Nuclear disasters as critical junctures: A Qualitative Comparative Analysis on nuclear energy public policy in European countries

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Contents

1. Introduction

April 2023 marked an interesting moment in the history of nuclear energy, as the month in which Germany closed their last operating nuclear reactors, phasing out nuclear energy for good. The German government has chosen the path towards a phase-out as a direct reaction to the 2011 nuclear accident at the Fukushima Daiichi plant in Japan (Saltori, 2023). By choosing to opt out of the often seen as controversial method of electricity production, Germany follows in the footsteps of Italy, which phased out nuclear energy production in 1988 due to a referendum following the 1986 Chernobyl disaster in Ukraine (Jensen, 2015). However, while both of these European countries decided to phase out nuclear power after the occurrence of a nuclear disaster, other European countries remained on the same course of nuclear power generation. For instance, the German decision contrasted with the UK, where policymakers remained determined to enhance nuclear power generation in the foreseeable future, despite of the Fukushima disaster (Wittneben, 2012). Interestingly, these two geographically close countries, which show cultural similarities and are both considered liberal democracies, reacted in opposing ways to the same incident.

Since its emergence in Europe in the 1970s, nuclear energy has increasingly become a topic of public debate. Advocates portray the energy source as an ideal way for a country to become more self-sufficient in its energy supply, becoming less dependent on foreign fossil fuel imports. However, opponents of nuclear energy claim that the risks of the technology are too high: radiation caused by nuclear accidents or waste could affect human health and local and global ecosystems. The first wave of critique against nuclear energy in the 1970s led some countries, such as Austria, to never implement nuclear energy, while other countries remained investing in the technology. After the Chernobyl accident on the European continent, a shockwave went through Europe, and both Italy and Switzerland decided to phase the technology out. In recent decades, with the emergence of climate policy, nuclear energy has been reframed as a way to decrease greenhouse gas emissions. Nuclear energy as a sustainable solution is speculated to lead to a 'nuclear renaissance' (Goodfellow, Williams, & Azapagic, 2011; Ylönen, Litmanen, Kojo, & Lindell, 2017). However, this same nuclear renaissance seemed to have lost momentum after the 2011 Fukushima accident, and nuclear energy's resurgence remains yet to be seen (Anastasi, 2014).

The paths taken per European country differ much, depending on how far they have invested in nuclear energy. Energy supply is often associated with path-dependent processes. Once a choice for a specific technology or source is made, increasing returns processes make it not as attractive to deviate from the chosen path (Fouquet, 2016). The nuclear path dependency is not only evident in economic, knowledge, or material terms but also in social terms (Lee & Gloaguen, 2015). Path dependency can be broken during a critical juncture: a moment in which strategic interactions can result in the choice for another path. Due to its controversy, the political justification behind nuclear energy is often called into question by the broader public or institutionalized actors. The question is, however, whether such an appeal is enough to break the path dependency by itself.

Throughout the decades, scholars have analyzed public nuclear policy and developed different perspectives on major policy change in nuclear energy. In her research on the role of anti-nuclear power movements in Western European countries, Yamasaki (2009) found the occurrence of a 'focusing event' to be one of the elements leading to a significant change of policy on nuclear energy. A type of such a focusing event is the occurrence of a nuclear disaster. The impacts and border-crossing radiation released during such an accident is closely followed worldwide, often leading to increased criticism of nuclear energy. Throughout the history of nuclear power, three nuclear disasters got worldwide coverage, namely the 1979 Three Mile Island incident in the US and the earlier mentioned 1986 Chernobyl and 2011 Fukushima nuclear disasters. Such a disaster can be seen as a critical juncture when due to the occurrence of these disasters, a country took a radically different policy direction regarding nuclear power was taken.

Nuclear disasters and their impacts on European countries have been studied through multiple lenses, for instance, the impact of the accident on public opinion about nuclear energy (Bauer, Glystorff, Bargmann Madsen, & Mejlgaard, 2018; Kim, Kim, & Kim, 2013), or the communication of radiation risks through news reporting (Tomkiv et al., 2016). While nuclear disasters and the policy debates around nuclear energy have been the subject of much research, the ingredients for a nuclear disaster to act as a critical juncture within a specific country have not been studied in much detail. Cross-country comparative research on approaches to nuclear energy is indicated as a future research avenue that will provide insights into public risk perception as well as the policy decision process of controversial technologies (Bernardi, Morales, Lühiste, & Bischof, 2018; Ho & Kristainsen, 2019). This leads us to the following research question: *Under what circumstances does the occurrence of a nuclear disaster abroad cause a deviation from the policy path of nuclear energy generation within different European countries?*

This research will assess conditions for a major policy change after a nuclear event in a Qualitative Comparative Analysis (QCA). Three types of conditions are tested: political, cultural, and contextual factors. Theory from the Advocacy Coalition Framework (ACF) will be used to shed light on political processes that occur within the nuclear public policy sphere. The ACF has the benefit of a structured approach to policy debates and is suggested by Rinscheid (2015) to be used in combination with a QCA research design. The different causal paths leading to major policy change after a nuclear can be identified through the QCA approach to causality, using sufficient and necessary conditions.

2. Theory

In this section, the theoretical background of this research is divided into three sections. First, the historical institutionalism concepts behind the study are explained in light of nuclear energy public policy. Then, the concept of critical junctures is explored using three different perspectives. Lastly, an overview of explanations found in literature for divergence in nuclear policy is given. The combination of perspectives on critical junctures and possible explanations for the course of nuclear public policy in a country culminate into different variables to be analyzed and hypotheses to be tested in this research.

2.1. Historical institutionalism and path dependency

This research tries to find answers as to why and how states diverge from a long-term policy path after the occurrence of an external shock. The research is rooted in historical institutionalism theory since it looks at the long-term configuration of public institutions and public policy. More specifically, it is connected to the idea of historical persistence, the idea that the composition of current political, economic and institutional domains is due to historical causes. As Acharya, Blackwell, and Sen (2023) argue, two ideas are central to path dependence. First, there are moments in time in which a particular path is taken, conceptualized as critical junctures. Then, due to a reproduction mechanism, the path taken persists. In economic terms, this reproduction mechanism was introduced as the increasing returns concept by Arthur (1989). The concept describes how once a certain path is taken or a particular technology is chosen, this choice will provide increasing returns, making it attractive to continue. As a result, there is uncertainty in predicting what the economic future will look like, as a historical event or seemingly trivial choice can significantly impact which path is taken (Arthur, 1989, p. 128).

As described by Arthur, nuclear energy is a stringent example of a techno-economic path dependency. Considering the high costs of developing a nuclear power plant (Fouquet, 2016), there is a 'lock-in effect' in which the investments in infrastructure established for a particular technology enforce the path taken. In addition, since large nuclear projects provide lots of electricity, there is a behavioral lock-in in which citizens are used to a stable and abundant energy supply (ibid.).

These techno-economical effects are, however, not the only effects contributing to the path dependency of nuclear energy. Regarding energy systems as socio-technical systems, there is both an institutional and societal dimension that is important to keep the energy system in place (Lee & Gloaguen, 2015). The institutional dimension contains both the formal and informal rules present in society and the formalized organizations that are part of the energy system. The organizations concerned with nuclear energy can be, for instance, national or privatized energy companies, nuclear regulatory bodies, and workers' unions. These organizations can exert influence on politics to maintain the status quo as this is in their interest (Vivoda, 2012).

The political system surrounding nuclear energy is dependent on the belief system around nuclear energy. In contrast with other technologies, nuclear energy is considered controversial and thereby inherently political (Tilly & Goodin, 2006). In liberal democracies, the political choice for nuclear energy must be sufficiently backed up by public support. This is where the energy system's human dimension becomes important: the perceptions and beliefs surrounding nuclear energy (Lee & Gloaguen, 2015; Vivoda, 2012). Lee & Gloaguen (2015) found that historical development and institutional structures such as education, economy, politics, as well as societal influences and media coverage all contributed to a positive perception of nuclear energy in France.

2.2. Critical junctures

Specific turning points in time give rise to the path-dependent process discussed earlier. In social science these moments are called critical junctures. The concept was first introduced by Lipset and Rokkan (1967), who traced the discontinuous change in the history of European nation-states, in which social cleavages led to conflicts, after which the social outcomes remained fixed for a time. Berins Collier and Collier (1991) expanded and formalized the concept of critical junctures in their large-scale comparative research of the political arena in Southern American countries. In their framework, depicted in Figure 1, they describe the different components of a critical juncture: antecedent conditions, the occurrence of a cleavage or crisis, and the critical juncture which leads to a legacy. This legacy can be seen as the path-dependent processes defined earlier, with a mechanism of reproduction or increasing returns process, deepening the path chosen. The framework by Berins Collier and Collier captures well the variety of possible outcomes of a critical juncture, which is relevant when we want to compare how the same event led to different critical junctures in different countries. In Figure 1, the horizontal arrow between antecedent conditions and legacy gives rise to the alternative hypothesis that not only the processes during the critical juncture but rather the antecedent conditions define the legacy or outcome of a critical juncture. Berins Collier and Collier conclude that outcomes are often a mix of both.

