to public pressure (Hayashi & Hughes, 2013). Despite some of these nations not lending themselves to this type of nuclear disaster due to not being on active tectonic plates or at risk of tsunami waves hitting their reactors. Therefore, this fear and difficulty regarding the implementation of nuclear power seems to be driven by low public awareness regarding nuclear power and a general time proximity to nuclear disasters, rather than actual safety concerns by experts. It therefore seems to be the case that nuclear power implementation is negatively affected by nuclear disasters through public opinion and especially when the disasters occurred recently.

Furthermore, education on/public awareness of nuclear power seems to also be a major social driver behind the support for nuclear power implementation. Due to public awareness regarding the risks and benefits of nuclear power seemingly varying widely between social and national groups (Aykol et al., 2002). This information asymmetry could lead different individuals to have different opinions on nuclear power. In some literature it is even recognized that the main driver behind negative opinion on nuclear power is fear (Office of Nuclear Energy, 2021). Therefore, it would seem likely that more informed individuals would be less opposed to nuclear power as they would see that the risks are minimal. Education itself, however, seems to in and of itself not directly influence the public support for nuclear power or innovation (Weakliem, 2002). However, it does seem to influence someone's political position regarding economic policy. (Weakliem, 2002). Whilst on the other hand, some research shows that education regarding nuclear power increased student’s opinions on nuclear power and its use (Han, 2014). However, the design of this education and its focus on the safety of nuclear power is considered of key importance (Han, 2014). This design aspect of these positive results is contrasted by the general finding that more informed individuals are actually more opposed to nuclear power and its use (Ramana, 2011). Due to the specific moral issues of unequal and involuntary risk which some people associate with nuclear power (Ramana, 2011). Whereby it is believed that people who live near a nuclear power plant are experiencing an involuntary risk due to the decision making regarding the placement of a plant, being taken outside of their control (Ramana, 2011). Which is compounded by the belief that these people experience an unequal risk, due to their proximity to the power plant relative to other beneficiary's/receivers of the nuclear power plants energy (Ramana, 2011). It therefore seems likely that higher levels of education will lead to lower public support for nuclear power unless the education design specifically addresses safety concerns. Therefore, the net effect that education level has on nuclear power implementation is in doubt.

The last public acceptance driver I will consider is trust (in government), which according to literature seems to be a major driver behind the public's acceptance of nuclear power **(**Ramana, 2011; Han, 2014). Since their trust is driven by the belief that the government/ nuclear power implementers have the best intentions and seek to safeguard the public (Ramana, 2011; Han, 2014). This literature-based assertions leads to the theoretical expectation that trust in government should drive the implementation of nuclear power through the positive perception of nuclear power it generates.

Entrepreneurialism

Entrepreneurialism seems to be another important driver for innovation implementation and through the innovation aspect of nuclear power, it could be one for nuclear power aswell. Its effects on innovation implementation according to the literature seems to be positive (Cummings, 2015). Entrepreneurialism is considered to consist of a coherent and predictable process enabling goals to emerge contingently over time from the varied and diverse aspirations of leaders and the people they interact with (Cummings, 2015). This positive effect is driven by entrepreneurship being considered a method of learning by doing, allowing development to occur gradually and organically rather than according to a grand plan (Cummings, 2015). Furthermore, breakthrough innovations are supposedly achieved by methodically making small bets in order to discover and develop new ideas (Cummings, 2015). Entrepreneurialism would be important to innovation due to this aspect and the process of reform being too complex/variable to be understood completely and thus requiring entrepreneurs which test innovations through trial and error (Cummings, 2015). Thus, entrepreneurship seems to be increasingly acknowledged as a collective activity, in which it is the particular nature of relationships between individuals that enables change to occur (Cummings, 2015). Therefore, it might be the case that the more entrepreneurs a nation has or the higher its entrepreneurialism. Since, a higher number of relationships between individuals can drive innovation and thus also drive a higher innovation implementation degree. This potential is further reinforced by the view that entrepreneurship demonstrates and drives innovation by putting the idea or concept into practical use with the infusion of resources, be it capital or the support of institutional leadership (Crumpton, 2012). Which would again imply that more entrepreneurs(ship) would lead to more infusion of resources/ testing of an innovation. However, the relationship between entrepreneurialism and nuclear power implementation/research is not certain. Since the relationship described earlier might differ significantly across markets, due to, for example the difference in capital investments per markets. Whereby I could radically disrupt the market for NFT's or non-fungible tokens, due to the low capital costs involved, whilst the investment necessary for nuclear power plants might be outside of my reach (Sharma, 2022). One could of course, use a more affordable option such as buying shares in a nuclear power plant. However, the difference in market structures does make the relationship between entrepreneurialism and innovation/nuclear power implementation uncertain and worth investigating.

Economic drivers

Market liberalization

Market liberalization is also found to be potentially relevant to the implementation of nuclear power (NUCLEAR ENERGY AGENCY, 2004). Mainly because most nations in the data set that I have chosen, have privatized their energy sectors and nuclear power generation during the market liberalization drive of the 1980-90s (NUCLEAR ENERGY AGENCY, 2004). This privatization trend includes the major nuclear power generating nations of the OECD such as the UK, Japan, US and Germany (Heddenhausen, 2007; Staff, 2018; World Nuclear Association, 2022c; United States Nuclear Regulatory Commission, 2022; NUCLEAR ENERGY AGENCY, 2004). Whereby France is the main exception with up to 90% of their nuclear power market being operated by stated owned companies, however they still partially fund their reactors privately through commercial loans whilst also commercially operating their reactors (World Nuclear Association, 2022b; NUCLEAR ENERGY AGENCY, 2004). With only safety measures being heavily regulated by state actors (NUCLEAR ENERGY AGENCY, 2004). In light of this market liberalization and its effect on the privatization of nuclear power, it would seem prudent to also look at the effect market liberalization as a whole has on nuclear power implementation. According to the literature market liberalization or the reduction of monopolistic power, increases the scope of variation for innovation activities at the level of the firm and of the energy sector. (Markard & Truffer, 2006). This supposedly occurs through a change in principles, strategic goals and organizational routines including daily business practices as well as investment generated by market liberalization (Markard & Truffer, 2006). Supposedly organizations which were initially resistant towards innovations under monopoly now have a more open view of innovation (Markard & Truffer, 2006). Market liberalization therefore seems to drive variation in innovation routes explored in the energy sector which can lead to an innovation increase due to more innovation routes being explored. However, the actual relationship between market liberalization and radical change has not yet been empirically proven (Markard & Truffer, 2006). Plus, the exploration of more innovation routes might cause a diffusion of resources as more paths explored leads to less money being invested in each particular path. Which could especially in cases of high upfront investments such as is necessary with nuclear power have the opposite effect. The effect of market liberalization on nuclear power, therefore, seems to be uncertain as the literature seems to suggest a positive relationship, whilst the nuclear power market itself has specific issues which might make these expectations not apply.

Energy replacements

The energy mix, or rather the existence of oil and other energy resources which nuclear is meant to replace, is another driver behind the implementation of nuclear power. Since nuclear power competes directly in electricity with oil and indirectly with some end products of oil such as gas and heat (Toth & Rogner, 2006; DEUTCH et al., 2009). Furthermore, nuclear power usage expanded in 70s due to the oil crisis causing nations to seek energy diversification (Toth & Rogner, 2006; Markard & Truffer, 2006). This started a trend where many OECD nations started to go nuclear and up to 75% of oils market share loss was taken over by nuclear power (Toth & Rogner, 2006). However currently nuclear and oil target different markets with nuclear focusing on bulk grid-based energy demand, whilst oil provides energy to remote and developing areas (Toth & Rogner, 2006). Furthermore, nuclear is also considered to be a replacement to coal in some areas of the energy market, mainly consisting of heat production (DEUTCH et al., 2009). This would make it likely that nuclear power is mainly implemented in nations that utilize coal, oil and gas as opposed to other forms of energy such as hydro and renewables.

Interest

From the literature I can also find the main driver behind the cost of nuclear power, which is its Interest costs. Nuclear power costs are relatively unique in this regard, with other competitors such as natural gas having fuel cost as its main driver and coal lying in-between these two extremes (DEUTCH et al., 2009; Du & Parsons, 2009; World Nuclear Association, 2021). These relatively high construction and low operating costs are supposedly driven by a plethora of long term and high-cost considerations which, essentially force nations such as France to go all in on nuclear power. This would grant them economies of scale in order to prevent very high initial average costs (World Nuclear Association, 2021; Electricité de France, z.d.). This makes it so that nations are required to have significant funds available in order to be able to implement nuclear power over other forms of power, which some nations do not possess (Abdulla & Morgan, z.d). Furthermore, private investment is limited by similar issues, mainly because uncertainty is high with regards to construction time, costs and even ability to produce (World Nuclear Association, 2021). This view is also supported by the consideration that developing nations mainly consider employing this energy source in collaboration with each other to offset the high capital costs and risks associated with nuclear power (Abdulla & Morgan, z.d). Thus, the initial capital costs of a nuclear plant makes a plant's profitability almost completely reliant on low interest rates (World Nuclear Association, 2021). Which inversely would mean that high levels of inflation would make nuclear power plants more profitable as well. However, it seems unlikely that it is related to the decision to invest in nuclear power, due to inflation in the long run being more unpredictable.

Slack resources/Wealth

The last drivers discussed here will be slack resources and wealth which seem to be very related concepts in relation to innovation and nuclear power implementation. Since the literature considers the possession of slack resources as a positive predictor for the adoption of innovation together with the possession of a wealthier constituency (Jun & Weare, 2011; Walker, 2008). Wealth seems to mean a higher income constituency, whilst the concept of slack resources is far less clear (Jun & Weare, 2011). However, it seems to be the case that slack resources can be divided into 3 types of slack resources:

Recoverable Slack (Overhead/net sales): Which consists of resources that have already been absorbed into the system design as excess costs which may be recovered during adverse times (Lee & Wu, 2016).

Available Slack (Cash flow/net sales, current ratio, quick ratio): Which consists of resources that are not yet assimilated into the technical design of the organization, e.g., excess liquidity. This slack easily redeployed **(**Lee & Wu, 2016**)**.

Potential Slack (Long term debt/net worth, Price/earnings ratio): Which consists of the capacity of an organization to generate extra resources from the environment. Such as the firm's borrowing ability or its future ability to generate resources (Lee & Wu, 2016).

Finally, it seems to be the case that when slack increases, experimentation and risk taking also increase (Lee & Wu, 2016). However, when overhead expenditures increase this relationship will first weaken and then reverse (Lee & Wu, 2016). This conception of slack resources together with the positive effect of wealth on innovation indicates that high levels of government revenue, general business revenue and state wealth should be positively associated with innovation implementation. Whilst high levels of overhead expenditures or the government equivalent of government expenditures should be negatively associated with innovation.

Hypotheses

This thesis has generated its hypothesis mostly based upon the 3 implementation driver categories. Although these categories have some overlap, with political support legitimacy and public acceptance being related despite not being in the same category.

Governance drivers hypotheses

The first hypothesis here is derived from the theory's presumed effects of political pressure on innovation implementation. As stated in the theory section, political pressure needs to be strong enough to break through the organizational inertia often found in public organizations. However, if it is strong enough it will be a driver behind innovation or in this case nuclear power implementation. This result is challenged by the idea that innovation coming from political pressure can hamper innovation through lack of planning, motivation and accountability concerns. However, the assertion in the theory that nuclear power implementation requires the favor of political actors. Together with the assertion that political support is a key stage in innovation implementation has led this thesis to hypothesize that:

Higher political support for nuclear power leads to a higher degree of implementation of nuclear power.

This hypothesis is made despite the possible opposite relationship asserted in the literature review.

The second hypothesis considers the centralization degree of the government. Here according to the theory used, centralization is expected to affect innovation in a negative way. Through both limiting personnel actions regarding innovation and by limiting risk taking in an organization due to accountability concerns. Whilst the opposite form of organic bottom-up organizations are positively associated with innovation. Although it is understood that these expectations do not directly relate to national centralization's effects on nuclear power, it does as discussed in theory, provide me with a direction as to what can potentially be expected. It is therefore expected that:

Higher degrees of centralization are negatively associated with nuclear power implementation.

The other variable that might affect this relationship consist of: The perceived legitimacy of nuclear power which should increase its implementation and is driven by public support. Together with the degree of bureaucratic competition which should have a positive effect unless bureaucratic complexity is too high. However, these are not included as hypotheses due to operationalization issues which will be discussed in the method section.

Social drivers hypotheses

The third hypothesis is derived from both the first hypothesis and the theory's discussion earlier where political actors are driven by the perception of legitimacy and citizens desires for a beneficial innovation. In other words, politicians are driven by a desire to win electoral or public support by implementing an innovation and not the other way around. Therefore, it would stand to reason that when the public support for nuclear power is high, the political support for nuclear power will be high as well. If the first hypothesis holds then this would positively affect nuclear power implementation. Public pressure also seems to result in innovation if the public considers this innovation to be beneficial. However due to severe stigmatization, public acceptance of nuclear power is incredibly low. This combined with the difficulty in/impossibility of finding reliable survey data, has made public acceptance itself unusable as a driver. Therefore, I will mainly focus on education whilst also looking at trust and the crisis effect rather than acceptance itself. This focus was caused by the theoretical assertions that there are varying relationships between education, trust, the crisis effect and public support. However, the nature of these relationships seems uncertain with both positive and negative effects being predicted. Whereby I would say that education has a negative, more well-founded and reliable relationship with public acceptance, making it the main part of this hypothesis. This decision is informed by its relationship, neither being based upon an event/crisis such as the crisis effect, whilst also having more literature used relative to trust. This thesis will therefore hypothesis these multi directional relationships as follows:

Higher education levels are negatively associated with political support and nuclear power implementation, whilst the crisis effect is negatively associated with the nuclear power implementation degree and trust is positively associated with nuclear power implementation degree.

This is based on the assertion that more informed individuals are more opposed to nuclear power and its use. Whilst education supposedly only generates a positive effect if it is specifically designed to do so. Also, the crisis effect is assumed to have a negative effect on public support and thus also political support via a decrease in public support at the occurrence of the disaster. Whereby this effect is expected to weaken over time and thus increasing public support and nuclear power implementation over time once the disaster has passed. Furthermore, trust (in government) was expected to positively affect public support and thus nuclear power implementation as well, via it making people believe in the benevolence of government/nuclear industry actors.

The fourth hypothesis concerns entrepreneurship. Here it seems that entrepreneurialism or rather the presence of many entrepreneurs in a country is considered to drive innovation according to the literature. The consensus considers that entrepreneurs invest into and explore innovation pathways organically through trial and error. Furthermore, if one of these trails results in a functional innovation then entrepreneurs will be the providers of institutional leadership and support whilst also providing further funding. It is therefore expected that:

Entrepreneurialism is positively associated with nuclear power implementation.

It is however once again worth noting that this hypothesis is based on innovation literature and thus tests the applicability of innovation literature to nuclear power in this context.

Economic drivers hypotheses

The fifth hypothesis here is derived from the economic side of nuclear power. Based upon the literature, nuclear power implementation seems to be driven by a group of economic predictors. The first one discussed here will be based upon the upfront capital costs. Here the profitability of a nuclear power plant is driven by high upfront capital costs. This means that the level of interest is a main driver for a nuclear power plants profitability, with a higher level of interest making a plant less profitable. Based upon this assertion it is hypothesized that:

Borrowing costs in the form of interest rates are negatively associated with the degree of nuclear power implementation.