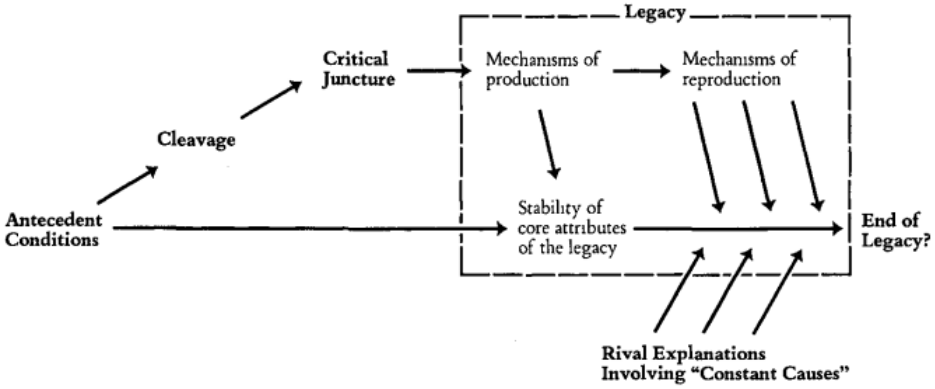

Figure 1. Critical junctures framework copied from Berins Collier & Collier (1991, p.30). Note that where a cleavage gives rise to a critical juncture in the Berns Collier and Collier case study, in this research the word cleavage should be replaced by crisis.

While the initial definition of critical junctures is quite structured, the concept has been picked up by scholars who redefine critical junctures in more general terms as moments in time that give rise to path-dependent processes. Capoccia (2016) gives an account of the contemporary uses of critical junctures within political science. One of the central debates revolves around the importance of antecedent conditions versus the influence of political and social actors in shaping the outcomes of a critical juncture. Authors with the antecedent condition viewpoint base this on the standard works on critical junctures mentioned earlier, who are convinced that "a critical juncture framework is most appropriate for analyzing situations in which a 'common exogenous shock' affects a set of cases (typically countries), causing them to 'diverge' as a consequence of the combination of their pre-existing structural configurations and the common shock." (Capoccia, 2016 p.93).

In contrast, other scholars believe the events during the period after a shock, which is the duration of the critical juncture, to be deciding for the outcome configuration. This view emphasizes the agency of political and social actors and the critical decisions they make during this period. While macro-structural antecedent conditions can be present, without the mobilization of political actors they do not matter, making mobilization a necessary condition (Capoccia, 2016). An agency-based view sees the outcome of a critical juncture as a result of political interaction and decision-making. Since outcomes are the result of strategic interactions, this explains why outcome configurations do not necessarily reflect the preferences of one actor.

Within the group of scholars studying institutional formation during a critical juncture, Capoccia (2016) defines a distinctive paradigm that emphasizes the role of ideational change in this process. The logic behind this view is that "the ideational terrain is where the main political battles are fought during a critical juncture" (Capoccia, 2016, p. 97). During the strategic interactions at a critical juncture, different parties seek public legitimation for their preferred outcomes of institutional change. These preferences are culturally constructed during the critical juncture.

2.3. Different explanations for divergence in nuclear policy

The above section explains three views that emphasize the role of antecedent conditions, the political formation process, or the ideational change for outcomes of a critical juncture. In this section, different explanations provided in literature for the divergence of nuclear policy in different countries will be assessed. The account of different explanations is not exhaustive but focus on different arguments encountered that fit into one of the three different perspectives on critical junctures.

2.3.1. Contextual or antecedent conditions

Multiple studies look at characteristics of the energy system as explanatory variables of differences in nuclear policy, such as the amount and density of nuclear power reactors (Bauer et al., 2018), the percentage of nuclear in energy production (Bernardi et al., 2018), the structure of energy markets (Skea, Lechtenböhmer, & Asuka, 2013), and the availability of renewable energy resources (Wittneben, 2012). Earlier in this theory section, producing electricity using nuclear technology is described as a path-dependent process. If a country largely depends on nuclear energy, it might be less prone to phase out nuclear after a nuclear disaster abroad. Let us, therefore, explore the different aspects of nuclear dependency.

Between countries, there are varying degrees of dependency on nuclear energy production. Figure 2 shows the percentage of nuclear within the electricity supply of the ten countries studied in this research. When nuclear energy contributes a large part to a country's electricity supply, the country might be more inclined to stay on that path due to increasing returns processes (Fouquet, 2016). Nuclear energy entered most countries' electricity mixes in the 1970s (WNISR, 2023), followed by a steep growth of the technology in the 1980s. The average percentage of all countries in Figure 2 peaks at an average of 35% of total electricity supply in 1986.

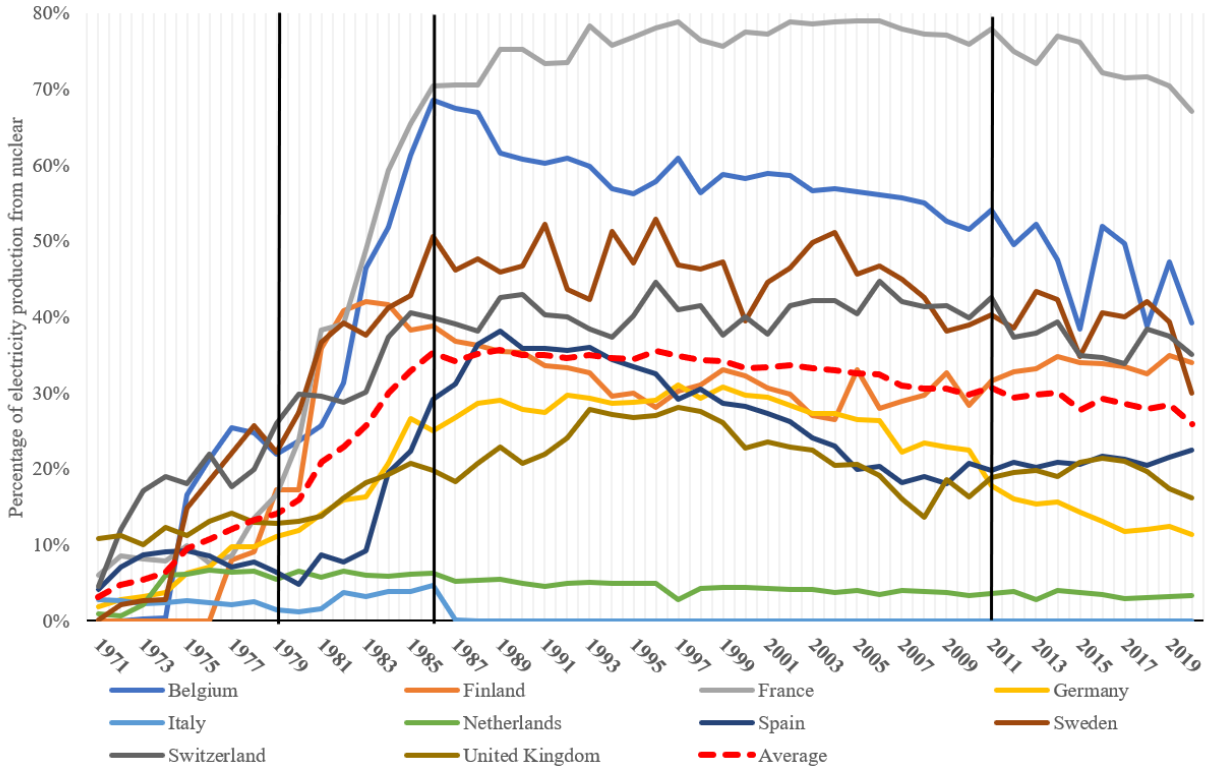

Figure 2. The percentage of electricity production from nuclear generation. The dashed red line indicates the calculated average of the 10 countries. The three vertical lines indicate the 1979 TMI, 1986 Chernobyl, and 2011 Fukushima nuclear disasters. Source of data: IEA, 2022. *Figure of own creation.*

Another part of nuclear dependence that might play a part is the self-sufficiency of a country in meeting national energy demand, also known as energy security (Skea et al., 2013). If a country decides to phase out nuclear, it becomes more dependable on foreign fossil fuel imports (Schulze, 2017). Figure 3 shows the net energy imports as percentage of the total energy supply of a country. There is a variance between different countries, where the United Kingdom has been considered a net energy exporter for some decades, and some countries are highly dependent on energy imports, for up to 90% of their energy supply. A sidenote to this data is that for small countries with open economies it is difficult to interpret trade data such as that portrayed here, as disproportional resource use of some sectors of the economy can give a distorted image. In this case, for instance, the oil refineries in the Netherlands give the country an erratic import dependency in Figure 3. The figure also shows a decrease in average import dependency in the 1970s and 1980s, which can be seen as a reaction to the 1973 oil crisis.

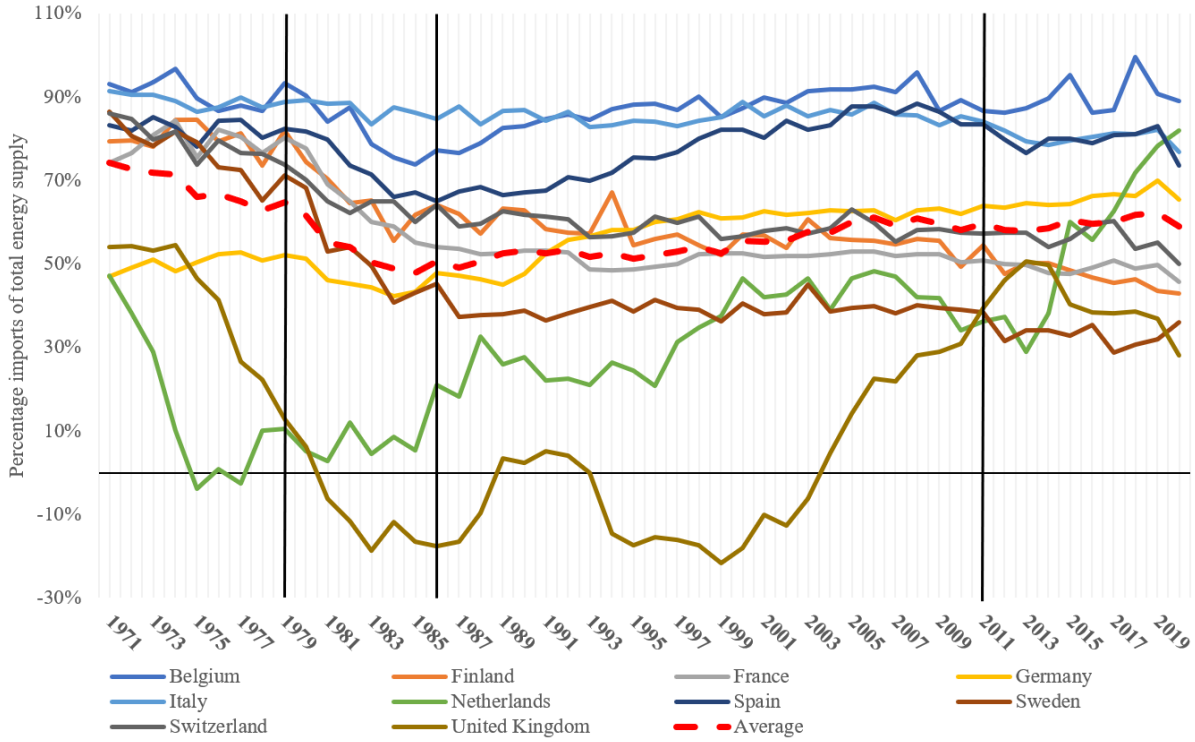

Figure 3. Percentage of total energy supply that is met by imports, calculated as imports minus exports divided over the total energy supply. When negative, the country is considered to be a net exporter of energy. The dashed red line indicates the calculated average of the 10 countries. The three vertical lines indicate the 1979 TMI, 1986 Chernobyl, and 2011 Fukushima nuclear disasters. Source of data: IEA, 2022. *Figure of own creation.*

2.3.2. Political processes

Multiple authors claim that the political process after a nuclear disaster is deciding for the policy outcome, which is in line with the perspective on critical junctures that emphasizes the role of political actors during these periods after an external shock, as described by Capoccia (2016). While the political process angle is used by many to explain the difference between Western European differences in nuclear energy policy, they do so by emphasizing different dynamics or actors, such as anti-nuclear movements, institutional factors, or dynamics between political parties. We can see political processes after a nuclear event as a 'black box', after which a policy change outcome can happen. In this section an account is given of different researchers that open up this 'black box' using different angles. This will set the context for the focus on the usage of policy subsystem orientation and imminent elections as measurable conditions in this study.

One of the earliest studies that opened up this black box is the study by Jasper (1988) of how political processes after the TMI accident led to different outcomes in different countries. He quickly comes to the conclusion that the one-sided explanations brought forward in the public debate only explain parts of the process. These separate explanations can be seen as different variables emphasized in a different moment in time, which comes close to the conceptualization of a critical juncture by Berins Collier and Collier (1991) mentioned earlier. The timeline in which different variables will differ due to different country contexts. As a result, there is no single general explanation that can explain all approaches to nuclear energy (Jasper, 1988), which corresponds to the QCA outcomes of a similar study by Yamasaki (2009). Based on these suggestions, a first hypothesis is phrased:

> *H1: There are multiple causal paths possible that can lead a country to shift away from nuclear energy after a nuclear accident.*

Searching for explanations, Jasper (1988) starts his search at the anti-nuclear social movements, the actors that are perhaps most recognizable and thus studied by many. Bernardi et al. (2018), argue that for a critical event to result in policy change, anti-nuclear mobilization is necessary. On the other hand, some authors suggest that their role in achieving actual policy change is overestimated (Giugni & Yamasaki, 2009; Schulze, 2017; Yamasaki, 2009). A nuance to the mobilization angle is that, for a substantive and consequential mobilization to happen, political opportunities are needed (Bernardi et al., 2018; Koopmans & Duyvendak, 1995), or a certain level of political conflict (Jasper, 1988). The idea of political opportunity structures was coined by Kitschelt (1986), who addresses the strategies and impacts of social movements in different western countries, considering differences in institutional configurations. These different configurations, called political opportunity structures, describe the openness of political input structures, as well as the strength of political output structures explained as government executive power. This thesis will not focus on the occurrence or extent of social mobilization after a nuclear accident, but instead will take a closer look at the political structures and the political processes these structures facilitate after a critical juncture.

In the book *The Politics of Nuclear Energy in Western Europe* (Müller & Thurner, 2017), the differences between nuclear policies in countries are assessed by considering the 'political game'. This game is defined by party dynamics and stakeholder involvement processes, of which the latter relates to the openness of political input structures by Kitschelt. The book by Müller and Thurner concludes that '…on a more general level we find the greatest common factor leading to nuclear energy policy changes in the competition of the established parties' (Schulze, 2017 p.319). This change is facilitated through two dynamics: a change of the governing coalition through the electoral cycle, or a change of stance of a major party on the nuclear topic due to perceived competition by small anti-nuclear parties. We will take a closer look at both of these dynamics, starting with the electoral cycle.

The basic system of party democracy is that important policy topics are directly tied to the electoral system. Parties take position on salient issues and are expected to act upon these stances when elected into government. Therefore most large policy changes will result from a change of parties taking office (Schulze, 2017). Following this logic, if a change of government is the main instigator for a nuclear policy change, upcoming elections after a nuclear accident heighten the change of a turn-around in nuclear policy. This argument is brought forward by Wittneben (2012) in her comparison of the British and German reaction to Fukushima and repeated by others (i.a. Skea et al., 2013).

Policy subsystem dynamics and the Advocacy Coalition Framework

Where the electoral cycle and the timing of elections are straightforward to investigate and compare between countries, a change of stance by ruling governments without elections approaching is harder to analyze in a structured way. The Advocacy Coalition Framework (ACF), coined by Sabatier (1998), offers an interesting perspective because it focuses on actor coordination processes within a policy subsystem. The framework can thereby offer tools to identify different variables and causal mechanisms that explain change in public policy (Nohrstedt, 2010). Due to these reasons, Nohrstedt (2010) and Rinscheid (2015) use the ACF to study nuclear policy change.

The central unit of analysis in the ACF is a policy subsystem in which public and private actors actively seek to influence the direction of public policy on a specific topic. These actors within a subsystem group together in several 'advocacy coalitions' on the basis of shared norms and beliefs and coordinate their activity on the policy topic (Sabatier, 1998, p. 103). The belief systems that hold such advocacy coalitions together are 'core beliefs', which are assumed to remain stable over time (Nohrstedt, 2010). Within the policy subsystem, there is often one dominant advocacy coalition holding power within the government executive branch and minority or opposition coalitions who are trying to alter the current policy direction (ibid.).

In search for causal mechanisms behind policy change in nuclear energy, Nohrstedt (2010, p. 314) finds that 'the greater the number of subsystem participants (and hereby the more open the policy subsystem), the greater the propensity for major policy change in response to crisis events', which brings us back to the openness of governments as brought up by Kitschelt (1986). Rinscheid (2015) comes to a similar conclusion, not by counting the total number of participants but by

categorizing a policy subsystem as either unitary or adversary. In a unitary subsystem, one major advocacy coalition is dominant, and there is no room for debate. Instead, there is room for opposing opinions in an adversary subsystem, and new movements can enter the debate or policy subsystem arena. He states that 'a policy subsystem that can be classified as unitary prior to a crisis is unlikely to translate post-crisis demands for change into policy shifts that go beyond symbolic changes or adjustments in secondary aspects' (2015, p. 38). Rephrased, we come to our second hypothesis:

> *H2: An adversary nuclear policy system is a necessary condition for policy change to happen after a nuclear accident*

2.2.3. Ideation

Schulze (2012, p. 321) argues that "Nuclear energy does not belong to the mainstream parties' core issue portfolio where positions can be directly derived from their ideology and historical mission", while others are convinced that being in favor of or against nuclear energy is a core conviction. The last argument ties in with the view of critical junctures that the ideological terrain is where the main debate takes place, where the interests and influence of actors are influential in shaping social constructions around nuclear energy. While ideational processes and their sociological causes are perhaps out of the scope of this research, some perspectives and ideas are mentioned in this section to provide context for analyzing media coverage and other cultural expectations in the QCA.