The sixth hypothesis concern the degree of market liberalization. The theory here considers market liberalization to cause a change in organizational behaviors towards one that is more in favor of innovation. This theory specifically addresses the energy sector and considers market liberalization as a way of allowing multiple avenues of innovation to be pursued at the same time and thus supporting innovation. It is however not empirically proven that liberalization would lead to radical change. Despite this I expect that:

The degree of market liberalization is positively associated with nuclear power implementation.

It is however once again worth noting that this hypothesis is based on innovation literature and thus tests the applicability of innovation literature to nuclear power in this context.

The seventh hypothesis concerns the presence of energy replacements in the form of coal, gas and oil. From the literature I can see a clear relationship between the presence of these energy replacements and nuclear power. With especially oil being a main competitor with nuclear power, as nuclear is considered to be a prime replacement for oil. This leads us to suspect that if a nation is reliant on these replacements, then it would most likely also attempt to use nuclear in order to replace them. This leads this thesis to the expectation that:

The presence of replacements is positively associated with nuclear power implementation.

The eight hypothesis concerns wealth and the presence of slack resources within a country. Here the literature states that wealthier constituencies generate more innovation. Meanwhile the presence of slack resources which is closely associated with wealth, is considered to drive experimentation and risk taking. However, it is also the case that if overhead expenditures increase, this positive effect of more slack resources seems to reverse and becomes negatively associated with innovation. Despite this I expect that:

The wealth and presence of slack resources within a country are both positively associated with nuclear power implementation.

Chapter 3 Method

Case selection

This thesis will use the cases of 10 OECD nations: Germany, France, Netherlands, Austria, Czech Republic, Poland, Japan, Spain, UK, US. These nations were chosen to be as representative as possible whilst at the same time having available data that can be used. The representativeness was considered which led to Japan being used as the representative of Asian OECD nations, since it was both the most numerous and easiest to collect data on. Whilst the Czech Republic and Poland were included in order to represent the former eastern bloc part of the OECD, mainly due to availability of data and relative size to most other east bloc OECD nations. Whilst the US represents the Americas, since it is both the most populous and influential of the American OECD. Furthermore, the UK represent the commonwealth nations overall, as it is the central commonwealth nation. Spain represents the Mediterranean countries due to ease of data collection and relative population to most other Mediterranean nations besides Italy. With Italy not being chosen due to an uncertainty regarding its classification, with it being either, central or southern European. Germany/ France represents western and central Europe due to both being the largest and most influential in their respective regions. Whilst the Netherlands and Austria represent smaller OECD nations in Europe, these were picked in the case of Austria due to the usefulness of a relatively extreme anti-nuclear position in the data set as an inclusion of such a country can give useful insights into why a nation would not adopt nuclear at all. Whilst the Netherlands was included due to ease of data collection and as the most influential nation of the Benelux. More nations were not added due to the limited time afforded for the writing of this thesis. The period of 1990s to 2010 was chosen as the time period, due to the earlier mentioned third generation of nuclear power plants coming into service providing a justification for the use of innovation theory. Whilst earlier periods such as the 50s were not chosen due to the lack of reliable data from before the 1990's. Furthermore, going beyond 2010 would allow the Fukushima disaster to pollute the results. A caveat to this point exists due to the use of a 7 year lagged variable used for one of the predictors for nuclear power implementation, the Fukushima disaster will be in data for that variable from 2004(2011) onward.

Research design

In order to attempt to falsify the earlier mentioned hypotheses this thesis will now explain what it will do in order to integrate different components of the study in a coherent and logical way. To start off I will show a number of descriptive statistics and models, regarding the operationalized indicators found in the hypotheses which will then mainly be analyses via a descriptive analysis. I will operationalize and find data on the following and earlier mentioned variables: Education, political support, entrepreneurialism, trust, the crisis effect, market liberalization, energy replacements, interest, wealth, slack resources and nuclear power implementation. Meanwhile bureaucratic competition, legitimacy and public acceptance will, although theoretically relevant as they can be considered omitted variables, not be measured. This is due to bureaucratic competition having issues with operationalization when it comes to data collection. Whilst public acceptance is already being measured through both the crisis effect and education levels, meanwhile legitimacy is very closely related to public acceptance when it comes operationalizing the variables. Furthermore, there is no data that shows public acceptance levels for nuclear power during the researched period for most nations involved. Which is due to a lack of nationwide public opinion polling on the issue for most nations, whereby the United States is a notable exception. Data collection will mainly occur via a documents and records review utilizing data from: the Norsk Senter For Forskningsdata, OECD, Our World in Data, International Energy Agency and various nation specific election sites and party news messages (Norsk Senter For Forskningsdata, n.d.;International Energy Agency, 2021;OECD, 2022a; Ritchie, 2020). These last two data collection methods will currently not be shown in an appendix since they are rather numerous with around 100 parties having been researched. With the goal of acquiring a single variable in the form of a yes or no answer to a single political topic (nuclear power support). This raw literature-based data is therefore considered to be overly cumbersome and unclear, it is thus excluded from being directly shown in this paper. Instead, only the resultant variable of political support will be shown. Furthermore, I will use some literature to give context to the confusing, outlying and interesting parts of the quantities data results when it seems useful. This data collected from these sources will be then used to construct descriptive statics in the form of a correlation table and a descriptives table of all operationalized variables. If by looking at these tables, it is found that a correlation between a nuclear power implementation variable and a driver is significant. Then I will construct a scatter plot figure in order to visually and further explain this relationship. All the relevant values in the tables and figures will be explained in the results chapter and later analyzed in the analysis chapter. Furthermore, if there are some strange results found in the figures, then I will try to find context in the form of literature, regarding the issue. In the analysis chapter I will then use theory to explain the results in the tables, figures and literature. In order to then, discover how these results relate to theory and how these relationships found could explain the research (sub)questions. These answers will then be used in order to answer the research question of: 'Why did OECD nations in the period of 1990-2010 not implement nuclear power to a greater degree?'.

Operationalization

In order to test the first set of hypotheses regarding governance drivers which are: 'Higher political support for nuclear power leads to a higher degree of implementation of nuclear power' and 'Higher degrees of centralization are negatively associated with nuclear power implementation'. This thesis will compare political support in 10 OECD nations, to nuclear power implementation, utilizing election years from 1990 to 2010. This thesis will operationalize political support by looking at the total number of politicians in the nation's parliament that are in favor of nuclear power. This will practically be measured by acquiring a political party's opinion on nuclear power from either contemporary news, archives with party manifestos, records or nuclear opinions of contemporary party leader positions. After which a party will be marked down as having been in favor or against nuclear power through a dummy variable of 1/0. Then the election results from these periods will be acquired from Norsk Senter For Forskningsdata (Norsk Senter For Forskningsdata, n.d.). After which the relative party size in parliament, of parties that are in favor of nuclear power will be added, creating total political support for nuclear power. Here it is assumed that party's will at the very least, attempt to implement policy's they promised to implement and that their members in parliament will try to stay with party policy. It is recognized that this is not a one hundred percent accurate measurement due to these assumptions not always holding. However, some literature on modern western democracies does suggest that politicians generally try to stay with/implement the party position (Bøggild, 2020). This will be compared to the degree of nuclear power implementation which will be derived from two variables, first a lagged variable of 84 months consisting of the total national energy percentage derived from nuclear power over time (Ritchie, 2020). The lag of 84 months is derived from the median construction time of a nuclear power plant, which means that nuclear power percentage data, recorded as 2000 will be derived from 2007's nuclear power percentages and so onwards (Statista, 2022). This is done because a change of variables that would lead to more nuclear power production, would require a 7 year wait of plant construction time and then lead to an actual increase in nuclear power production. This would for example mean that, support for nuclear power goes up at time t whilst the nuclear power percentage that result from this support would be measured at t+7(84 months). Whilst the second variable will consist of public nuclear power research, design and development expenditure ppp, derived from the International Energy Agency (International Energy Agency, 2021). The RD&D expenditures will be used due to these being more easily and directly adjusted by politicians and thus not requiring a lag to correct for construction time, as RD&D expenditures can be altered near immediately as seen by the Japanese reduction in RD&D expenditures right after 2010 (International Energy Agency, 2021). It furthermore exists as a more fitting representative for the innovation aspect of nuclear power implementation. These variables will also be compared between 10 OECD nations over a period of 1990 to 2010. Meanwhile, I will operationalize the degree of centralization via relative local autonomy levels of European governments. This method of measurement was chosen as local autonomy levels are essentially the opposite of centralization degree since it considers less centralization of power at the top of a national government. Therefore, if autonomy levels are high then inversely centralization levels are low and the analysis will take this into account. Data will be collected utilizing the research of Ladner et al, which concerns local autonomy in 39 countries (Ladner et al., 2016). In his research Lander attempts to address part of the issue I mentioned regarding centralization, mainly that the literature on it, addresses many different aspects of centralization/autonomy and in the case of Lander it could be said that there is no agreed upon operationalization of local autonomy, which is the problem he seeks to remedy (Ladner et al., 2016). To this end he measures local autonomy via a code book containing: Institutional depth, policy scope, effective political discretion, fiscal autonomy, financial transfer system, financial self-reliance, borrowing autonomy, organizational autonomy, legal protection, administrative supervision and central or regional access (Ladner et al., 2016). This form of data is relevant to my research in two ways, first it relates more generally to national governmental control over its subsidiary parts since it discusses parts such as self-reliance and local discretion over politics. Whilst it also relates to nuclear power implementation and construction through its financial and legal variables, since as stated in the theory section it is generally considered necessary to logistically organize nuclear power in a centralized way via large organizations such as the government. It therefore follows that a nation with high degrees of financial self-reliance, borrowing autonomy, fiscal autonomy and more general autonomy for its subsidiary parts, could be affected in its ability to support, research and implement nuclear power inside its nation, since on the one hand higher local autonomy causes less ability to centralize logistical/financial resources whilst on the other its sub governments now have more financial/logistical power to research/ implement any number of policy's such as the research, implementation and support of nuclear power. Furthermore, Japan and the US will not be included here due to this source not discussing them and this being the only data found that covers the period regarding government centralization degree.

For the second set of hypotheses regarding social drivers which are: ' Higher education levels are negatively associated with political support and nuclear power implementation, whilst the crisis effect is negatively associated with the nuclear power implementation degree and trust is positively associated with nuclear power implementation degree' And 'Entrepreneurialism is positively associated with nuclear power implementation'. This thesis will therefore first compare nuclear implementation degree and political support in 10 OECD nations, with national education levels, utilizing election years from 1990 to 2010. Here I will use the earlier variables of political support and nuclear power implementation as the independent variable and compare it to the degree of nuclear power implementation. Meanwhile this thesis will operationalize the national education level by looking at the percentage of the population that has completed tertiary education. This will be done as it is the highest level of education and therefore has its subjects covering the most amount of information. Which would make this metric more encompassing regarding the concept of an individual being better informed/educated on nuclear energy than other levels of education. Furthermore, trust in government will be measured and tested by using survey data questioning individuals, if they trust their government, either somewhat, completely or not at all (OECD, 2022b). However, the amount of data points found here are relatively small and thus conclusions based upon this data have limited reliability. The crisis effect will be measured via the distance from Chernobyl, as it is the most recent disaster for the researched period. This will be done via the time in the form of the date as a variable whereby 2010 is 10 years further away from Chernobyl then 2000 and so on, here public acceptance is expected to go up as time passes. Lastly, entrepreneurialism and its related hypothesis will be measured through entrepreneurialism as a percentage of self-employed and education level respectively. This is done because entrepreneurialism as a concept relevant to the innovation aspect of nuclear power, it concerns more individuals investing into an innovation and thus exploring more innovation paths, which should cause more innovation implementation.

For the third set of hypotheses regarding economic drivers which are: ' Borrowing costs in the form of interest rates are negatively associated with the degree of nuclear power implementation', ‘The degree of market liberalization is positively associated with nuclear power implementation’, ‘The presence of replacements is positively associated with nuclear power implementation’ and ‘The wealth and presence of slack resources within a country are both positively associated with nuclear power implementation’. I will use the earlier mentioned two variables for nuclear power implementation. As for interest, I will look at national interest levels per year and per nation. I will also look at the degree of wealth and slack resources by looking at national GDP per capita, which will be used as a predictor for wealth since wealth is generally represented through this metric. Whilst I will operationalize slack resources by looking at total government tax revenue per capita and as a percentage of GDP (OECD, 2022a). This is done due to the theory’s assertion that (available)slack resources mainly consist of cash flows/ company income. Which on the level of national governance can be best compared to national government revenue. However, since I want to control for different national populations, I look at tax revenue per capita. Meanwhile income as a percentage of GDP is used to represent the overhead of the nation as a whole as a result of the tax revenue. Which should if too high, negatively impact the effect of revenue per capita on innovation. Percentage of GDP is chosen as a representative of overhead as it essentially shows how much of the national economy is extracted by the state. This should control for/distinguish between high and low tax nations, relative to high/low-income nations. The data for these indicators will be acquired from the OECD (OECD, n.d.-a; OECD, n.d.-b). This will again be compared to implementation degree operationalized as before, between 10 OECD nations over a period of 1990 to 2010. I will furthermore look at the degree of energy replacements by looking at the percentage of energy in the energy mix derived from coal, gas and oil (Ritchie, 2020). As this should directly show the amount of replacement/competing energy sources that are used per nation. Whilst market liberalization will be operationalized as economic freedom along the lines of the economic freedom index consisting of: The rule of law, government size, regulatory efficiency and open markets as identified by the economic freedom index (The Heritage Foundation, 2022). This is done since data was easily accessible and because the measurements here seem to directly and indirectly represent lower economic market dominance by any particular party. Which was the main aspect of the concept of market liberalization which is relevant to innovation. This can be seen in both the rule of law and open markets measurements both aspects which should drive competition and lower monopolistic power which would result in higher market liberalization. Furthermore (smaller)government size should result in less (government based) monopolistic power, within the economic sectors in which it participates. Which would also result in a higher degree of market liberalization, further supporting the use of this index.

Chapter 4 Results

This section will initially display and explain relevant descriptive statistics in the form of correlation tables utilizing all the operationalized variables, which will be used to examine the expected relationships. These data points were all derived in the way the research design states. Furthermore, I will use scatterplots to emphasize the significant correlation table results and allow for further individual explanations of the variables and their results. This thesis will also have a section with general statements on the data, to explain some recurring data phenomenon found. Lastly this data set will have some auxiliary literature data, that provide more context to some of the irregularities found in the results.