Nuclear energy is perhaps the most contested source of energy. Some groups claim that the risks associated with the production process and the disposal and treatment of nuclear waste are altogether too substantial. Additionally, nuclear energy production in its current state is impossible without the support of large public subsidies (Bauer et al., 2018). Therefore, if a modern democracy is producing nuclear energy, this must be met by sufficient social support. Governments use opinion polling to get an idea of this support besides the electoral system. Numerous studies are analyzing such polls to study the effects of nuclear disasters on public opinion (e.g. Bauer et al., 2018; Kim et al., 2013; Latré, Thijssen, & Perko, 2019). Opinion polls are, however, not always comparable between countries and over time. Also, there are cases, such as Spain and Finland, in which public opinion is predominantly anti-nuclear, while the government still enacts policies in favor of nuclear energy (Schulze, 2017). Since an opinion poll or other idea of public opinion does not always reflect the public debate, it might be good to look at the role of ideas and framing within this debate instead.

In an ideal world, an event is covered by the media, based on which the public forms their opinions, which are then the base for political decisions. However, if this were the case, all European governments would respond similarly to a nuclear disaster abroad, which we know they do not (Kepplinger & Lemke, 2015). In the critical juncture following such a crisis, through ideation processes, different perspectives on nuclear energy are amplified in the public debate where actors, such as organizations or politicians, try to frame the crisis in line with their point of view (Koopmans & Duyvendak, 1995). There is a strand of research in which the convictions and beliefs of all actors in such a debate are analyzed in-depth, which results in a detailed mapping of such framing processes (e.g. Bernardi et al., 2018; Rinscheid, 2015). An intermediary factor between these actors and the public is the mass media. The media also frames the nuclear accident

by highlighting certain aspects or selecting specific experts for interviews (Kepplinger & Lemke, 2015). Therefore, this research focuses on media amplification of nuclear perspectives as a proxy for the public debate.

The media plays an essential role as far-away accidents like nuclear disasters are experienced by citizens mostly indirectly through mass media reporting (Perko et al., 2019). Mass media quickly picks up the event of a nuclear accident, partly due to the possibility of radiation risks at home, the extent or absence of which is often broadly covered. At this stage, media need to be careful in their reporting, following guidelines on reporting radiation exposure, in order to not instigate public fear (Friedman, 2011; Tomkiv et al., 2016). A few weeks after an accident, the media tends to shift the focus from emergency actions to evaluating the crisis response. Countries producing nuclear energy keep a closer watch: the media in these countries were found to cover the Fukushima accident more intensively than other, non-producing European countries (Gallego et al., 2017). In some cases, the evaluation turns into a discussion on the rationale behind the domestic nuclear program, parallel to public concerns about the political justification for nuclear energy.

Throughout all stages but more explicitly in the later stages, media becomes an actor itself or a social institution that has contact with policymakers and selects from a range of sources and experts for their articles (Mercado-Sáez, Marco-Crespo, & Álvarez-Villa, 2019). Studies show that each country has a different framing of risk communication and nuclear disasters. For instance, the perspective on health is emphasized in Italy, while in other countries, an economic paradigm has been dominant (Kristiansen, 2017). Such country differences can be due to cultural reasons and public opinion regarding nuclear topics at that time. The media then acts as an intermediary reinforcing dominant positive or negative paradigms on nuclear energy (Fabbri, 2015; Kepplinger & Lemke, 2015; Mercado-Sáez et al., 2019). However, it is also suggested that instead of only amplifying salient viewpoints, the media can have an agenda of their own. Additionally, Kepplinger and Lemke (2015) suggest that the media is always looking to exaggerate risks and dramatize the crisis to create a scandal, which makes mass media more prone to amplifying negative views on nuclear energy.

3. Methodology

This research conducts a qualitative comparative analysis (QCA) of 10 European countries. In this section, a short explanation of QCA will be given, followed by a justification of the choice of research method. Then, the case selection and the coding of variables are explained.

3.1. Rationale behind QCA

Qualitative comparative analysis is a relatively new research methodology developed by Ragin (1987) to formalize comparative research between a small number of cases, that public administration scholars have increasingly adopted. In public policy analysis, the number of case studies is often limited, for instance, by the number of countries in a region. Using QCA enables a researcher to make comparisons between different cases and generalize findings without losing the depth and complexity of individual case studies (Rihoux, Rezsöhazy, & Bol, 2011).

As a method that is in-between formal quantitative research and in-depth qualitative research, QCA has limited power in claiming causality. Instead, the causality that can be identified is conjunctural or combinatorial causation: multiple causal paths can lead to the same outcome (Toshkov, 2016). These 'causal paths' are found by establishing necessary and sufficient conditions. A condition is *necessary* when an outcome is not possible without it. When a condition is *sufficient,* a specific outcome will always occur when it is present in a case. A third option is the *INUS* condition: an Insufficient but Non-redundant part of an Unnecessary but Sufficient condition, which means a condition is part of a sufficient condition.

The multiple path causation behind QCA makes the method fit to answer this thesis's research question, as it is a way to regard each country's unique situation vis-à-vis nuclear energy but still find general patterns in which a nuclear disaster can cause a significant policy shift. The main advantage of QCA over quantitative regression analysis is that it acknowledges that variables do not work in isolation and captures the complexity of real life situations better by looking at set relations between variables rather than the net effect of a single variable (Rihoux et al., 2011; Toshkov, 2016). This reflects real-life policy practices since it is argued that policy outcomes depend on regional configurations and sector-specific elements, which is why different administrative traditions require differentiated policy implementations (Rihoux et al., 2011). Considering that two studies that performed regression analyses of public opinion after a nuclear disaster disagree with the interpretation of the outcomes (Bauer et al., 2018; Kim et al., 2013), the topic might benefit from being studied using the QCA approach to complexity. In addition, a QCA can focus on whether an outcome is achieved, reflecting real-life goal-orientated policymaking practices (Rihoux et al., 2011), which also reflects that after a nuclear disaster, countries have either decided to shift away from nuclear energy production or decided to remain on the same course.

In her research on the impact of social movements regarding nuclear energy, Yamasaki (2009) traces back the policy process in the years before a large policy change by conducting a QCA to understand what conditions led to such a change. Due to the similarity of the research topic, the methodology of Yamasaki is used as inspiration for the research design of this study. However, our research applies a different logic, namely tracing the policy situation after a nuclear disaster and whether this resulted in a significant policy change or not, thereby also concentrating on the cases in which a large policy change, or path divergence, did not occur. In addition, the book chapter on crisp-set QCA (csQCA) by Rihoux and De Meur (2008) is used as a process guide, and both the Microsoft Excel QCA add-in and TOSMANA software by Cronqvist (2019a, 2019b) are used to perform the Boolean minimization calculations.

This research performs a csQCA, which is the simplest QCA method and uses dichotomous coding of variables. The simplicity of the research design makes the research more transparent, resulting in improved traceability and communication of the research findings (Rihoux et al., 2011; Yamasaki, 2009). Dichotomous coding means a condition, speculated to contribute to a positive outcome, is either present [1] or not present [0] (Rihoux & De Meur, 2008). After coding the variables, a truth table is constructed, also known as the process of Boolean minimization, from which the different causal paths leading to a specific outcome can be traced. An added benefit of a QCA is that after the formalized processing of variables, the cases can be revisited in order to understand the outcomes and narratives behind the different causal paths (Yamasaki, 2009).

3.2. Case selection and reconstruction

The outcome condition of interest in this research is a radical change, or absence thereof, in nuclear energy policy after an internationally salient nuclear disaster abroad. Establishing a set timeframe for each case is difficult since critical junctures can vary between 'moments of significant structural change' to a policy period that could encompass multiple governments (Berins Collier & Collier, 1991, p.21). The conditions that are analyzed for each case focus on either the situation in a country just before the accident, or the situation in the moment after, which is conceptualized as the critical juncture. For this critical juncture there is no set time, because the time of policy discussions can vary between a few months to a few years. The implementation of its outcome can even be up to 5 years, roughly the length of an entire policy cycle, since some outcomes can take longer to become public.

The nuclear disasters that got international attention are the 1979 Three Mile Island accident in the USA, the 1986 Chernobyl accident in Ukraine, and the 2011 Fukushima accident in Japan. All these accidents had essential impacts on views on nuclear power in Europe, with differing degrees per country and incident. Since the 1979 TMI accident is followed up quickly by the 1986 Chernobyl accident, it is hard to distinguish the separate impact of the TMI accident. The TMI accident intensified existing debates on the rationale behind and safety of nuclear energy production (Jensen, 2015). In a few European countries, namely Sweden, France, and Austria, this ongoing debate was notably triggered by the TMI accident, after which direct policy impacts can

be seen (Brouard & Guinaudeau, 2015; Jasper, 1988; Jensen, 2015; Nohrstedt, 2010; Yamasaki, 2009). We can say that the TMI accident acted as a critical juncture in these countries, which resulted in either deviating from or remaining on the path of nuclear energy production. However, in other European cases, we see such a trigger of the debate after the 1986 Chernobyl accident. For this research, the choice is made to, per country included, observe either the TMI or the Chernobyl accident as a moment of possible critical juncture, as shown in Table 1. The aftermath of the Fukushima accident form a case for each country.