Descriptive statistics results

Table 1

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Nation	210	1	10	5,50	2,879
Time	210	1990	2010	2000	2217
Nuclear power percentage	210	,0	40,9	9,729	10,7694
Interest	188	1,0	14,7	5,353	2,2792
Education	158	9,9	44,8	25,262	8,7173
Political support	196	0	100	62,17	30,018
R&D spending *1000	178	,0	3046,1	572,895	865,0588
GDP per capita	210	5949	48580	25888,42	9403,898
Entrepreneurship	165	13,7	73,6	34,776	14,2076
Replacement percentage	210	54,9	99,7	84,118	12,0735

Economic freedom	159	51	81	69,24	6,420
Autonomy	168	17,4	27,5	23,358	3,3029
Government revenue GDP	165	30	51	40,91	6,044
Government revenue per capita	165	3382	20338	11298,27	3998,019
Trust	10	27	64	40,87	11,083
Valid N (listwise)	8				

Note. This table demonstrates the descriptives of all the earlier mentioned variables

Table 2

Correlation coefficient matrix

		Nation	Time	Nuclear power percentage	R&D spending *1000
Nation	Pearson Correlation	1	,000	-,220	-,031
	Sig. (2-tailed)		1,000	,001	,678
	N	210	210	210	178
Time	Pearson Correlation	,000	1	-,050	-,070
	Sig. (2-tailed)	1,000		,471	,354
	N	210	210	210	178
Interest	Pearson Correlation	,168	-,712	,040	-,388
	Sig. (2-tailed)	,021	,000	,590	,000
	N	188	188	188	178

Education	Pearson Correlation	,430	,399	-,135	,496
	Sig. (2-tailed)	,000	,000	,092	,000
	N	158	158	158	137
Political support	Pearson Correlation	,118	,010	,466	,449
	Sig. (2-tailed)	,100	,891	,000	,000
	N	196	196	196	165
GDP per capita	Pearson Correlation	,095	,679	-,012	,030
	Sig. (2-tailed)	,170	,000	,866	,695
	N	210	210	210	178
Entrepreneurship	Pearson Correlation	,399	,084	-,269	-,367
	Sig. (2-tailed)	,000	,285	,000	,000
	N	165	165	165	147
Replacement percentage	Pearson Correlation	,485	-,061	-,728	-,165
	Sig. (2-tailed)	,000	,383	,000	,028
	N	210	210	210	178
Economic freedom	Pearson Correlation	,431	,205	-,318	-,043
	Sig. (2-tailed)	,000	,010	,000	,620
	N	159	159	159	137
Autonomy	Pearson Correlation	-,392	,166	,133	,279
	Sig. (2-tailed)	,000	,031	,087	,001
	N	168	168	168	136

Government revenue GDP	Pearson Correlation	-,749	-,036	,393	-,228
	Sig. (2-tailed)	,000	,650	,000	,006
	N	165	165	165	143
Government revenue per capita	Pearson Correlation	-,275	,556	,065	-,047
	Sig. (2-tailed)	,000	,000	,406	,575
	N	165	165	165	143
Trust	Pearson Correlation	,072	.	-,172	-,416
	Sig. (2-tailed)	,843	,000	,635	,232
	N	10	10	10	10

Note. This table demonstrates the correlations between the independent and dependent variables

Table 3

Correlation Political support and Education

		Political support
Education	Pearson Correlation	-,234
	Sig. (2-tailed)	,004
	N	150

Note. This table shows the correlation between Political support and Education

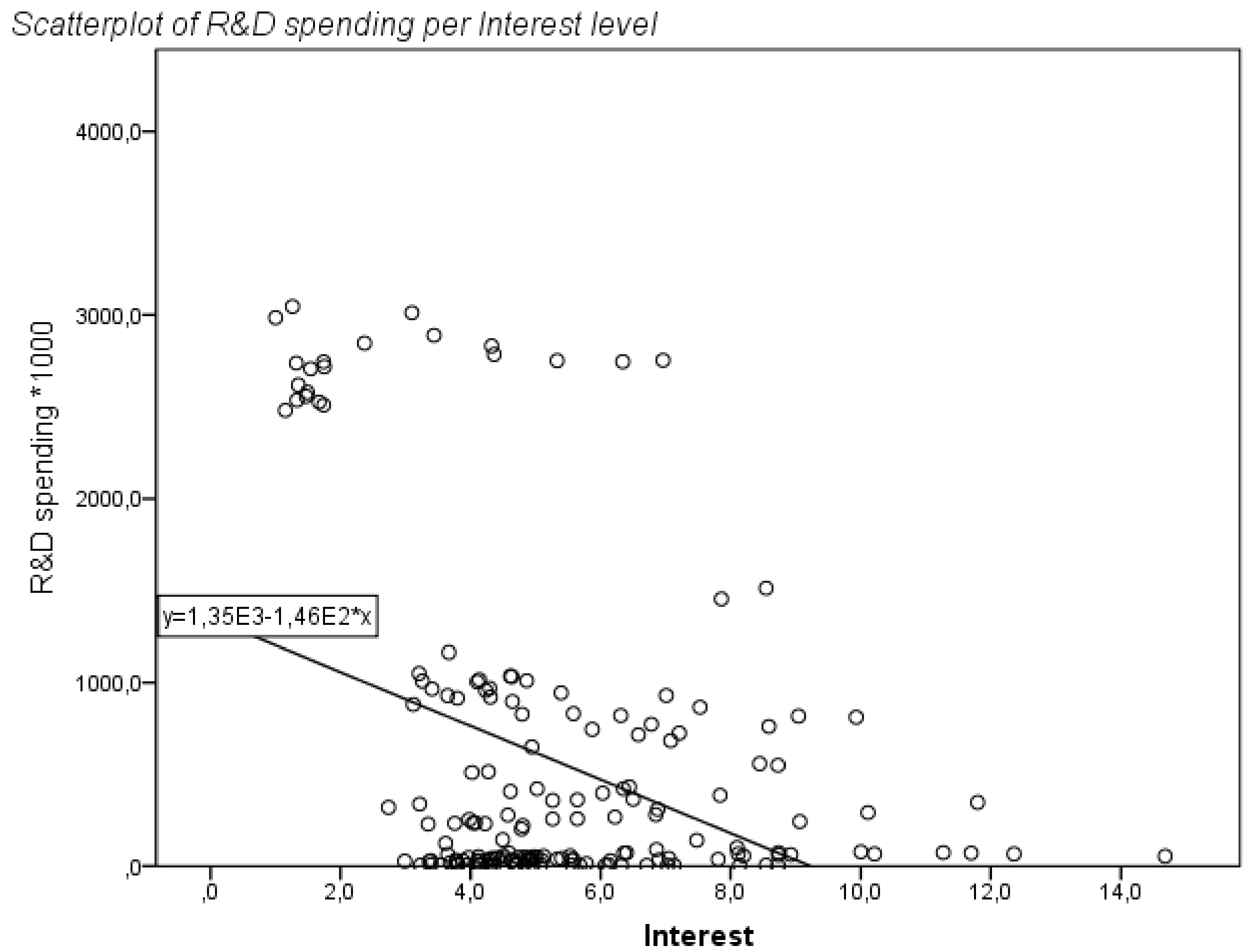
Variable results explanation

Interest

Interest has a minimum of 1 and a maximum of 14,7, whilst also having a mean of 5,4 and a std deviation of 2,3. In the Pearson r correlation relating to interest, I find that interest has an insignificant relationship with nuclear power as a percentage of the total energy net meaning that, there is no degree of correlation between interest and nuclear power as a percentage of the total energy net, that I can discern. I also find that interest has a significant and negative relationship of -,388 with R&D spending for nuclear power. This means that there is a moderate degree of correlation between interest and R&D spending for nuclear power.

This relationship can be seen in the trend line below.

Figure 1



Note. This figure shows a scatterplot of R&D spending per Interest level.

Here a negative trend line with a decrease of 146 in R&D spending per
1 increase in interest can be seen. Most interesting here are the outliers of Japan, Poland and Austria. Japan is seen in the highest points around 3000 R&D spending. Whilst Poland and Austria are near the bottom with essentially no R&D spending, which is also concentrated around the 4 to 6 percent interest rate. The rest of the nation’s seemingly follow the trend line more closely. However, it does seem to be the case that Japan could have pushed the trend line upwards around the lower interest levels. Since it has both the lowest interest levels of the cases and the highest R&D spending.

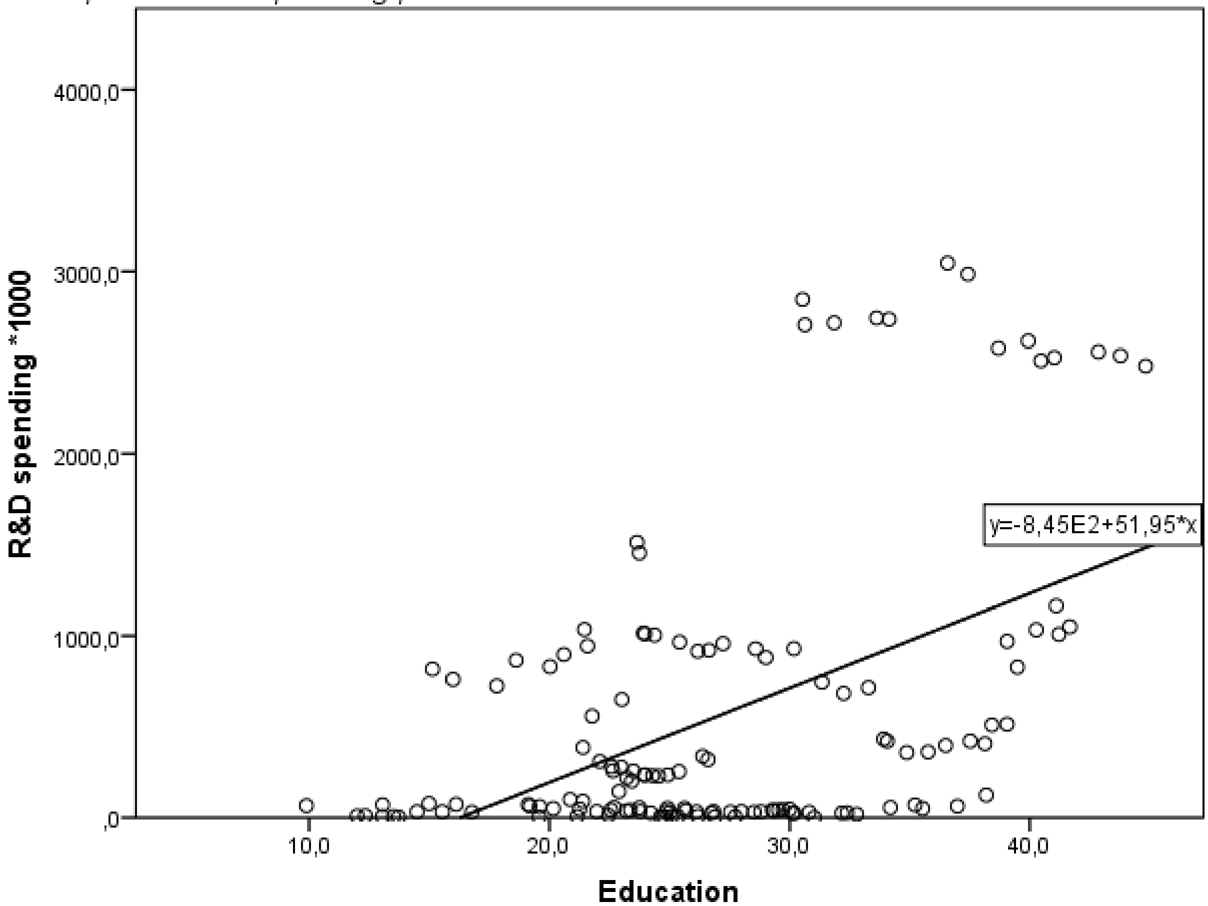
Education

Education has a minimum of 9,9 and a maximum of 44,8, whilst having a mean of 25,3 and a std deviation of 8,7. For education I find that it has an insignificant relationship with nuclear power as a percentage of the total energy net meaning that, there is no degree of correlation between education and nuclear power as a percentage of the total energy net that I can discern. I also find that education has a significant and positive relationship of ,496 with R&D spending for nuclear power. This means that there is a moderate degree of correlation between education and R&D spending for nuclear power. Lastly, I find that education is significantly and negatively associated with political support. This means that there is a weak degree of correlation with of -,234 between education and political support.

This relationship can be seen in the trend line below.

Figure 2

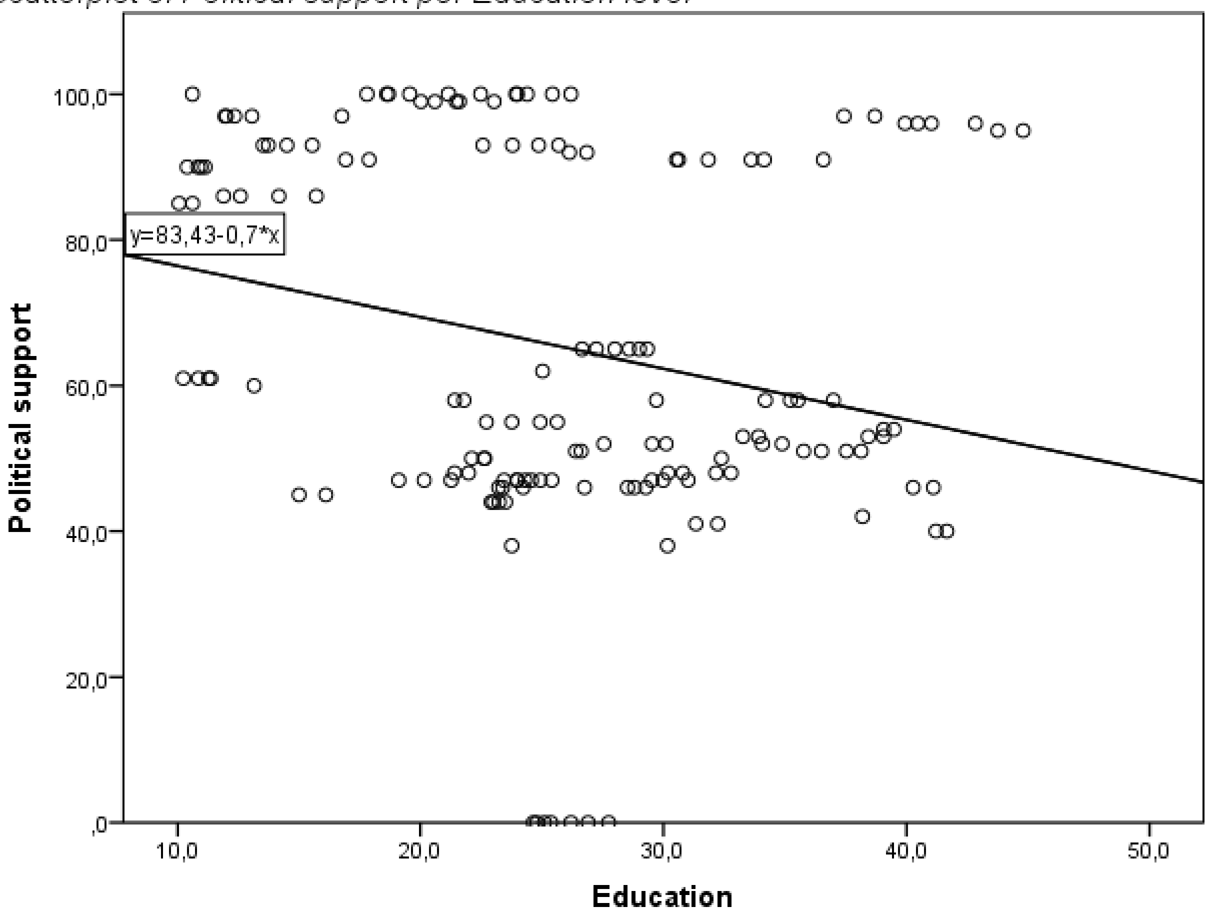
Scatterplot of R&D spending per Education level



Note. This figure shows a scatterplot of R&D spending per Education level.