This research only focuses on Western European countries to increase the comparability of cases. Next to data availability, a reason for this selection is that countries that were under a communist regime know a history of nuclear energy that is different from other European countries. Adding to that, at the time of the Chernobyl accident, multiple Eastern European countries were still under a communist regime, which affected the reaction to the disaster. Furthermore, only countries that produced nuclear energy at some point between 1979 and 2011 are considered because these were on the path-dependent process of producing nuclear energy in the timeline considered. These selection criteria leave us with ten countries: Belgium, Finland, France, Germany, Italy, Spain, Sweden, Switzerland, the Netherlands, and the United Kingdom. Each country will contribute two cases, resulting in a total of 20 cases.

Table 1. Showing the case selection for this study. For each country, the period after either the 1979 or 1986 nuclear disaster is chosen to be studied as a critical juncture. The TMI acronym stands for Three Mile Island.

Country	**1979 *TMI***	**1986 Chernobyl**	**2011 Fukushima**
Belgium		x	x
Finland		x	x
France	x		x
Germany		x[1]	x
Italy		x	x[2]
Spain		x	x
Sweden	x		x
Switzerland		x	x
the Netherlands		x	x
the United Kingdom		x	x

[1] For this case, West-Germany is analyzed, in line with research by Koopmans & Duyvendak (1995), Kitschelt (1986) and Müller & Thurner (2017)

[2] In 2011 Italy was no longer a producer of nuclear energy. However, plans for building of new facilities were in the making, which is why this case is also included.

3.2. Coding of conditions

The different variables chosen for the QCA, following the literature review in section 2.2., are shown in Table 2. The last column shows which dichotomy the coding will represent. The method behind coding will now be explained for each indicator. The sources that were used for the qualitative case construction and coding are given in Appendix A. The logic behind the coding is that a score of [1] is given if the condition likely to contribute to a positive outcome is present (Rihoux & De Meur, 2008), with this research's 'positive' outcome being a policy deviation from nuclear energy production.

Table 2. The indicators used in the QCA. The explanation of the argument the indicator belongs to is found in section 2.2. The third column shows which dichotomy the coding of the indicator will represent.

Argument	Indicator	Abbreviation	Coding [1/0]
Outcome variable	Deviation from policy path		Yes/No
Antecedent conditions	Share of nuclear energy	SNE	Low/High
	Energy import dependency	IMP	Low/High
Political processes	Policy subsystem orientation	POL	Adversarial/Unitary
	Imminent elections	ELEC	Yes/No
Cultural ideation	Media amplification	MEDIA	High/Low

Outcome: Deviation from policy path

This study's outcome of interest is a deviation from the policy path as a result of a critical juncture instigated by a nuclear disaster abroad. A country is found to have deviated from the policy path when it decides to phase out nuclear energy or not to build any new nuclear plants. The significance of these policy proposals is assessed qualitatively within the context of that country. While an increased commitment to nuclear policy, through proposals for a rapid increase of installed capacity, can also be seen as a deviation from a policy path, it is not a logical reaction after a nuclear disaster. It is, therefore, not seen as a direct result of the critical juncture and scored [0].

Share of nuclear (SNE)

The percentage of nuclear-generated electricity within a country's electricity mix is obtained from the International Energy Agency (IEA) (2022). A benchmark is set to score countries as having either a low [1] or high [0] share of nuclear in the year of occurrence of the nuclear disaster, corresponding to a large or smaller dependency on this source of energy. The benchmark is set as the average share of nuclear, indicated by the red dashed line in Figure 2. For 1979, the benchmark is relatively low at 14%, as most European countries only introduced nuclear energy in the same decade. The 80s saw a rapid acceleration of nuclear capacity, which is why the benchmark for 1986 is set at over a third of a country's electricity supply, 35%. A similar benchmark is set for 2011, namely 31%, which is explained by the fact that nuclear energy production somewhat plateaued in the previous decades.

Import dependency (IMP)

The methods for coding self-sufficiency of energy supply are similar to that of the share of nuclear and are based on the IEA data shown in Figure 3. An import dependency lower than the average is scored [1], and higher than the average is scored as [0]. The benchmark for 1979 is an import share of 65% of all total energy supply, a share of 51% for 1986, and 60% for 2011.

Policy subsystem orientation (POL)

A score of [1] is given when the policy subsystem of nuclear energy in a country is deemed collaborative or adversarial at the time of the nuclear disaster, and a score of [0] is given to unitary policy subsystems. For each case, multiple qualitative sources are consulted, see Appendix A, to provide an idea of the policy subsystem at the time of the nuclear accident. Two sources providing ACF classifications were used to guide the coding process: a table by Weible (2008) summarizing the three types of policy subsystems and a table providing the possible pathways of the three types of policy subsystems after a crisis by Nohrstedt and Weible (2010). Both tables are provided in Appendix B. In most cases, the policy subsystem interpreted the nuclear accident as a crisis. For these cases, the crisis pathways the cases resemble are decided according to the table in Appendix B, the categorization these cases can be found in the same appendix.

Imminent elections (ELEC)

A score of [1] is given when countries had upcoming national or relevant regional elections up to 60 weeks after the nuclear disaster. The occurrence of elections was obtained from the qualitative sources in Appendix A and cross-referenced with the ParlGov database (Döring, Huber, Manow, Hesse, & Quaas, 2023). The timeframe of 60 weeks is based on the elections that were furthest away from a nuclear disaster, but said to revolve around the nuclear issue in the aftermath of the accident, namely the UK 1987 elections (Schulze, 2017).

Media amplification (MEDIA)

The following question is used: *Did the media give significantly more attention to the accident than other countries, exaggerate the risks according to experts, predominantly give a voice to anti-nuclear voices, or was the news dominated by a discussion on domestic nuclear power instead of the accident abroad?* If the question can be answered 'yes', according to evidence from multiple sources, the variable is scored [1]. For the '79 and '86 cases, a mix of old and newer references is consulted to put the media reporting in context. For the '11 cases, the research by Bernardi et al. (2019) gives a consistent overview of the balance between pro- and anti-nuclear opinions in media reporting of Fukushima in all ten countries.

4. Analysis

Table 3 shows the cases with dichotomous coding for all conditions, also called the truth table. The consistency scores in the last row explain to what extent a condition is necessary for the outcome. From these scores, it can be derived that, overall, the model is a good fit for explaining the outcome. The presence of a [1] for POL in all positive outcome cases hints that this condition might be sufficient or necessary.

Table 3. Truth table showing the scoring of cases on the five conditions, sorted on country and year, with the two numbers behind the country showing the last two numbers of the year in which the nuclear accident of the case happened.

Case	Major policy change	SNE	IMP	POL	ELEC	MEDIA
France 79	0	0	0	0	0	1
Sweden 79	1	0	1	1	1	1
Belgium 86	0	0	0	0	0	0
Finland 86	0	0	0	1	1	1
Germany 86	0	1	1	0	1	1
Italy 86	1	1	0	1	1	1
Netherlands 86	0	1	1	1	1	0
Spain 86	0	1	0	0	1	0
Switzerland 86	1	0	0	1	0	0
United Kingdom 86	0	1	0	0	1	0
Belgium 11	0	0	0	0	0	1
Finland 11	0	0	1	1	1	0
France 11	0	0	1	0	1	0
Germany 11	1	1	0	1	1	1
Italy 11	1	1	0	1	0	1
Netherlands 11	0	1	1	0	0	0
Spain 11	0	1	0	1	1	0
Sweden 11	0	0	1	0	0	0
Switzerland 11	1	0	1	1	1	1
United Kingdom 11	0	1	1	0	0	0
Consistency[3]		**50%**	**17%**	**100%**	**67%**	**83%**

Boolean minimization is applied to the cases from which a minimized expression that explains causal paths to the outcome is derived. The algorithm used for this process creates logical remainders, speculative cases added to the truth table as simplifying assumptions to create a formal expression that is as minimal as possible. These logical remainders are checked manually to see if they align with the theory. The full report of the QCA results, including the logical remainders, is shown in Appendix C.

[3] Consistency is calculated as the number of cases with the specific condition and a positive outcome, divided over the total number of cases with a positive outcome, as explained by Rihoux & De Meur (2008, p.47).

Boolean minimization is applied to both the positive [1] and negative [0] outcome cases. However, for both outcomes to be complementary, there must be no overlap in the logical remainders, a phenomenon called contradictory simplifying assumptions (Yamasaki & Rihoux, 2012). The solutions chosen to present in this section are the ones that have no overlap in logical remainders (the fourth solution for the positive cases and the first outcome for negative cases in Appendix C). The outcome formulas, minimized by including logical remainders, are represented in the formulas below. Formula 1 represents the positive outcomes [1], and Formula 2 the negative outcomes [0].

$$POL * \begin{cases} elec \\ MEDIA * \begin{cases} SNE \\ IMP \end{cases} \end{cases} \rightarrow major\ policy\ change \quad (1)$$

$$pol + ELEC * \begin{cases} media \\ sne * imp \end{cases} \rightarrow continuation \quad (2)$$

The formulas are represented using a notation typical to QCA research: the uppercase notation of a condition (e.g. 'POL') means that the condition needs to be present for the outcome, and a lowercase notation (e.g. 'pol') means that the condition needs to be absent. In addition, '*' means AND, which refers to an interplay of two conditions, and '+' means OR, showing that different causal paths lead to the same outcome. The factorization of the formula gives insights into the conditions shared by some causal pathways. Table 4 summarizes all minimal formula paths and cases that adhere to these paths. As is common in QCA, all pathways will now be reflected upon individually, after which general conclusions can be made.