Figure 3

Scatterplot of Political support per Education level



Note. This figure shows a scatterplot of Political support per Education level.

Here a positive trend line with an increase of 52,95 of R&D spending per 1 point increase in education levels and a negative trend line where political support decreases with .7 per 1 point increase in education can be seen. Most relevant here is the spread-out nature of the plot points along clearly definable national lines rather than along the trend line. And the opposing directions of the trend lines in spite of the expectation that both should have similar relationships. The clear national differences can be best seen in Austria at the bottom of the figure with 0 political support.

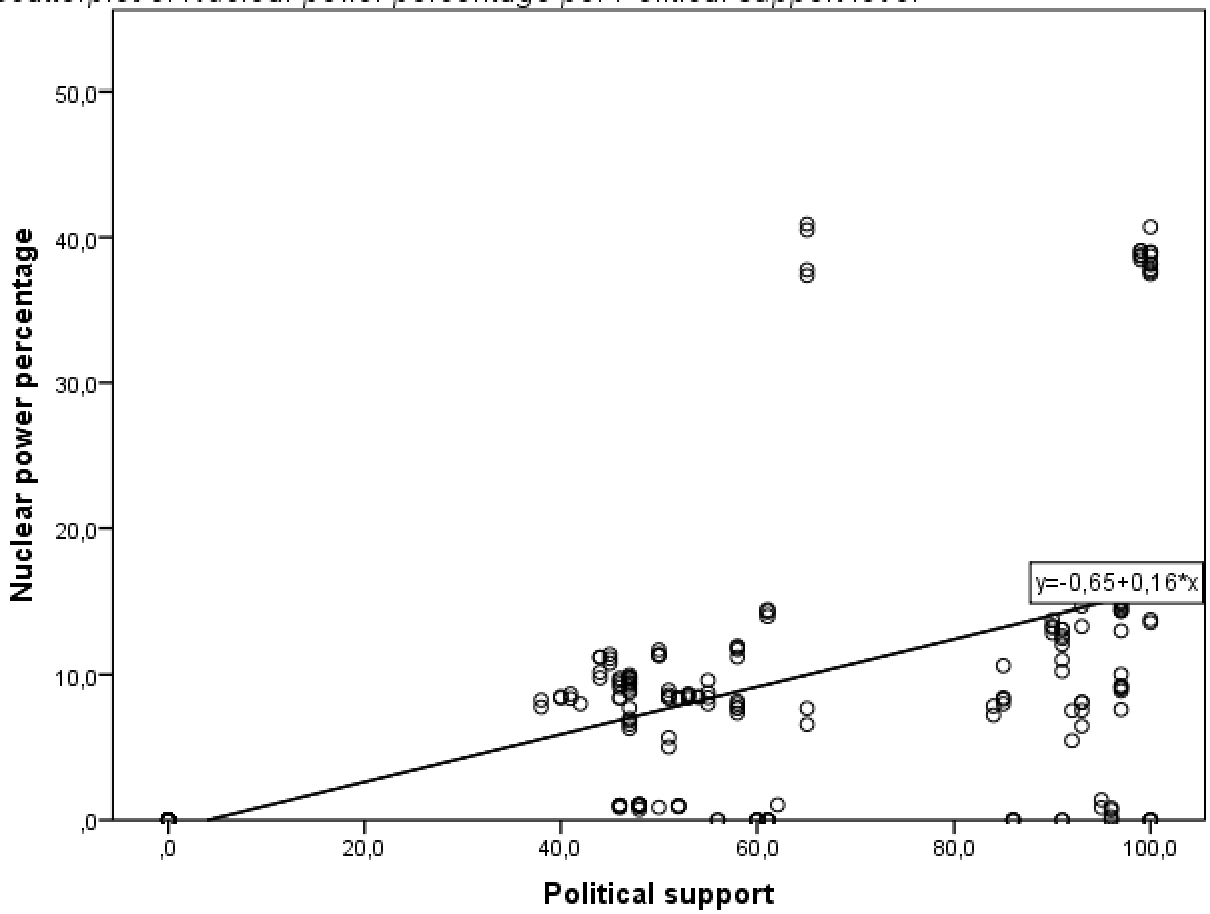
Political support

Political support has a minimum of 0 and a maximum of 100, whilst having a mean of 62,2 and a std deviation of 30. For political support I find that it has a significant and positive relationship of ,466 with nuclear power as a percentage of the total energy. This means that there is a moderate degree of correlation between political support and nuclear power as a percentage of the total energy net. I also find that political support has a significant and positive relationship of ,449 with R&D spending for nuclear power. This means that there is a moderate degree of correlation between political support and R&D spending for nuclear power.

These relationships can be seen in the trend lines below.

Figure 4

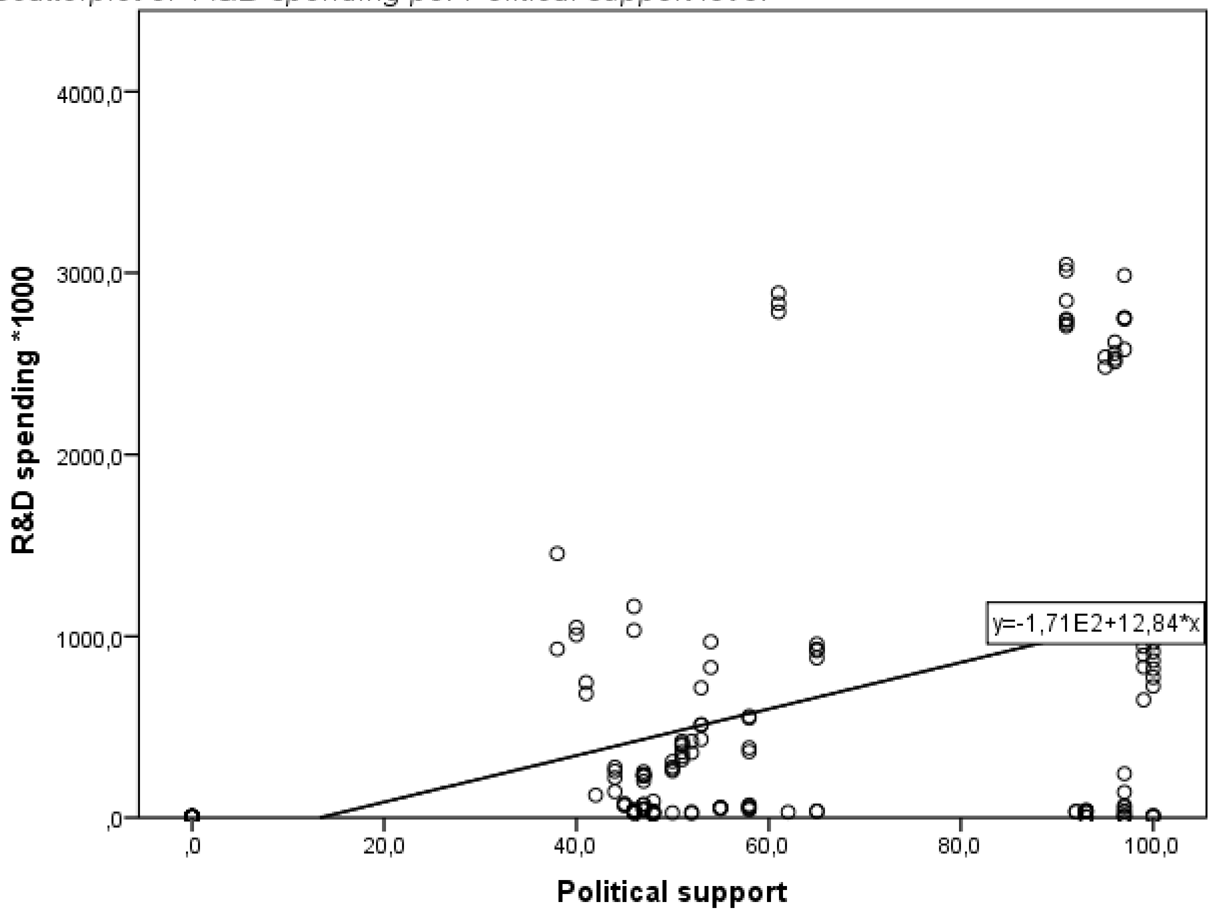
Scatterplot of Nuclear power percentage per Political support level



Note. This figure shows a scatterplot of Nuclear power percentage per Political support level.

Figure 5

Scatterplot of R&D spending per Political support level



Note. This figure shows a scatterplot of R&D spending per Political support level.

Here two positive trend lines with a similar angle in the trend lines of both R&D spending and nuclear power percentages can be seen. Most interesting here are the outliers of France, Austria, Japan and Poland. With France having a much higher implementation degree then the rest of the set and also a high degree of political support being in the top right corner here. Whilst Japan is in a similar situation with it having a significantly higher R&D spending whilst also being at the upper end of political support leaving it in the top right regarding the R&D relationship. Meanwhile, Poland has significant support, but no implementation degree as seen with it being in the right corner. Whilst Austria being is in the left bottom with 0 implementation and support. Most other nations stay in the middle with both middling support and implementation of nuclear power.

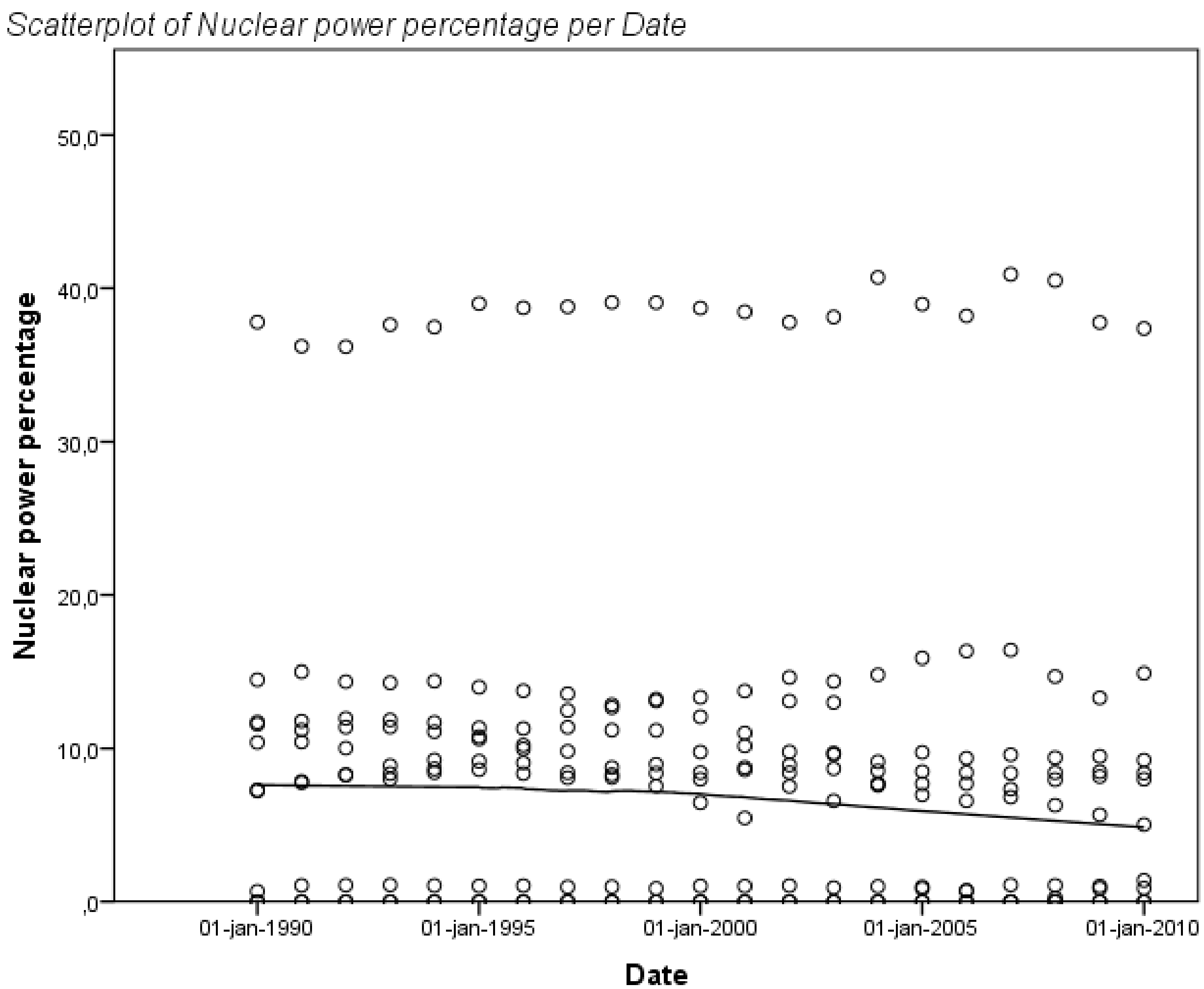
GDP

GDP has a minimum of 5949 and a maximum of 48580, whilst having a mean 25888 of and a std deviation of 9403,9. For GDP per capita I find that it has an insignificant relationship with both nuclear power as a percentage of the total energy net and R&D spending for nuclear power. Meaning that there is no degree of correlation between GDP and the dependent variables that I can discern. It will therefore be excluded from further analysis.

Crisis effect

Crisis effect has a minimum of 1990 and a maximum of 2010, whilst having a mean of 2000 and a std deviation of 2217. The strange std deviation is the result of Spss only allowing me to record dates as 1st of January year(n). For time/the crisis effect I find that it has an insignificant relationship with both nuclear power as a percentage of the total energy net and R&D spending for nuclear power. Meaning that there is no degree of correlation between the date or time and the dependent variables that I can discern. However, I do find some interesting graphic and nation specific results if I use a loess line:

Figure 6



Note. This figure shows a scatterplot of the Nuclear power percentages per Date.

Here I utilize a loess trend line to identify a decreasing usage of nuclear power as a percentage, its tipping point is roughly recorded in 2003 or with the lag measured in 2010 or one year before the Fukushima disaster. Most nations however saw no to very little impact form this as can be seen in the figure. Japan however did see some relevant changes which can be seen in the following table for this period in Japan:

Table 4

Nuclear power percentage per year in Japan

2000(2007)	2001(2008)	2002(2009)	2003(2010)	2004(2011)	2005(2012)	2006(2013)	2007(2014)	2008(2015)	2009(2016)	2010(2017)
12.1	11	13.1	13	7.6	0.8	0.7	0	0.2	0.9	1.4

Note. This table shows the percentage of nuclear power within the Japanese energy net over time

Here it can be seen that lagged data from 2004/2011 onward, regarding Japan's nuclear power implementation, shows a steep decline in nuclear power implementation to 0 percent, after which its implementation percentage increases again. The bracketed years should normally show the outcomes of the planning that happened during the non-bracketed years, whilst here a radical change in trend can be seen.