Table 4. Minimal formulas for major policy change in nuclear energy policy after a nuclear disaster, using logical remainders. The '' symbol means AND, the '+' symbol means OR.*

Outcome	Path	Case
Major policy change	POL*elec +	Italy 11; Switzerland 86
	POL*MEDIA*SNE +	Germany 11; Italy 86; Italy 11
	POL*MEDIA*IMP	Switzerland 11; Sweden 79
Continuation	pol +	France 11; Belgium 11; France 79; Netherlands 11; United Kingdom 11; Sweden 11; Belgium 86; Germany 86; Spain 86; United Kingdom 86
	ELEC*media +	Finland 11; France 11; Spain 11; Netherlands 86; Spain 86; United Kingdom 86
	ELEC*sne*imp	Finland 86

4.2. Positive outcome paths

*POL*elec*

The first pathway represents how an adversary policy subsystem (POL), combined with an absence of elections (elec), is sufficient for a major policy change in nuclear energy policy after a nuclear disaster. Note that the separate elements of the sufficient condition can be regarded as an INUS condition. The required absence of upcoming elections is interesting since, in the theory section, the elections are speculated to lead to a regime change that can instigate a major policy change. Instead, this path represents an alternative, where there is no change of government, but the adversary subsystem facilitates another advocacy coalition to become dominant over another, leading to a policy change.

This pathway is derived from the Italy 2011 and Switzerland 1986 cases. Noteworthy is that, in the Italy case, a referendum was held three months after the Fukushima disaster, the outcome of which led to a repeal of the plans for the reintroduction of nuclear energy (Franchino, 2017). In the Swiss case, the country's direct democracy is mentioned to be one of the factors contributing to the outcome: with the pressure of the opposition being able to call for a referendum, the government, previously in favor of nuclear due to its ties with the industry, decided to switch directions and cancel plans for an upcoming plant (Kriesi, 2017).

*POL*MEDIA*SNE + POL*MEDIA*IMP*

The other two paths leading to a positive outcome can be analyzed in parallel: they describe how an adversary policy subsystem (POL), together with the amplification of nuclear risks through media (MEDIA), as well as a low nuclear dependency through either a small percentage of nuclear electricity (SNE) or a low import dependency (IMP) led to a major policy change. The paths have a similar structure and describe an interplay between all three types of theorized conditions: political, cultural, and contextual.

The interplay between an adversary policy subsystem and amplification through media is interesting. By amplifying their arguments, the media helped anti-nuclear advocacy coalitions mainstream their convictions. How this resulted in a departure from the pro-nuclear energy policy course differs for two groups of cases. In the German and Swiss cases in 2011, the media attention on the Fukushima disaster led to an extensive debate in parliament, closely followed by citizens (Kriesi, 2017; Thurner, 2017). In both cases, the pressure of upcoming elections (ELEC) might have led to resolute decision-making by the ruling governments, afraid to lose the support of the larger public. In the other cases, Italy in 1986 and 2011, and Sweden in 1979, an additional element led to the outcome: in all cases, a national referendum was held shortly after the nuclear disasters (Schulze, 2017).

In all cases, the occurrence of a referendum or the pressure of upcoming elections explains the relation between POL and MEDIA. However, POL*MEDIA alone is not sufficient: some form of being relatively independent of nuclear energy is required to complement these dynamics. The pressure through media and political processes only yields the result of a nuclear phase-out when politicians can afford to do so since the country is not highly dependent on nuclear energy.

4.2. Negative outcome paths

pol

The first path that describes a continuation of the nuclear policy course is described by one condition only: the absence of an adversary subsystem (pol), which means the presence of a unitary subsystem. The presence of a unitary subsystem describes 10 out of the 14 cases (71%) where a negative outcome was present and is considered a sufficient condition. One of the most striking cases is Germany after Chernobyl, where all other conditions were present: the country had a low dependency on nuclear energy and fossil imports, there were upcoming federal elections, and the media coverage on Chernobyl was extensive and shed a negative light on the usage of nuclear energy (Kepplinger & Lemke, 2015). These circumstances led to a growing resistance of both anti-nuclear and peace movements. However, the crucial fact that these movements were extra-parliamentary and their views were not yet reflected in the largest political parties seems to explain why no major policy change happened (Thurner, 2017)

In a unitary nuclear energy policy subsystem, the opinion of the dominant advocacy coalition is most important. In all cases described, this dominant coalition favors maintaining the status quo regarding nuclear energy production. What is often seen in these cases is that in reaction to the nuclear disaster, the pro-nuclear cost is toned down to maintain the equilibrium, in line with the first unitary subsystem response to a crisis as theorized by Nohrstedt & Weible (2010, see Appendix B). Minor policy changes are implemented. For instance, the Belgium parliament prolonged decisions about nuclear plant lifetime extensions in 2011, and the West-German government established a Ministry of Environment in reaction to the mobilization after Chernobyl (Schulze, 2017; Thurner, 2017). However, in some cases, the dominant coalition does not address domestic policy after the event of a nuclear disaster, thereby not acknowledging it as a crisis for the domestic policy subsystem. An example is France's case in 2011, where Fukushima did not affect the public debate much, and this did not result in an alteration of nuclear policy (Brouard & Guinaudeau, 2015).

*ELEC*media*

This path describes upcoming elections (ELEC) with an absence of media amplification of nuclear risks after a nuclear accident, resulting in a remaining status quo. Amongst these cases are two cases in which the sufficient condition of an adversary subsystem is not present (POL), namely Finland in 2011 and the Netherlands in 1986. Table 5 shows the timing of elections after a nuclear disaster for all cases scored [1]. Interestingly, both cases following this path are in the top 3 elections that most closely followed the date of the nuclear accident, as seen in Table 5. Perhaps the occurrence of elections this short after a nuclear disaster means that there were other issues more salient during the elections, or there was no time for the issue to become salient.

Table 5. Cases with imminent elections after a nuclear accident, sorted from closest to furthest away elections. The weeks after the nuclear accident were calculated as the difference between the election date, obtained from the ParlGov database (Döring et al., 2023)*, and the date of the nuclear disaster.*

Case	Type of elections	Weeks after nuclear disaster
Germany 11	Regional	2.3
Netherlands 86	Parliament	3.6
Finland 11	Parliament	5.3
Spain 86	Parliament	8
Sweden 79	Parliament	25
Switzerland 11	Parliament	32
Spain 11	Parliament	36
Germany 86	Parliament	39
Finland 86	Parliament	46
France 11	Parliament (first round)	58
United Kingdom 86	Parliament	59
Italy 86	Parliament	59

*ELEC*sne*imp*

This pathway is intuitive: citizens tend to vote on pro-nuclear parties due to the country's high dependency on nuclear energy. The case explained by this path is that of Finland in 1986, which is interesting since there was growing nuclear opposition after the Chernobyl accident (Ylönen et al., 2017). An interesting aspect of the Finnish nuclear policy subsystem is that the pro-nuclear coalition uses, next to the usual pro-nuclear arguments, the argument of 'Finnish exceptionalism', which 'portrays Finland as the safest, most prepared and thus ideal country for the production of nuclear power' (Ylönen et al., 2017, p. 270). If you combine this phenomenon with a high dependency on nuclear power, it is no surprise that the government stayed on the same course, with the backing of the majority of voters.

5. Discussion

In this section, the findings of this study are discussed and put into a broader context. First, the main findings will be discussed. Then, the research design is contemplated by discussing the case selection, its underlying assumptions, simplifications, and limitations. The contribution to public administration literature is assessed and suggestions for further research are given.

5.1. Conditions for nuclear policy change

The most interesting findings of this research revolve around the 'POL' indicator. In all cases with a major policy change as outcome, an adversary policy subsystem was in place, making it a necessary condition for a positive outcome, in line with H2. This is also in line with the findings by Rinscheid (2015). When looking at the negative cases, a reversed causation is also observed, where a unitary policy subsystem alone (pol) is a sufficient condition for no policy reversal to occur. The importance of the subsystem orientation suggests that a paradigm focusing on strategic interactions is most fit for analyzing critical junctures. Such a focus on political interactions is in line with research by, for instance, Kitschelt (1986) and Bernardi et al. (2019).

The condition using the ACF has shown to be the most salient of all conditions tested. According to Nohrstedt (2010, p.1), previous studies miss the initial target of ACF, which is to 'identify and specify independent variables and causal mechanisms explaining change in policy-oriented belief systems and, ultimately, in public policy programs'. This research showed that a QCA research design is appropriate for testing such variables. However, similar to Rinscheid, this research loosely interpreted the different policy subsystem types. Instead of distinguishing two types, Weible (2008) distinguishes between adversary, unitary, and collaborative subsystems. Further research with a stricter implication of the ACF definitions, coding different interactions based on qualitative sources executed by multiple researchers, could yield interesting results. The identification of different types of subsystem and crisis pathways, as indicated by Nohrstedt & Weible (2010), in Appendix B could provide a starting point.