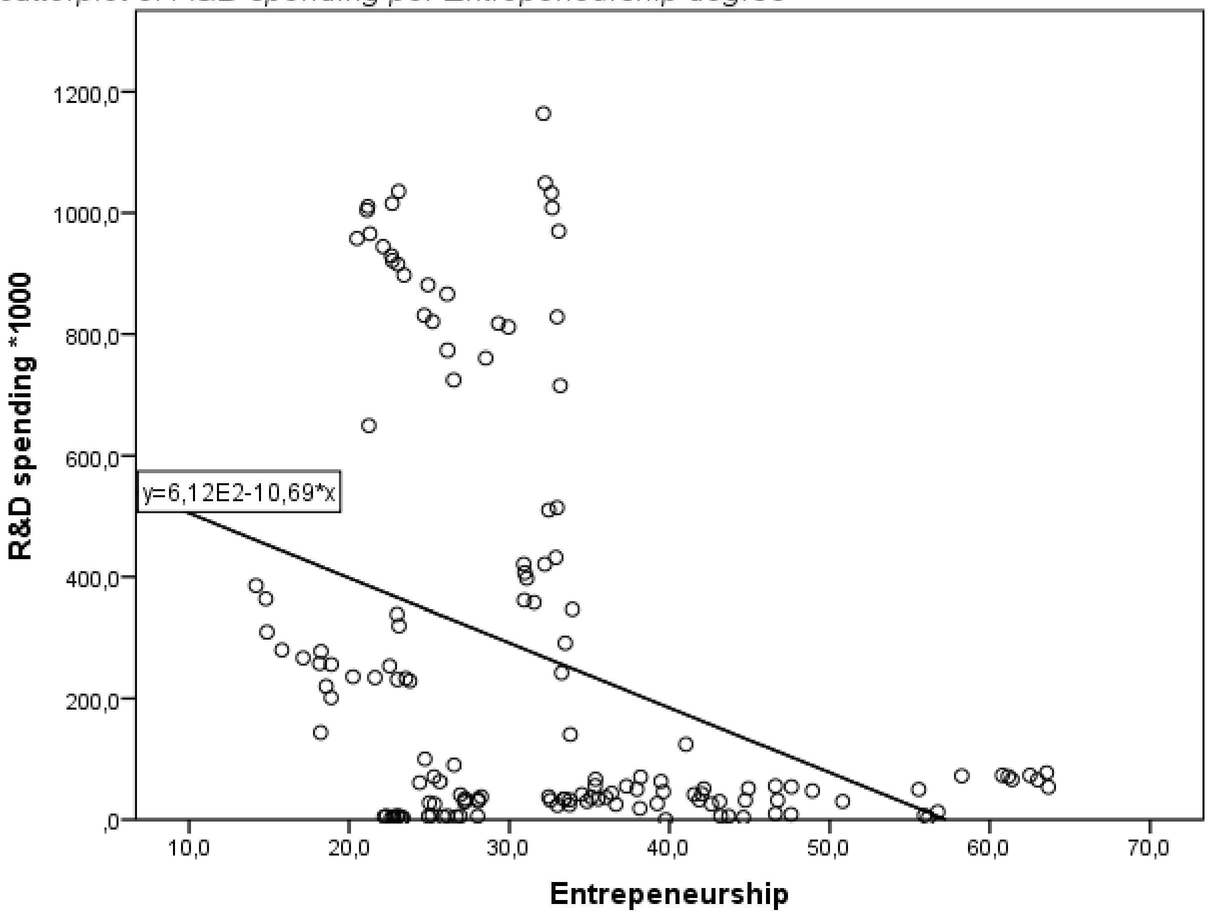
Entrepreneurship

Entrepreneurship has a minimum of 13,7 and a maximum of 73,6, whilst having a mean of 34,8 and a std deviation of 14,2. For entrepreneurship I find that it has a significant and negative relationship of –269 with nuclear power as a percentage of the total energy. This means that there is a low degree of correlation between entrepreneurship and nuclear power as a percentage of the total energy net. I also find that entrepreneurship has a significant and negative relationship of -,367 with R&D spending for nuclear power. This means that there is a moderate degree of correlation between entrepreneurship and R&D spending for nuclear power.

These relationships can be seen in the trend lines below.

Figure 7

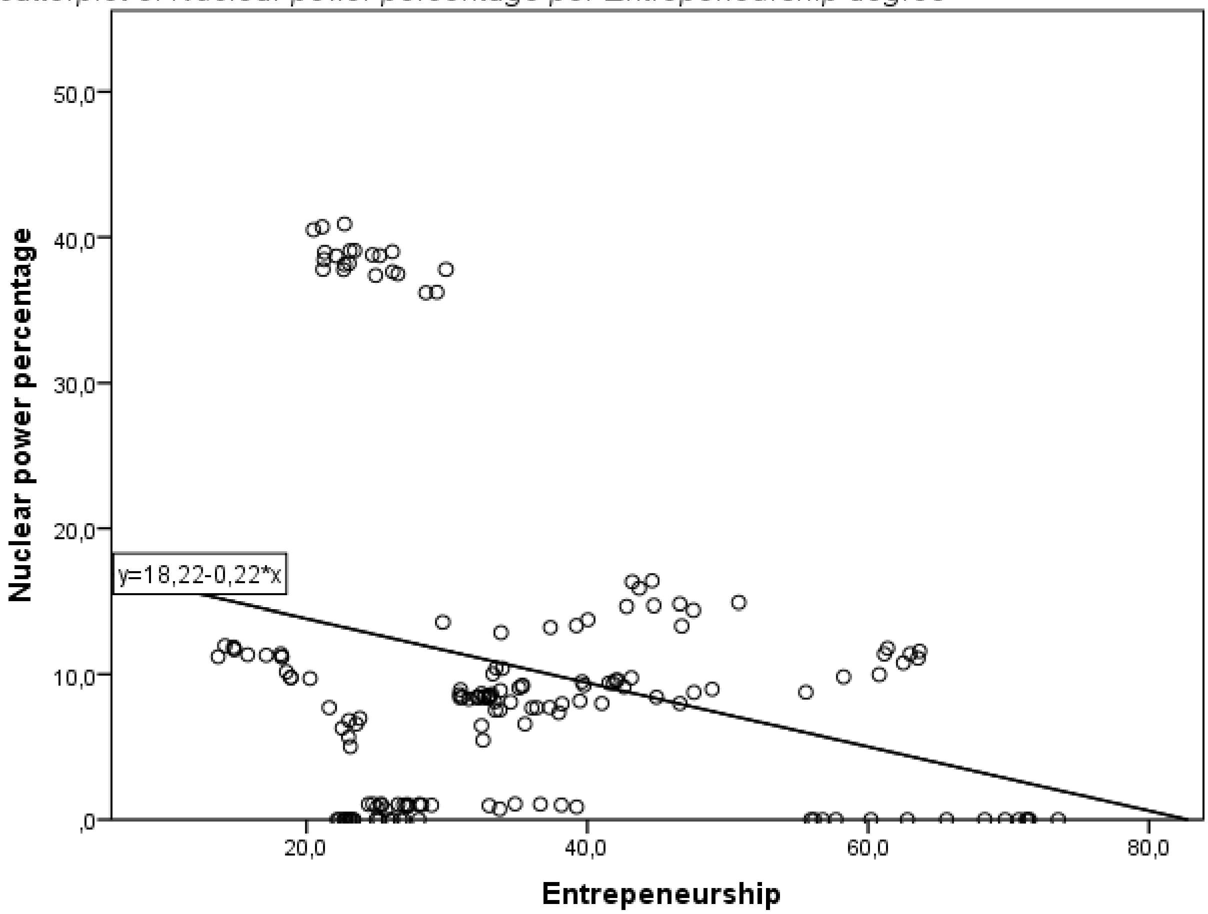
Scatterplot of R&D spending per Entrepeneurship degree



Note. This figure shows a scatterplot of R&D spending per total percentage of entrepeneurs in a country.

Figure 8

Scatterplot of Nuclear power percentage per Entrepeneurship degree



Note. This figure shows a scatterplot of Nuclear power percentage per total percentage of entrepeneurs in a country.

Here two negative trend lines with a similar downwards angle can be seen. However most relevant here are the outlying nations of France and Poland. With France having low levels of entrepreneurship and high nuclear power percentages, which can be seen in the point concentrations on the top left regarding both figures. Meanwhile Poland has one of the highest degrees of entrepreneurship, but also very little nuclear power implementation in both figures. This can be seen in the bottom right of both figures.

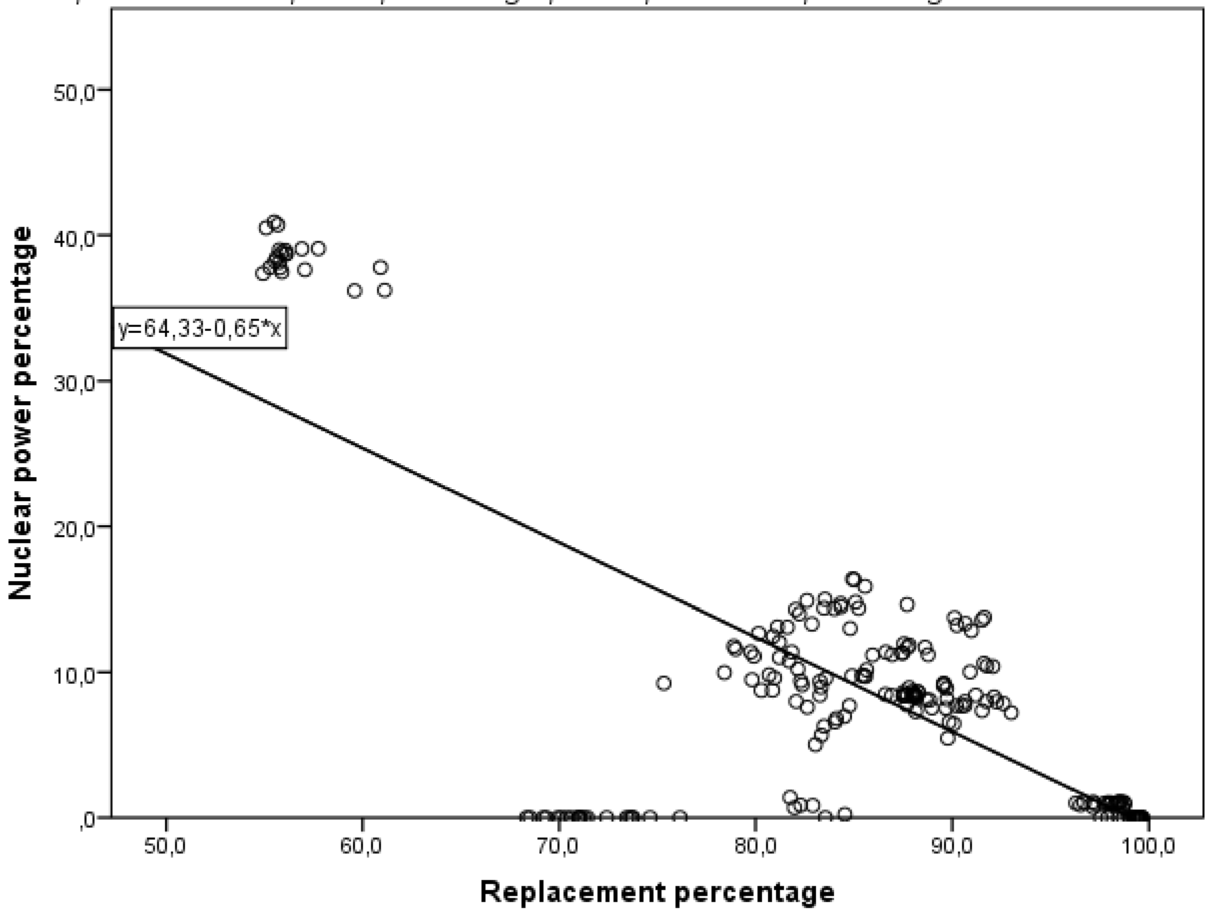
Oil, gas and coal

Replacement percentage has a minimum of 54,9 and a maximum of 99,7, whilst having a mean of 84,1 and a std deviation of 12,1. For the presence of oil, gas and coal in the energy mix I find that it has a significant and negative relationship of -,728 with nuclear power as a percentage of the total energy. This means that there is a high degree of correlation between the presence of oil, gas and coal in the energy mix and nuclear power as a percentage of the total energy net. I also find that the presence of oil, gas and coal in the energy mix has a nearly significant and negative relationship of -,165 with R&D spending for nuclear power. This means that there is most likely a low degree of correlation between the presence of oil, gas and coal in the energy mix and R&D spending for nuclear power.

These relationships can be seen in the trend lines below.

Figure 9

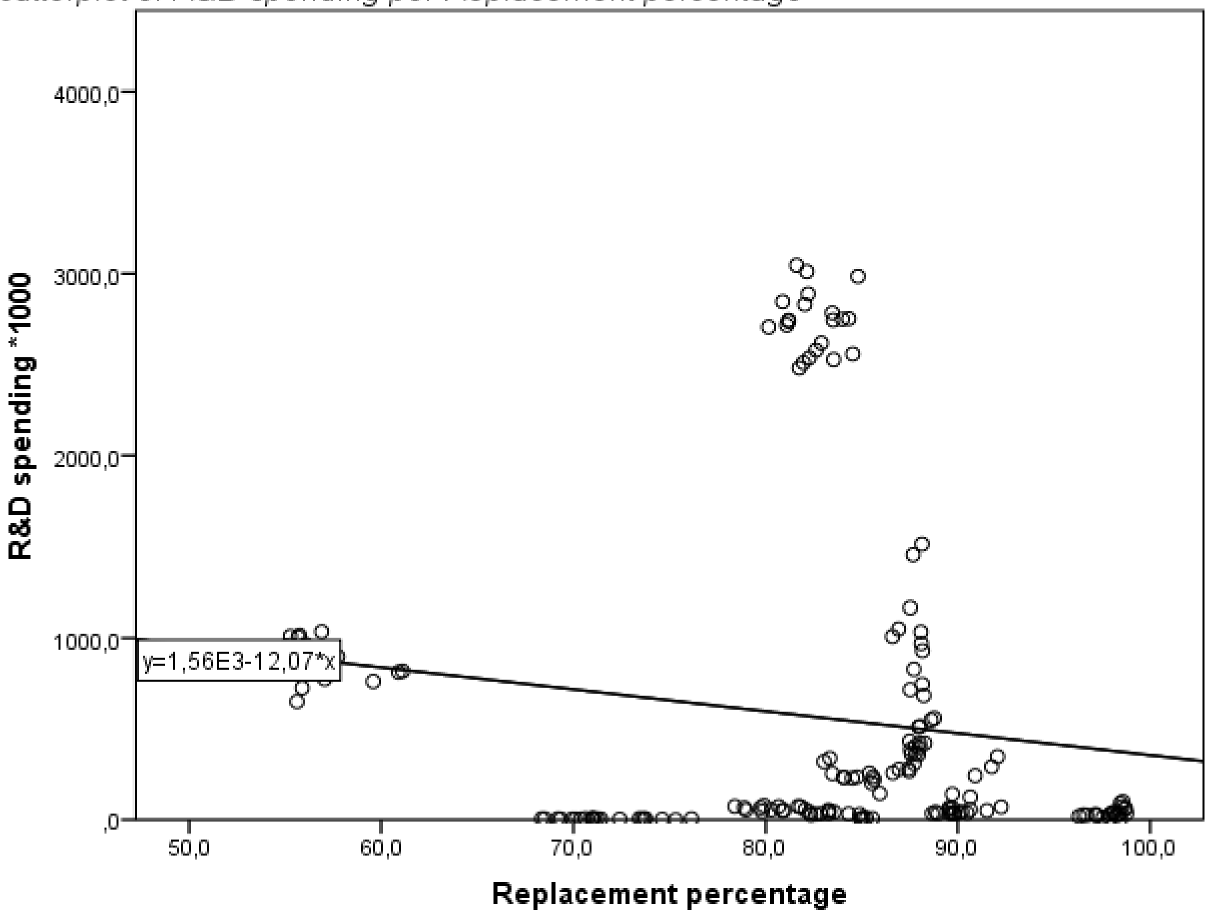
Scatterplot of Nuclear power percentage per Replacement percentage



Note. This figure shows a scatterplot of Nuclear power percentage per Replacement percentage.