Contrary to subsystem orientation, a condition that showed unexpected results was the presence of imminent elections. While imminent elections were theorized to lead to a higher likelihood of a major nuclear policy change, their absence, in combination with a unitary policy subsystem, proved to lead to this result. As shown in the analysis, elections very close to the nuclear disaster will likely lead to a remaining status quo in nuclear energy policy. From the results of this study, it is difficult to theorize what the causal mechanism of elections could be. Another complication is that Wittneben (2012), who hypothesized the critical role of imminent elections, based this on the 2011 regional elections in Germany. A clearer operationalization of the timing and type of imminent elections could shed light on the role.

The interplay of the election condition with an adversary policy subsystem is found to, in both cases, work through direct democracy. The specifics of the electoral system have been decisive in both cases: in the Swiss case, the pressure of the possibility of a referendum, and in the Italian case, a national referendum on nuclear energy. Including specifics about the electoral system, especially referendums, would be an interesting focus in future research design. Franchino (2017,

p. 205) regards such dynamics as the primary explanatory variable for nuclear policy change in Italy and explains 'party positioning and coalition politics [….] heavily depend on the electoral systems, which shape voting behaviour and political competition, and on referendums, which may raise issue salience and likelihood of policy change'.

In general, there is a variety within the outcome paths discussed: there are multiple different ways in which cultural, contextual, and political factors contribute to a major policy change after a nuclear disaster, a finding in line with H1. The presence of all three types of conditions in the outcome formulas indicates that the combination of the three possesses explanatory power. While the relevance of contextual factors related to energy supply came forward relatively less in the literature review, the results indicate that the inclusion of import dependency and share of nuclear electricity partly explains the differences between countries. However, coding the conditions using the mean of all countries is debatable, and it would be better to draw the condition thresholds based on values found in theory, as discussed by Rihoux and De Meur (2008). In further research, other contextual factors, such as the development of nuclear expertise within a country or a country's population density, could be tested on whether they hold similar explanatory power.

The third type of condition included was related to cultural factors, for which only the media condition was included. This condition functioned, in combination with other conditions (INUS), in line with what was expected: a presence of media amplification contributed to a positive outcome and an absence to a negative outcome. The coding of this variable is based on anecdotal evidence from different country sources. However, the comparability of such anecdotal evidence is questionable. For instance, while older sources tend to view the coverage of Chernobyl in the media as exaggerated, newer sources comparing Chernobyl media coverage to that of Fukushima say that 1986's coverage was modest compared to the latter. There might be a case of a recency bias, where events that have just happened seem to be of greater importance (Rudiawarni, Made Narsa, & Tjahjadi, 2020). Although more labor intensive, a content analysis of news coverage would be a tactic to eliminate such biases and make the research design retraceable. In addition, other cultural factors might be interesting to include in further studies, for instance, phenomena such as the 'Finnish exceptionalism' (Ylönen et al., 2017), the nuclear renaissance (Bauer et al., 2018), or cultural memory of earlier nuclear disasters (ibid.).

5.2. Case selection

While other comparable studies concentrated on a smaller group of countries, one specific nuclear disaster, or one specific policy outcome, this research focusses a relatively high number of cases. As a result, the comparability of cases is limited. The recency bias in anecdotal evidence of news coverage of different nuclear disasters is an example of how the comparability over time is limited. A larger critique on comparing the different cases over time is that the reaction on a nuclear disaster is not a stand-alone event. Rather, the collective memory of TMI and Chernobyl might have resulted in a stronger response to Fukushima. We can see this when looking at nuclear policy change in Germany. In 1986 a surge of anti-nuclear movements was to no effect. However, when another nuclear disaster happened in 2011, this time a major policy change was made.

There are also limitations to the comparability of countries. While a nuclear disaster abroad comes close to a natural experiment, not all countries were impacted the same by the Chernobyl fallout. Impacts are felt differently between, for instance, Finland and Spain, who are not only physically but also culturally distanced. Also, other focussing events can happen within a country or regional context. An example is the 2008 incident at a Slovenian nuclear plant, after which all EU member states were warned of radiation risks, which turned out to be a false alarm (Tomkiv et al., 2016).

Next to comparability, the case selection itself can be debated. Firstly, countries that never started nuclear energy production are not included. However, if the decision to do so was made in reaction to a nuclear disaster, this moment functioned as a critical juncture for that specific country. Including such cases would add to the diversity of cases. Secondly, it is debatable whether a case, such as France in 1986, that did not result in a 'near-miss' of the outcome of a major change, where the occurrence of a nuclear disaster did not lead to a debate in the public policy sphere is a true negative case. Related to this discussion is the limitation of translating policy change in the nuclear policy sphere into a dichotomous variable. There is a multitude of different courses to be taken: countries can remain on the same course, freeze future extension plans, make a significant turn-around and decide to phase-out nuclear power, extend the lifetime of existing reactors, or plan an increase in nuclear power. Perhaps multivariate QCA (mvQCA), which facilitates the analysis of categorical variables, allows for the inclusion of this nuance into a future research design (Toshkov, 2016).

6. Conclusion

This research aimed to answer the question: *Under what circumstances does the occurrence of a nuclear disaster abroad cause a deviation from the policy path of nuclear energy generation within different European countries?* using a QCA to analyze ten western European countries' reactions to two large nuclear disasters.

The minimal formulas resulting from the boolean minimization process illustrate that various causal pathways lead to the outcome of a policy turn-around. In these causal pathways all three types of conditions theorized play a role: contextual conditions, conditions related to political processes, and conditions related to ideation processes. The main finding is that an adversary policy subsystem is a necessary condition for a country to divert its nuclear energy policy after a nuclear disaster. A unitary policy subsystem is a sufficient condition for the adverse outcome, remaining of the status quo. These results suggest a further focus on strategical interactions during a critical juncture that follows a nuclear disaster. In this research, the ACF theory has proven to be helpful in theorizing the causal mechanisms behind these interactions. Testing these ACF causal mechanisms with a QCA research design would be an interesting future exploration.

In an adversary policy subsystem, different opinions are present, and the system is open for emerging actors. An adversary policy subsystem, in combination with an absence of upcoming elections, proved fruitful for a deviation from nuclear energy path dependency. In these cases, aspects of direct democracy made the government more responsive to public concerns regarding nuclear energy, resulting in a major policy change after a nuclear disaster. The role of imminent elections is counterintuitive: the presence of imminent elections, combined with modest media reporting of the disaster or a high import and nuclear energy dependency, actually led to a remaining status quo. The timing and role of elections during a critical juncture after a nuclear disaster therefore could use further study.

Energy path dependency and adaption of different energy sources and technologies will remain an interesting topic for the coming decades. Comparative public policy research allows us to study the adoption of these beyond country borders and daily politics. This research showed that, while the setup of democratic political processes seems decisive in decision-making, contextual factors regarding energy supply and economy and factors revolving around the transmission of ideas are relevant to explaining policy change and should not be overlooked. In a world where technology is becoming more complex, and energy supply is becoming a central issue of debate, social and democratic values are of growing importance and should included in decision-making processes.

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Appendix A: Sources used for coding

Table A.. The qualitative sources consulted per country during the coding of the QCA variables.

Country	Sources
Belgium	Latré, Thijssen, & Perko, 2019; Schulze, 2017; Yamasaki, 2009
Finland	Bernardi et al., 2018; Schulze, 2017; Yamasaki, 2009; Ylönen, Litmanen, Kojo, & Lindell, 2017
France	Brouard & Guinaudeau, 2015, 2017; Kepplinger & Lemke, 2015; Koopmans & Duyvendak, 1995
Germany	Kepplinger & Lemke, 2015; Kitschelt, 1986; Koopmans & Duyvendak, 1995; Laka Foundation, 2012; Renn, 1990; Rinscheid, 2015; Saltori, 2023; Thurner, 2017
Italy	Franchino, 2017; Perko et al., 2019; Yamasaki, 2009
Spain	Mercado-Sáez, Marco-Crespo, & Álvarez-Villa, 2019; Schulze, 2017
Sweden	Holmberg & Hedberg, 2017; Jensen, 2015; Nohrstedt, 2006, 2010
Switzerland	Kepplinger & Lemke, 2015; Koopmans & Duyvendak, 1995; Kriesi, 2017; Yamasaki, 2009
the Netherlands	Aarts & Arentsen, 2017; Koopmans & Duyvendak, 1995; Laka Foundation, 2012; Yamasaki, 2009; van Walsum, 2021
the United Kingdom	Bernardi et al., 2018; Kepplinger & Lemke, 2015; Renn, 1990; Schulze, 2017; Wittneben, 2012; Yamasaki, 2009

Appendix B: Policy subsystem coding

Table B.1. Directly copied from Weible (2008). "A Summary of Three Ideal Types of Policy Subsystems"

	Unitary Subsystems	Collaborative Subsystems	Adversarial Subsystems
1. Coalitions	Single coalition with high intra-coalition belief compatibility and high intra-coalition coordination	Cooperative coalitions with intermediate inter-coalition belief compatibility and high inter and intra-coalition coordination	Competitive coalitions with low inter-coalition belief compatibility and high intra-coalition and low inter-coalition coordination
2. Policy images	Single	Reconciled	Debated
3. Degree of centralization and interdependence	Authority is centralized and interdependence with other subsystems is ignored	Authority is decentralized, fragmented across policy subsystems, or both. Coalitions share access to authority.	Authority is centralized but fragmented within the policy subsystem, fragmented across policy subsystems, or both. Coalitions compete for access to authority
4. Venues	Coalition influences decisions in one or two amiable venues (legislature, agencies)	Coalitions use a variety of venues, including ones based on consensus-based institutions	Coalitions seek to influence decisions in any amiable venue (courts, legislatures, agencies)
5. Policy designs	Policies distribute benefits to single coalition	Policies are voluntary, win–win, and flexible in means	Policies are coercive, win–lose, and prescriptive in means

Table B.3. Table showing the cases coded for the POL variable as well as a suggestion for which pathway was followed after a crisis event. Note that the pathway codes correspond to the pathway codes shown. A '-' means that the nuclear accident was not perceived as a crisis by the policy subsystem of the case.