Figure 10

Scatterplot of R&D spending per Replacement percentage



Note. This figure shows a scatterplot of R&D spending per Replacement percentage present.

Here both a strong and weak/nearly significant negative trend line for nuclear power as a percentage and R&D spending relative to the percentage of oil, gas and coal can be seen. Interesting here is that most points fit the general trend line well, whilst the two main outliers of France at the high end of nuclear power percentage and Austria at 0 percent nuclear power implementation do not. France can be seen at the top left of nuclear power percentage with roughly 40 percent of its energy being derived from nuclear power and roughly 60 percent being derived from replacements. Whilst Austria is at the bottom with strangely enough around 70 percent of its energy being derived from replacements but none from nuclear. This will later be further contextualized with auxiliary data. Furthermore, it seems interesting to note that for most points the adding up of nuclear power percentage and replacement percentage will result in a number of roughly around 100 percent. Lastly Japan is once again an outlier regarding R&D spending due to its higher than usual R&D spending.

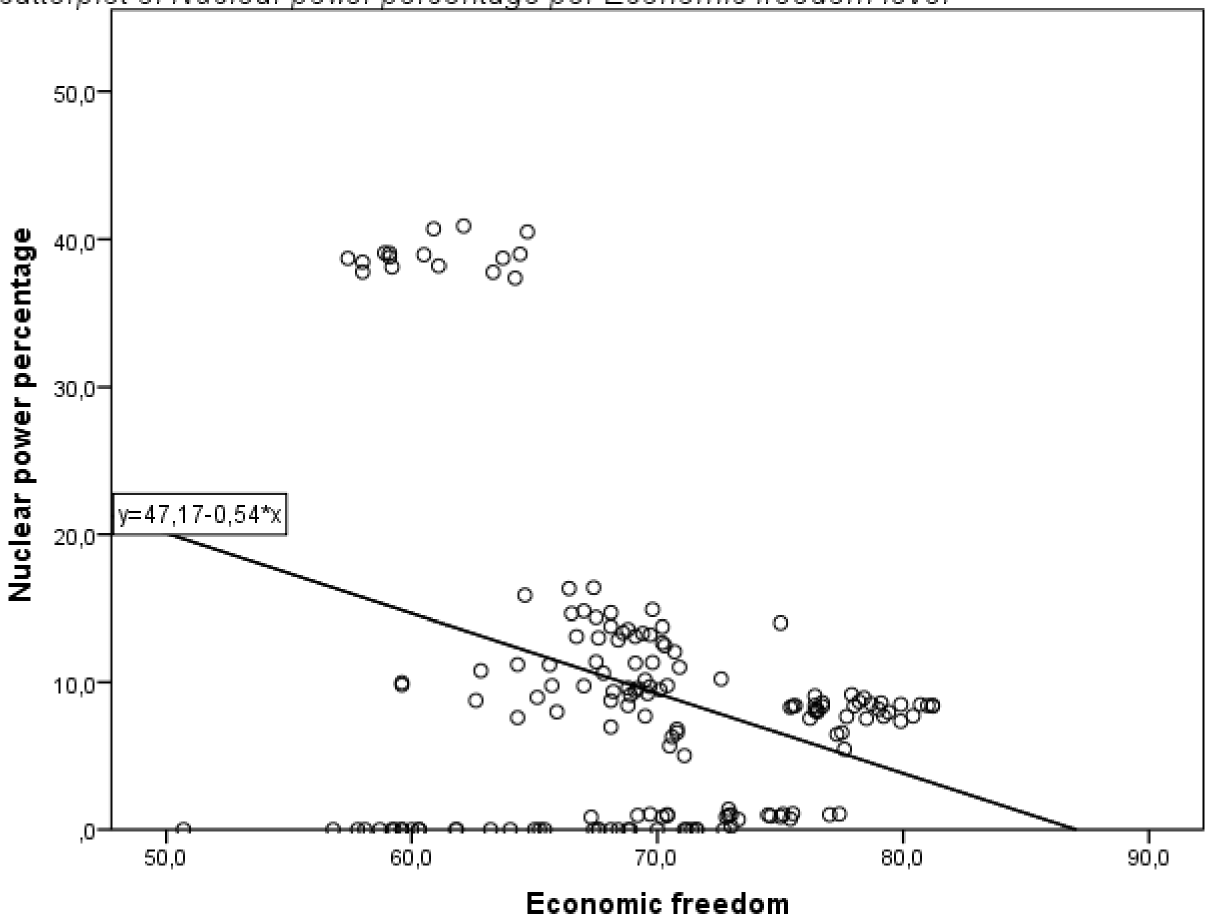
Economic freedom

Economic freedom has a minimum of 51 and a maximum of 81, whilst having a mean of 69,2 and a std deviation of 6,4. For economic freedom I find that it has a significant and negative relationship of -,318 with nuclear power as a percentage of the total energy. This means that there is a moderate degree of correlation between economic freedom and R&D spending for nuclear power. I also find that economic freedom has an insignificant relationship with nuclear power as a percentage of the total energy net meaning that, there is no degree of correlation between economic freedom and R&D spending for nuclear power that I can discern.

This relationship can be seen in the trend line below.

Figure 11

Scatterplot of Nuclear power percentage per Economic freedom level



Note. This figure shows a scatterplot of Nuclear power percentage per the degree of Economic freedom.

Here a negative trend line with most plot points actually fitting around the trend line of nuclear power percentage can be seen. Whereby France at the top and Poland/Austria at the bottom do not fit around the trend line. It can be seen that France with a relatively lower economic freedom index has a higher degree of nuclear power percentage. Whilst Poland and Austria have at the bottom also relatively low/middling economic freedom coupled with no nuclear power implementation. Lastly the rest of the nation's seem to have lower levels of nuclear power percentages at higher levels of economic freedom, as the negative trend line would suggest.

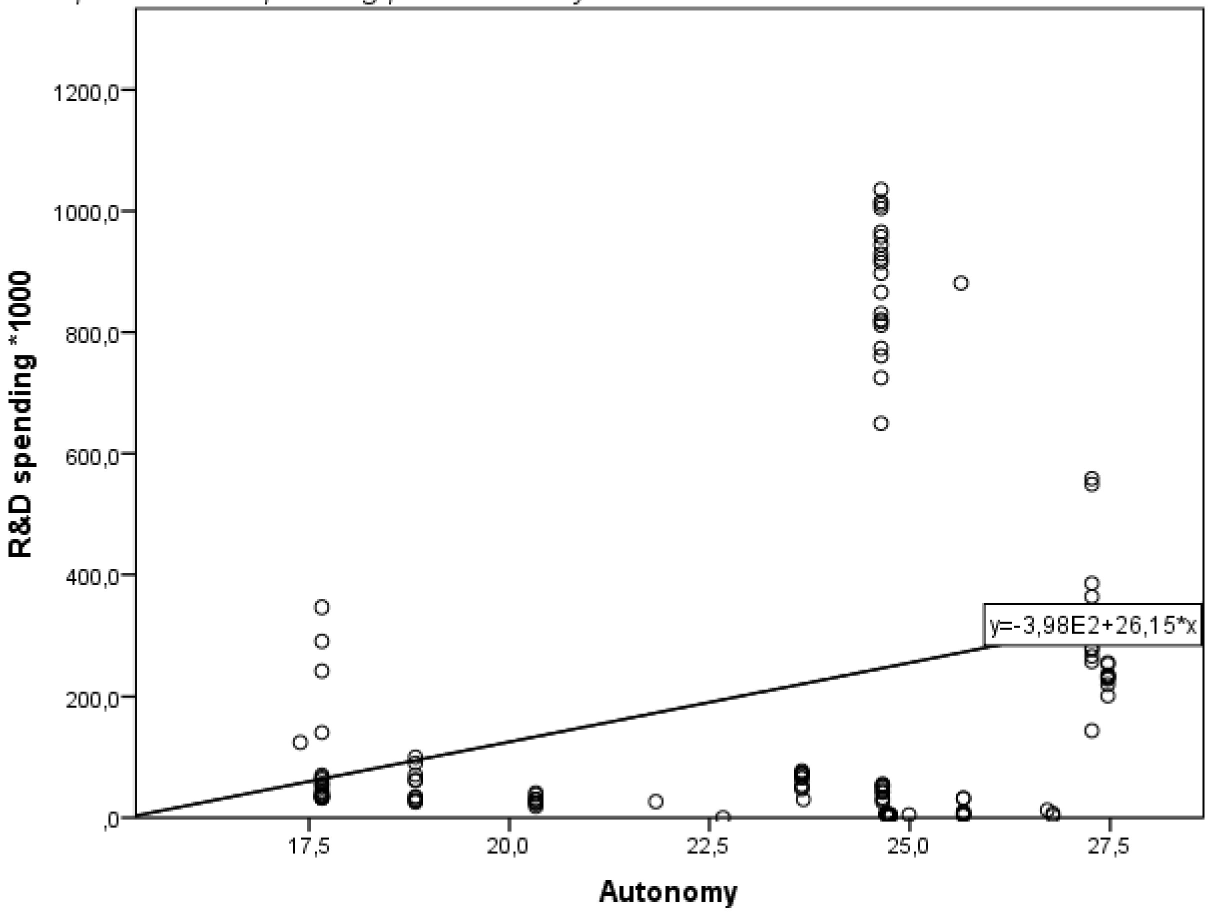
Autonomy

Autonomy has a minimum of 17,4 and a maximum of 27,5, whilst having a mean of 23,4 and a std deviation of 3,3. For Autonomy I find that it has an insignificant relationship with nuclear power as a percentage of the total energy. This means that there is no discernible correlation between Autonomy and nuclear power as a percentage of the total energy net. I do find that Autonomy has a significant and positive relationship of .279 with R&D spending for nuclear power. This means that there is a low degree of correlation between Autonomy and R&D spending for nuclear power.

This relationship can be seen in the trend line below.

Figure 12

Scatterplot of R&D spending per Autonomy level



Note. This figure shows a scatterplot of R&D spending per Autonomy level.

Here a positive trend line with some plot points fitting around the trend line can be seen, whereby France at the top and Poland in the right bottom do not fit the trend line. Here it can be seen that France with its relatively high R&D spending is in the top right whilst also maintaining a relatively high autonomy level. Whilst Poland is in the bottom right around the 25 level of autonomy with also almost no R&D spending opposing the trend. Meanwhile most nations stay somewhere around the trend line with lower autonomy groupings tending to have lower R&D spending whilst higher autonomy levels tend to have higher R&D spending. Also, important to note is that the strange line shapes of the point groupings are the result the data being recorded in 10 yearly groupings. Generalizing these results to the whole period, can be justified by the relative stability of the autonomy levels recorded. With differences between the 10-year groupings generally staying within a range of 1 to 5.

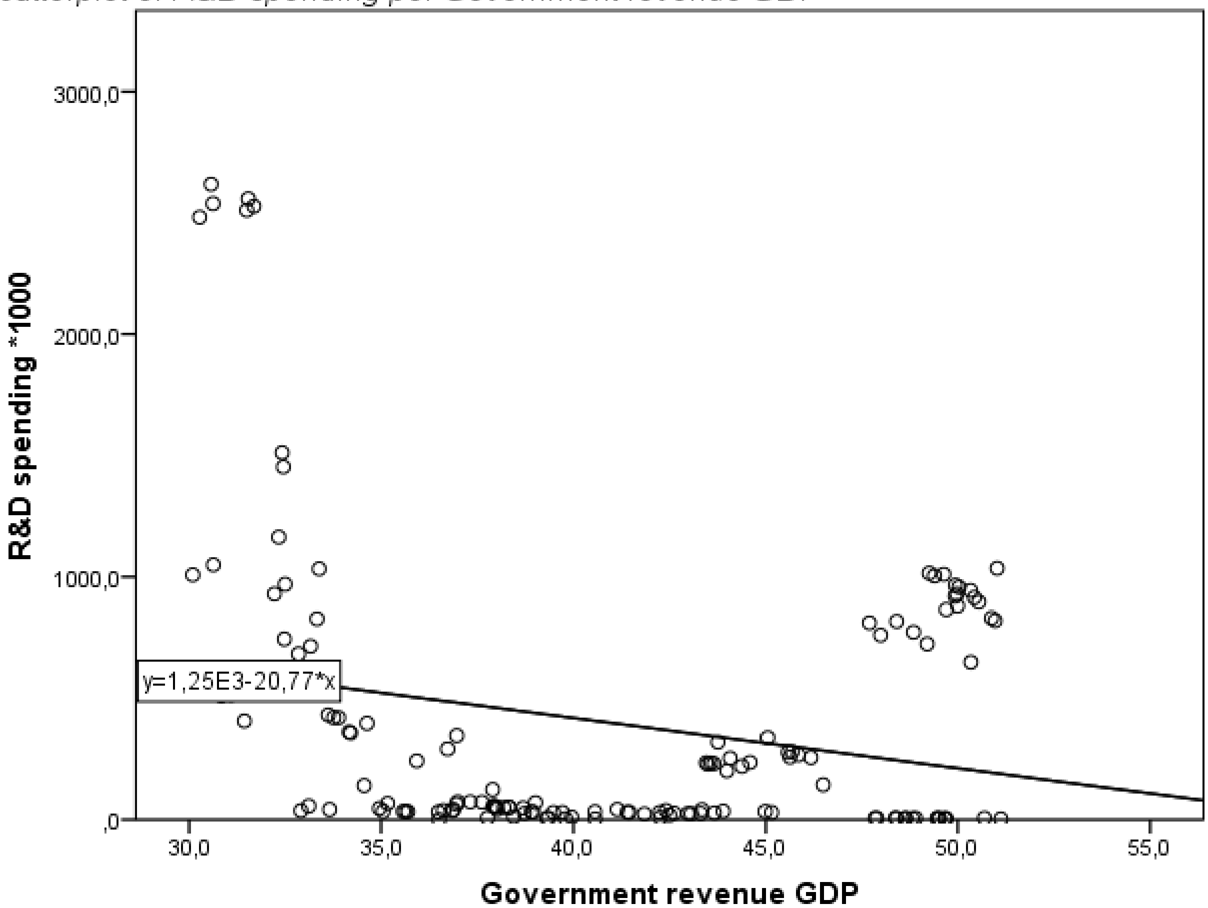
Government revenue as a percentage of GDP

Government revenue as a percentage of GDP has a minimum of 30 and a maximum of 51, whilst having a mean of 40,9 and a std deviation of 6. For government revenue as a percentage of GDP I find that it has a significant and positive relationship of, 393 with nuclear power as a percentage of the total energy. This means that there is a moderate degree of correlation between government revenue as a percentage of GDP and nuclear power as a percentage of the total energy net. I also find that government revenue as a percentage of GDP has a significant and negative relationship of –,228 with R&D spending for nuclear power. This means that there is a low degree of correlation between government revenue as a percentage of GDP and R&D spending for nuclear power.

These relationships can be seen in the trend lines below.

Figure 13

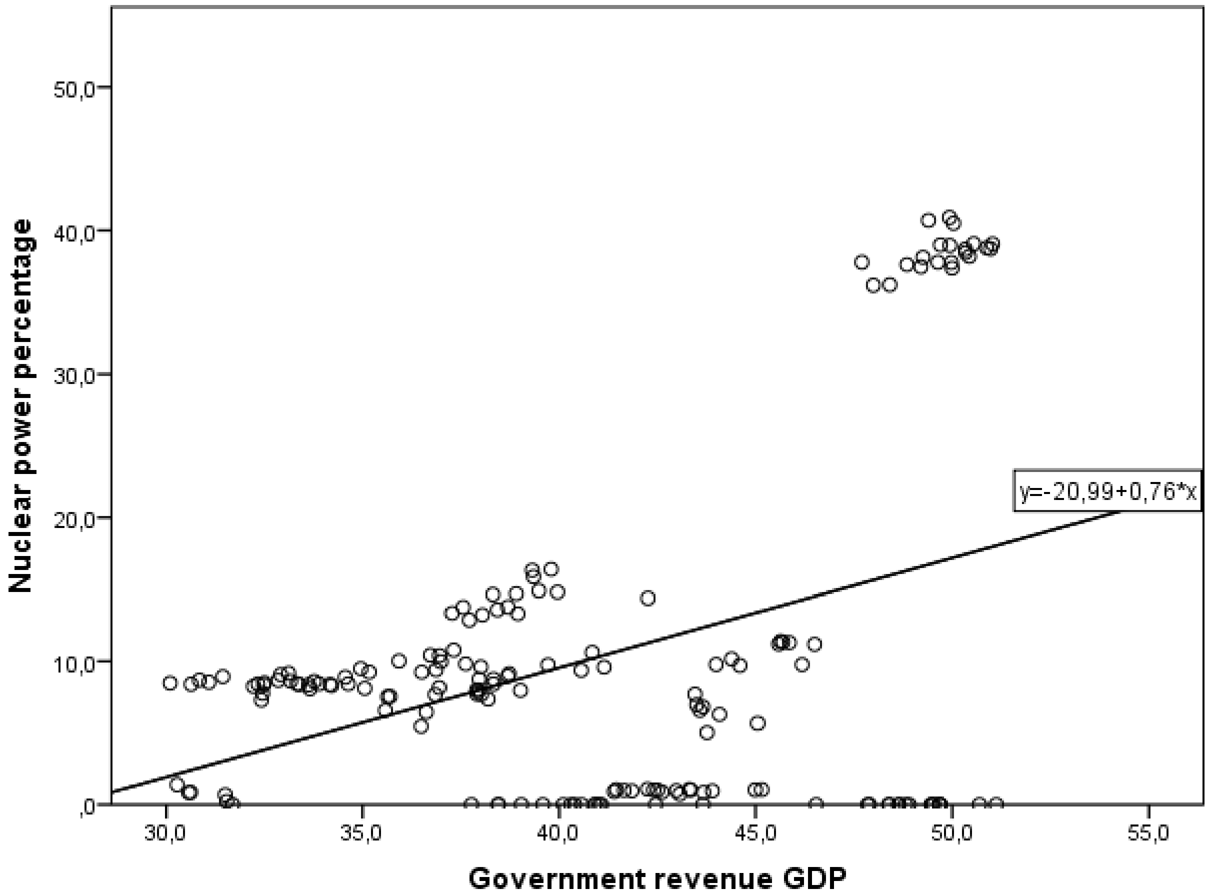
Scatterplot of R&D spending per Government revenue GDP



Note. This figure shows a scatterplot of R&D spending per Government revenue as a percentage of GDP.

Figure 14

Scatterplot of Nuclear power percentage per Government revenue GDP



Note. This figure shows a scatterplot of Nuclear power percentage per Government revenue as a percentage of GDP.

Here two opposing trend lines can be seen. The plot points of the R&D line center more around their nations and are scattered around the trend line. Whilst the nuclear energy percentage line seems to have its plot lines fit more around the trend line to a greater degree. The R&D line shows mostly that points with high levels of government revenue as a percentage of their GDP have lower levels of R&D spending. Whilst the nuclear power percentage line shows that, points with a higher nuclear power percentage also tend to have a higher percentage of their GDP as government revenue. This is most strongly seen in France, which is at the top right and is an outlier in both cases. France is in line with the trend regarding nuclear power percentage whilst going against the trend regarding R&D spending.

Government revenue per capita

Government revenue per capita has a minimum of 3382 and a maximum of 20338, whilst having a mean of 11298,3 and an std deviation of 3998. For government revenue per capita I find that it has an insignificant relationship with both nuclear power as a percentage of the total energy net and R&D spending for nuclear power. Meaning that there is no degree of correlation between government revenue per capita and the dependent variables that I can discern.

Trust

Trust has a minimum of 27 and a maximum of 64, whilst having a mean of 40,9 and a std deviation of 11,1. Trust will be further represented as a table due to its limited number of data points making a figure lack any form of relevance whilst the correlation results are also insignificant:

Table 5

Comparison of Trust means per nation

Nation	Mean	N	Std. Deviation
1 AUT	49,20	1	.
2 CZE	31,20	1	.
3 FRA	40,10	1	.
4 DEU	39,50	1	.
5 JPN	27,00	1	.
6 NLD	63,60	1	.
7 POL	35,60	1	.
8 ESP	30,30	1	.
9 GBR	50,40	1	.
10 USA	41,80	1	.

Total	40,87	10	11,083

Note. This table shows a comparison of means for all nations regarding trust essentially representing the level of trust per nation in the measured year of 2010

Here it can be seen that, a comparison of means also does not really reveal any relationship between trust levels and national nuclear power implementation degree. This observation is derived from the lowest trust and highest trust levels of the recorded nations being on the lower and middling side of implementation. Whilst the higher implementation degrees tend to be around middling trust levels with Japan being an exception due to its high R&D expenditures.

General statements and points

It might have become apparent to some that there have been some constant outliers in the data mainly Austria, France, Japan and Poland. Here I will seek to provide additional information that might be useful for the analysis later on. Austria seems to have had a complete political rejection of nuclear power whilst also not using any (Boeck & Drábová, 2006). Which has resulted in it being a major outlier in the data set. It has however remained in since it does represent a group of OECD nations which seeks to avoid nuclear power. It therefore serves as an example of the no nuclear option. Also, according to my data set between 23% and 30% of Austria's energy was produced by hydro during that time. Which could explain its interesting results in the energy replacements section. France's high degree of nuclear power percentages inversely are an upwards representative for the nuclear option and as such stayed in. With its high degree of political support seemingly, having been the result a French political understanding and later tradition of being in favor of nuclear power as a solution to oil dependence (Electricité de France, z.d.). Japan seems to have a high and outlying focus on R&D spending and thus seems to somewhat bias the results upwards. It has stayed in as its nuclear power percentages are within the norm. Furthermore, its R&D spending could be explained by its high level of involvement with the deployment/usage of the 3rd generation reactors as opposed to older European/us reactors (World Nuclear Association, 2020). Lastly Polish data as it comes to nuclear power percentages is a strange case, however some of it can be put into context by Poland's only nuclear power plant being used for medical purposes during the researched period (Krzysztoszek et al., 2007). Poland stayed in due to its value as an east bloc representative being considered more important to this research, than its inability to produce one of the dependent variables. Especially since it does have R&D spending data points at a less outlying level.

Chapter 5 Analysis

Here I will first examine each of the variables separately and explain how their results relate to their hypotheses. After which I will compare the hypotheses variables within the wider context of their categories.

Variable analysis

Political support

Regarding the relationship between political support and nuclear power I can see moderate correlations for both predictors of nuclear power in the expected positive direction. This supports the theoretical assertion that the degree of nuclear power implementation is partially driven from the degree of political support or pressure in favor of it. However, due to this being a correlation I can only state that the relationship is likely positive but not for certain as other omitted variables might cause this positive effect instead. I can however assert that political support its positively associated with nuclear power implementation on both counts. Since both correlation models/figures show an increase in nuclear power implementation when political support increases. An analysis of the outliers here, might create further proof in support of the theory. This can mainly be seen in France at the far top right. It has had a high degree of support for nuclear power for the whole researched period and has also had the highest degree of nuclear power percentages of all researched nations. Based upon my literature review of French nuclear politics there seems to have had a constant and focused political drive for using more nuclear power which supports the theory (Electricité de France, z.d.). Austria on the other hand has been in the opposite situation with no support for nuclear power existing in its political system and this having supposedly led to the dismantlement and future abstinence of nuclear power this again supports the theory (Boeck & Drábová, 2006). It therefore seems to be the case that both the top and bottom scorers of the implementation degree and political support follow the theoretically expected relationship. Which consists of high political support generating high implementation degree and thus inversely low political support generating low implementation degree.

Centralization

Regarding centralization I find that autonomy has no discernible relationship with nuclear power percentages and a weak/positive correlation with the R&D spending aspect of nuclear power implementation. The relationship I do find, is in the expected direction since the local autonomy degree is the inverse of the degree of centralization and its relationship with nuclear power implementation is expected to be negative. This can be seen in the results in which the points/nations with higher degrees of autonomy or lower degrees of centralization, also have a higher degree of R&D spending. This means that the supposed negative association between centralization and nuclear power implementation is partially supported by this result. However, the support is only partial due to the other metric of nuclear power percentages being insignificant. This difference in results can be explained by the theory's focus on centralization's relationship with innovation. Stating that more centralized organizations generate accountability concerns and limit diversity of tasks, which limits innovation adoption further. Therefore, it seems possible that centralization only significantly impacts the innovation aspect of nuclear power implementation in the form of R&D spending. Whilst the purely nuclear implementation part of the measurements, in the form of nuclear power percentages is not measured as significant.

Crisis effect

Due to the lack of any significant correlation between time passing and nuclear power implementation I cannot find any relationship between the crisis effect and nuclear power implementation. However as can be seen in the data collection chapter, I can find a significant divergence from the norm, when in concerns nuclear power implementation regarding Japan. Mainly right after the disaster at Fukushima I can see that Japan stops using nuclear power going from around 12 percent of its power being derived from nuclear power to between 0-1 percent. With Japan starting to increase its nuclear power percentages again around 5 years after Fukushima. These results could explain why the correlations are insignificant since Chernobyl occurred with an eleven-year time lag before the measured period. Therefore, it seems plausible that seeing as Japanese nuclear power production started to increase after 5 years. The effect of

Chernobyl simply is not included in the data set due to the time lag introduced in the nuclear power percentages. Furthermore, the effect seems to be highly localized as Japan seems to be the only nation affected this drastically by the disaster with other OECD nations not showing much of an effect as seen by the figure. It therefore seems likely that the crisis effects correlation with nuclear power implementation is difficult to generalize outside of directly affected nations and that the effect lasts for a period of less than 11 years. Which although this will not be empirically substantiated in this thesis, could be seen once again in the resent renewed interest in nuclear power as can be seen in the early 2020s, as of writing this thesis.

Education

Education seems to have a moderately positive correlation with R&D spending and no significant relationship with nuclear power implementation. This is against the expectation that education through an increased degree of information would lead to a negative association with nuclear power implementation. This thesis does however not consider this relationship to be in support of the alternative view, that increased education, if well designed, would lead to an increase in public support for nuclear power. Since education does seem to have the expected negative effect on political support which would be in support of the expectation that education negatively affects public support and through this also affects political support negatively. The opposite directions of the lines can instead be explained by looking at the specific measurement for the degree of nuclear power implementation. Since it seems plausible that R&D spending on nuclear power being positively associated with education, is not the result of a relationship between education and nuclear power implementation. But rather the result of a relationship between general (nuclear included) R&D spending and education levels. These results therefore seem to partially show the expected results, since education is negatively associated with political support which itself is negatively associated with nuclear power implementation. Whilst the opposite result found can be considered as a fault in the dependent variable selection for this specific independent variable of education.

Trust

Regarding trust, this research has found no significant correlations between it and nuclear power implementation. I therefore cannot confirm any of the theoretical expectations and are thus forced to consider trust as having no significant effect on nuclear power for this research. These results can however be explained by the limited number of data points used for this variable.

Entrepreneurialism

Entrepreneurship has a significant and negative correlation with both dependent variables, which is against expectations. Which can be seen by the points showing that nations with lower degrees of entrepreneurship have higher degrees of implementation regarding both measurement types. This empirical divergence from theory cannot easily be explained by outlier bias. Since there are similar numbers of outliers on both sides of the trend line. Instead, it seems to be the case that the theoretical assertion that more entrepreneurs/ entrepreneurialism leads to more innovation is wrong or at least not confirmable through this method. This result therefore could indicate that either entrepreneurship does not drive innovation/nuclear power. Or that entrepreneurship is not really a collective action that can be measured via the amount of Entrepreneur's participating in it. Furthermore, it could be that the high up-front costs associated with nuclear power actually cause the increase of entrepreneurs in a nation to have a negative association with nuclear power implementation. Since the increase in entrepreneurs might cause a diffusion of investments which should drive innovation as theory suggests but might also lower the size of each individual investment. Causing most of these potential investments to not have the capital necessary for nuclear power implementation and thus generating a negative association.

Market liberalization

Regarding economic freedom I find that it is moderately negatively correlated with nuclear power percentages. This is further reinforced by figure 11, which shows that nations/data points with higher degrees of economic freedom inversely have lower degrees of the energy supply which is derived from nuclear power. This finding is opposed to the expectation that economic freedom and nuclear power implementation would be positively associated. This can be explained by parts of the theory. Since it does not definitively state the relationship has to be positive, but rather that market liberalization drives organizations to explore more innovation routes. Therefore, it could be that this increase in innovation routes explored, actually diffuses innovation/implementation funds and thus actually reduces the chances of any particular innovation succeeding. Since they now have less resources to succeed. This presumption is reinforced by the realization that nuclear power is particularly expensive in initial construction/development cost as stated earlier. Therefore, the diffusion of resources might have made firms/nations less able to assemble sufficient funds for nuclear power development and thus reducing its implementation. This potential relationship is especially interesting due to the same type of relationship seemingly existing between the number of entrepreneurs and the implementation degree, through the diffusion of investments.

Energy replacements

Energy replacements seem to have a very strong negative correlation with nuclear power percentages as opposed to what was expected. This can also be seen in figure 9, where nations with higher degrees of replacement percentages seem to have a near one for one replacement within/reduction of their nuclear power percentages. Whilst there is an insignificant relationship with the other variable of R&D expenditure. This insignificance can only really be explained by the theory when one considers the relationship between nuclear power implementation and energy replacements, through the lens of competition in the energy mix. A relationship between R&D and energy replacements is therefore neither expected nor plausible in this research. The negative relationship can be explained by the theory. Here the expectation was that nuclear power would be used to replace other forms of energy, which is also shown by the data. However, the expectation that the relationship would be positive was the result of underestimating the degree of oil/gas and coal usage in the total energy net as opposed to hydro and nuclear power. Which made the relationship between nuclear power percentages and the presence of energy replacements one of direct replacement which would obviously be negative as shown by the theory and data. Rather than one where energy replacements served as a predictor of where one would use nuclear power to replace them. Another important point regarding the outliers is that all nations including France seem to nearly one for one replace their energy replacement usage with nuclear power. All except for Austria, this is the result of the earlier stated unique for this data set, reliance on hydro power by Austria. Whereby hydro seems to essentially have the same replacement function as nuclear does for other nations.

Interest

The interest results as stated earlier are mixed, with interest being moderately and negatively correlated with R&D spending as expected. This can be seen in figure 1 where nations and data points with higher interest levels also have lower levels of R&D spending. Whilst its relationship with nuclear power percentages is actually insignificant, which would go against expectations. This difference in significance's could be explained by the mechanism through which interest is meant to affect nuclear power implementation. This specifically regards the assertion in the theory that lower interest levels also lower the operating costs of nuclear power plants and thus increase their profitability. Whilst R&D can be considered an easily adjustable investment in nuclear power, relative to the building of nuclear power plants. It therefore seems plausible that the increase in profitability as expected by a decrease in interest levels. Would affect the investment prospects into nuclear power through R&D rather than the construction of nuclear power plants itself. This increase in profitability might have generated a belief in the future of nuclear power plants, rather than an immediate demand for more current power plants. It therefore seems to be the case that a reduction in interest has not driven a direct implementation of nuclear power as expected by the theory. Instead, it might have indirectly generated or is at least correlated with the interest in nuclear power plants, through R&D spending, making it affect nuclear power implementation this way.

Slack resources/Wealth

Regarding slack resources I find that government revenue per capita used to symbolize slack resources is not significantly correlated with nuclear power implementation. Which would mean that I cannot confirm if the theoretical assertion that, increased slack leads to or is correlated with more innovation is true. However, I do find that government revenue as a percentage of GDP is moderately and positively associated with nuclear power percentages whilst it's low and negatively associated with R&D spending. Which can be seen in figures 13 and 14 where in the nations/data points that have a higher percentage of their GDP generating their governments revenue, also have a lower degree of R&D spending and a higher degree of nuclear power in their energy networks. The R&D spending aspect of this result can be explained by the theory which states that, when overhead expenditures increase the positive relationship between slack resources and innovation will first weaken and then reverse. However, that does not fully explain the effect since there is no significant relationship between slack and R&D found. Therefore, it seems that when a nation extracts more of their GDP, they will be less likely to spend this money on nuclear power research, independently of their total tax revenue. Although this cannot be confirmed as I have found no theory that provides a reason for this. The effect found gets even more disconnected from the theory when you consider that government revenue per GDP is positively correlated with nuclear power percentages. This would mean that when a nation extracts more of their GDP, they will also be more reliant on nuclear power. This is difficult to explain with the theory at hand, however it could be possible that the type of nation that has high taxation levels is also interested in building nuclear reactors. Either because they require more funds to build/maintain them or as the product of a potential ideological similarities between the concepts. This is however speculation and further exploration is recommended regarding this relationship. It could also simply be that government revenue as a percentage of GDP is not a good way to measure the national equivalent of overhead costs.

Regarding GDP per capita this research has found no significant correlations between it and nuclear power implementation. I therefore cannot confirm any of the theoretical expectations and are thus forced to consider GDP as having no significant effect on nuclear power for this research. This result could also be explained by GDP per capita potentially not being an accurate predictor for wealth as could be suggested by this insignificant result.

Hypotheses

Governance drivers

Regarding governance drivers, I find that both expectations are supported by the data and figures generated during this research. With nuclear power implementation being positively associated with political support and negatively associated with the degree of governmental centralization. With this finding I can also somewhat confirm the hypothesis that: 'Higher political support for nuclear power leads to a higher degree of implementation of nuclear power'. Since I find the expected relationship in the expected direction. Furthermore, the other hypothesis regarding governance also affects nuclear power in the expected way, here it states that: 'Higher degrees of centralization are negatively associated with nuclear power implementation', which supports the theory further. However, since only a correlation analysis has been done no claim about true causality can be made and thus the findings here regarding political support need to be adjusted to: Higher political support for nuclear power is associated with a higher degree of implementation of nuclear power.

Social drivers

Regarding the social drivers I find that the results are mostly in conflict with the theory and that the effects associated with the crisis effect, trust and education are mostly in the wrong direction or insignificant. Whilst entrepreneurialism is in the wrong direction and significant on both nuclear implementation variables. It shows that the theory regarding most social drivers was not verified in this research, whilst also providing data that sometimes supports an opposite relationship as to what was expected, this means that further research might be required in this field. However, the expected effect of education on political support does seem to stand, due to it having a negative and significant relationship in the expected direction which could be useful for future research designs. Despite this, the hypothesis that: 'Higher education levels are negatively associated with political support and nuclear power implementation, whilst the crisis effect is negatively associated with the nuclear power implementation degree and trust is positively associated with nuclear power implementation degree' cannot be confirmed wholly due to:

Education being insignificant for nuclear power percentages and in the opposite direction for R&D spending, whilst the crisis effect is largely insignificant except when you look at only Japan and due to a lack of data point/significant results regarding trust. Furthermore, the hypothesis that: ‘entrepreneurialism is positively associated with nuclear power implementation’ cannot be confirmed. Instead, it seems to be the case that the opposite is true, and that entrepreneurialism is negatively associated with nuclear power implementation.

Economic drivers

Regarding economic drivers I find that the results are generally against the expectations of the theory sections but can be explained by the theory. With market liberalization having the opposite but significant effect of being negatively associated with nuclear power implementation. As to the hypothesis that: ‘The degree of market liberalization is positively associated with nuclear power implementation’. This could be useful to the body of literature on the subject, as it provides some direction for the relationship between a freer market and innovation, since this relationship as has been stated in theory, has not yet been well tested. Energy replacements has had an unexpected relationship whereby the presence of energy replacements did not serve as a predictor for the presence of nuclear power. As the hypothesis that: ‘The presence of replacements is positively associated with nuclear power implementation’ would suggest. But rather its relationship seems to consist of it being a replacement for oil/gas and coal, which is also supported by the theory. Slack resources and wealth seemed to have an insignificant or unexplained relationship with nuclear power implementation. Which would prevent me from confirming the hypothesis that: ‘The wealth and presence of slack resources within a country are both positively associated with nuclear power implementation.’ Finally, regarding interest, I find that its hypothesis that: ‘Borrowing costs in the form of interest rates are negatively associated with the degree of nuclear power implementation’, gets a conflicting answer from this research. With it being significantly and moderately associated with public R&D spend on nuclear power in the expected negative way. Whilst its relationship is insignificant with nuclear power percentages as a whole. I will therefore only be able to state that the level of interest is significantly associated with the research into nuclear power. Whilst not being able to make any kind of statements regarding its effects on nuclear power implementation as a whole, with any confidence. Meaning that I cannot confirm its theorized relationship within this research completely.

Answering the partial questions

Now this thesis will answer the partial questions for the purpose of answering the main question in the conclusion.

What processes and drivers have had a significant effect on an OECD nation's decision to implementation of nuclear energy?

Based upon the descriptive statistics shown earlier I can state that political support, centralization, education, entrepreneurialism, market liberalization, energy replacements, interest, the GDP percentage of government revenue and the crisis effect have all had significant or relevant degrees of association with the implementation of nuclear power in one way or another. However, based upon the earlier analyses I can only say that political support, centralization, entrepreneurialism, market liberalization, energy replacements, and interest are potential drivers with any degree of empirical and statistically significant support derived from the descriptive statistics shown earlier. Since the other results are either not really significant, reliable or conflict so much with theory that nothing of any reliability and relevance can be said about them with any degree of confidence. Furthermore, since only descriptive analysis have been used, I cannot say that these variables have had a significant effect on an OECD nation's decision to implementation of nuclear energy with any certainty, what I can say with some confidence is that: political support, centralization, entrepreneurialism, market liberalization, energy replacements, and interest are most likely drivers behind an OECD nation's decision to implement nuclear energy. Due to their strong degrees of association and theory supporting/explaining these associations found. These results are therefore usable indicators of the relationships but no definitive proof.

What motivations drive the implementation of nuclear power in OECD nations?

Based upon the analyses and the answer to the first question I can with some degree of confidence say that political support, low interest levels and the desire to replace oil/gas and coal have motivated the implementation of nuclear power. Whilst higher degrees of centralization, more entrepreneurs in a country and market liberalization have all served to demotivate the implementation of nuclear power. Lastly it seems relevant to note that a higher level of education seems to have a demotivating effect upon political support for nuclear power and thus demotivates its implementation in this way. Whilst the crisis effect although insignificant over the whole OECD, seemingly has a strong negative effect on nations directly hit by the disaster. However, it seems difficult to make any reliable statements on its effect outside of Japan. Since this effect is only measured in Japan and its effect is potentially not long lasting. Most important to these assertions is that although the relationships and their directions are mostly confirmed by the descriptive statistics. The causality of these relationships and the exact strength of these supposed causal relationships cannot be confirmed with this method, only indicated.

Chapter 6 Conclusion

To conclude, this thesis has considered a number of factors relating to the problem of nuclear power not being implemented enough and the question as to why this has happened. To answer this question, I have discussed 3 major categories of drivers, consisting of governmental, social and economic drivers, with a total of 8 hypotheses. Which should according to existing literature relate to nuclear power or innovation implementation. Both nuclear power and innovation literature were considered because nuclear power is considered an innovation for the purposes of this thesis. The data collected here mainly consisted of descriptive statistics derived from the OECD site, nuclear power related organizations and election results. Whilst some outliers have also been further explained using additional literature and theory. Finally, it has discussed how the literature relates to the results and used this analysis to answer the sub-questions of this thesis.

Furthermore, this thesis I will now endeavor to answer the research question. Despite the nature of the results forcing a somewhat limited conclusion to the question of: Why did OECD nations in the period of 1990-2010 not implement nuclear power to a greater degree?

Based upon the answers to the sub questions it is possible to state that OECD nations where probably driven by governmental and economic factors in their (lack of) nuclear power adoption. With the results on social factors being relatively indecisive and thus although relevant they are not considered to be the main answer to the why question. From the analysis I can see that political support was key in the adoption of nuclear power. Therefore, the overall lack of high degrees of political support for nuclear power during the period, could have been a major driver behind the lack of nuclear power implementation. This can be seen in the models through most nations have stayed around a middling 40 to 60% of political support for nuclear power. Secondly the lowering of interest rates seems to have been a driver behind research into nuclear power with it essentially laying the groundwork for future reactors through potentially stimulating its research. Therefore, the relative middling of interest levels as can be seen in the model, could be considered a possible reason for the lack of nuclear power implementation during the period, due to the relatively high operating costs these levels would force onto nuclear reactors. Meanwhile the presence of energy replacements should have generated more nuclear power implementation. However, it instead was negatively associated with nuclear power implementation due to it and nuclear power being used as substitutes. It can therefore be reasoned that some of the OECD nations like Austria, might have been partially driven in their lack of nuclear power implementation, by the presence of other alternative to oil, gas and coal, such as hydro. Whilst nations that didn't have these options and stayed with oil, gas and coal generally fall into the middling part of political support for nuclear power. And as such might not have seen the need for or had the desire to replace oil, gas and coal at all. Therefore, the lack of nuclear power implementation here could have been caused by a lack of will from the politicians to switch from oil, gas and coal. Furthermore, it was found that centralization, the number of entrepreneurs and the level of market liberalization where all negatively associated with nuclear power implementation. These could therefore all have been drivers behind the lack of nuclear energy implementation within the OECD, through its members having potentially high degrees of centralization, market liberalization and many entrepreneurs. Regarding weak social drivers, education seems to have had a potentially negative effect on nuclear power implementation through its negative effect on political support. Whilst the crisis effect seems highly localized and temporarily negative for nuclear power implementation. Meanwhile GDP, government revenue per capita and trust all do not have any discernible relationship with nuclear power implementation. Whereby trust simply has not had sufficient data to derive any statistically significant results from that data. Meanwhile GDP and government revenue per capita might simply not have been good measures for wealth and slack resources respectively.

To conclude, it could be said that OECD nations in the period of 1990-2010 potentially did not implement nuclear power to a greater degree due to: the OECD’s high levels of, market liberalization, centralization, interest, education and its many entrepreneurs. Whilst its middling degree of political support for nuclear power relative to the alternatives, was unable to overcome these negative factors. Which lead to nations generally choosing/maintaining their use of oil, gas, coal and potentially other alternatives such as hydro energy, over nuclear power.

Discussion and limitations

Regarding the limitations of this research, it cannot be stressed enough that I did not do any regression analyses. Therefore, any of the relationships found are not causal effects but rather correlations where the actual causality and size of the relationship is uncertain. This can also be seen in the analysis and conclusion, where it must be stressed that this thesis has attempted to make educated guesses, which were based on the correlation results and how they relate to the theory. It should therefore be said that the conclusion of: The OECD's supposed middling degree of political support for nuclear power, together with its supposed high levels of, market liberalization, centralization, interest, education and its many entrepreneurs, being a likely cause for the lack of nuclear power implementation. Should be researched further as this is no definitive proof and should serve as a direction for future research. Furthermore, I would like to note that trust and the crisis effect where not tested to the best degree. This is due to trust missing many of its data points, whilst the crisis effect should have been tested with a difference in difference test around Chernobyl, since the similar effect seen around Fukushima seems to not last long. This thesis could therefore serve as a motivation to further improve and elaborate on these two variables as well. Another peculiarity found was the effect of government revenue as a percentage of GDP. Since this effect was not expected at all and could be investigated further by other papers. The last limitation I would like to address is the use of nuclear power as a percentage of the energy net and its measurement via RD&D spending. Since the lag for nuclear power percentages in the energy net, has introduced some issues. Sadly, it was necessary for measuring nuclear power expansion, due to power plant construction time. However, it was completely counterproductive for nuclear power reduction. This can be seen in the case of Japan when it pertains to the crisis effect, since there I can see an immediate reduction in nuclear power usage. This means that if any reductions had taken place, they would get measured 7 years to early whilst the expansions get measured on time, in this model. Further research should attempt to address this problem. Furthermore, nuclear power as RD&D spending into nuclear power has limited reliability as it is also affected by variables which are related to RD&D as a whole such as education. So, when one uses this as a dependent variable this relationship should be taken into account and controlled for. Also relevant is that GDP**, g**overnment revenue per capita and trust were all found to do not have any discernible relationship with nuclear power implementation. Regarding this, trust should probably be tested in another research with an operationalization or data set that allows from more cases to be introduced. Meanwhile GDP and government revenue per capita might simply not have been good measures for wealth and slack resources respectively, which would mean that these in future research, should be operationalized in a different way.

As a final statement I would like to use my results, to recommend that policy makers which desire more nuclear power implementation, do the following: lower interest rates, lobby politicians, decentralize government, centralize the economy whilst preventing entrepreneurs from operating to easily and designing more education on nuclear power, which focuses on the specific moral issues related to and safety of nuclear power. This is recommended since all these actions could lead to more nuclear power implementation as is partially substantiated by this research. Furthermore, it might be prudent to conduct more research on these subjects, if a policy maker desires a more causally substantiated advice.

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