Case	Pathway code	POL
Sweden 79	A4	1
France 79	U -	0
Finland 86	C -	1
Italy 86	C3	1
Switzerland 86	A2/1	1
Belgium 86	U1	0
Germany 86	U1	0
Netherlands 86	C1	1
Spain 86	U2	0
United Kingdom 86	U1	0
Germany 11	C1	1
Italy 11	A3	1
Switzerland 11	A3	1
Belgium 11	U1	0
Finland 11	C -	1
France 11	U -	0
Netherlands 11	U1	0
Spain 11	A2	1
Sweden 11	U4?	0
United Kingdom 11	U1	0

Table B.2. Directly from Nohrstedt & Weible (2010). "Hypothesized Pathways from Crisis to Policy Subsystem Response". The coding on the right hand side, 'pathway codes' are added for this study.

In *Unitary* policy subsystems, an immediate or policy-proximate crisis will lead to one of four policy subsystem responses:	U1
(i) The dominant coalition will tone down the policy implications that potentially emerge from the crisis and/or attempt to interpret the crisis as supportive of the status quo, thereby maintaining existing subsystem equilibrium or accepting minor policy change.	
(ii) The dominant coalition will attend to the crisis, interpret the crisis as supportive of the status quo, and respond by instigating minor policy changes.	U2
(iii) The dominant coalition will use the crisis as pretext to introduce major policy change, which is most likely to be accompanied by counter-mobilization of oppositional forces and the emergence of an adversarial subsystem.	U3
(iv) A sufficient number of dominant coalition members will defect and/or new actors will enter the subsystem to form a rival coalition, shifting the dominant mode of subsystem interaction from unitary to adversarial or collaborative.	U4
In *Collaborative* policy subsystems, an immediate or policy-proximate crisis will lead to one of three policy subsystem responses:	
(i) The cooperative coalitions will collectively alter their perception of subsystem causes and problems leading to minor or major policy change.	C1
(ii) A crevasse will emerge between the cooperative coalitions, thereby shifting the subsystem from collaborative to adversarial.	C2
(iii) Actors mobilize either into the subsystem or by defections from existing coalitions, to challenge the existing policies and thereby shifting the subsystem from collaborative to adversarial.	C3
In *Adversarial* policy subsystems, an immediate or policy-proximate crisis will lead to one of four policy subsystem responses:	
(i) Competitive coalitions will interpret the crisis as supporting their policy core beliefs, magnifying the polarization of coalition beliefs and the intensification of conflict.	A1
(ii) Subsystem resources will be redistributed, giving one coalition the upper hand, leading to minor or major policy changes.	A2
(iii) Subsystem resources will be redistributed and one coalition will collapse, creating one dominant coalition and the emergence of a unitary policy subsystem.	A3
(iv) Subsystem resources will be redistributed, competing coalitions will be unable to find venues amiable to their objectives and perceive the status quo as unacceptable, a hurting stalemate will ensue, negotiations will commence, and the subsystem will shift from adversarial to collaborative.	A4

Appendix C: QCA reports

Tosmana Report

Algorithm: Graph-based Agent

File: C:\Users\judit\Documents\PA_IEG MSc\p34 Thesis\QCA\TOSMANA performing qca.xml

Settings:

Minimizing: 1

including: R

Truth-Table:

Case	SNE	IMP	POL	ELEC	MEDIA	Outcome
Belgium 86	0	0	0	0	0	0
Belgium 11, France 79	0	0	0	0	1	0
Switzerland 86	0	0	1	0	0	1
Finland 86	0	0	1	1	1	0
Sweden 11	0	1	0	0	0	0
France 11	0	1	0	1	0	0
Finland 11	0	1	1	1	0	0
Switzerland 11, Sweden 79	0	1	1	1	1	1
Spain 86, United Kingdom 86	1	0	0	1	0	0
Italy 11	1	0	1	0	1	1
Spain 11	1	0	1	1	0	0
Germany 11, Italy 86	1	0	1	1	1	1
Netherlands 11, United Kingdom 11	1	1	0	0	0	0
Germany 86	1	1	0	1	1	0
Netherlands 86	1	1	1	1	0	0

Result(s):

POL * elec + sne * IMP * MEDIA + SNE * imp * MEDIA

(Italy 11+Switzerland 86) (Switzerland 11,Sweden 79) (Germany 11,Italy 86+Italy 11)

Simplifying Assumptions SNE{0}IMP{0}POL{1}ELEC{0}MEDIA{1} +
SNE{0}IMP{1}POL{0}ELEC{0}MEDIA{1} +
SNE{0}IMP{1}POL{0}ELEC{1}MEDIA{1} +
SNE{0}IMP{1}POL{1}ELEC{0}MEDIA{0} +
SNE{0}IMP{1}POL{1}ELEC{0}MEDIA{1} +
SNE{1}IMP{0}POL{0}ELEC{0}MEDIA{1} +
SNE{1}IMP{0}POL{0}ELEC{1}MEDIA{1} +
SNE{1}IMP{0}POL{1}ELEC{0}MEDIA{0} +
SNE{1}IMP{1}POL{1}ELEC{0}MEDIA{0} +
SNE{1}IMP{1}POL{1}ELEC{0}MEDIA{1}
Number of Simplifying Assumptions: 10

POL * elec + sne * IMP * MEDIA + SNE * POL * MEDIA

(Italy 11+Switzerland 86) (Switzerland 11,Sweden 79) (Germany 11,Italy 86+Italy 11)

Simplifying Assumptions SNE{0}IMP{0}POL{1}ELEC{0}MEDIA{1} +
SNE{0}IMP{1}POL{0}ELEC{0}MEDIA{1} +
SNE{0}IMP{1}POL{0}ELEC{1}MEDIA{1} +
SNE{0}IMP{1}POL{1}ELEC{0}MEDIA{0} +
SNE{0}IMP{1}POL{1}ELEC{0}MEDIA{1} +
SNE{1}IMP{0}POL{1}ELEC{0}MEDIA{0} +
SNE{1}IMP{1}POL{1}ELEC{0}MEDIA{0} +
SNE{1}IMP{1}POL{1}ELEC{0}MEDIA{1} +
SNE{1}IMP{1}POL{1}ELEC{1}MEDIA{1}
Number of Simplifying Assumptions: 9

POL * elec + SNE * imp * MEDIA + IMP * POL * MEDIA

(Italy 11+Switzerland 86) (Germany 11,Italy 86+Italy 11) (Switzerland 11,Sweden 79)

Simplifying Assumptions SNE{0}IMP{0}POL{1}ELEC{0}MEDIA{1} +
SNE{0}IMP{1}POL{1}ELEC{0}MEDIA{0} +
SNE{0}IMP{1}POL{1}ELEC{0}MEDIA{1} +
SNE{1}IMP{0}POL{0}ELEC{0}MEDIA{1} +
SNE{1}IMP{0}POL{0}ELEC{1}MEDIA{1} +
SNE{1}IMP{0}POL{1}ELEC{0}MEDIA{0} +
SNE{1}IMP{1}POL{1}ELEC{0}MEDIA{0} +
SNE{1}IMP{1}POL{1}ELEC{0}MEDIA{1} +
SNE{1}IMP{1}POL{1}ELEC{1}MEDIA{1}
Number of Simplifying Assumptions: 9

POL * elec + SNE * POL * MEDIA + IMP * POL * MEDIA

(Italy 11+Switzerland 86) (Germany 11,Italy 86+Italy 11) (Switzerland 11,Sweden 79)

Simplifying Assumptions SNE{0}IMP{0}POL{1}ELEC{0}MEDIA{1} +
SNE{0}IMP{1}POL{1}ELEC{0}MEDIA{0} +
SNE{0}IMP{1}POL{1}ELEC{0}MEDIA{1} +
SNE{1}IMP{0}POL{1}ELEC{0}MEDIA{0} +
SNE{1}IMP{1}POL{1}ELEC{0}MEDIA{0} +
SNE{1}IMP{1}POL{1}ELEC{0}MEDIA{1} +
SNE{1}IMP{1}POL{1}ELEC{1}MEDIA{1}
Number of Simplifying Assumptions: 7

sne * IMP * MEDIA + SNE * imp * MEDIA + sne * imp * POL * media

(Switzerland 11,Sweden 79) (Germany 11,Italy 86+Italy 11) (Switzerland 86)

Simplifying Assumptions SNE{0}IMP{0}POL{1}ELEC{1}MEDIA{0} +
SNE{0}IMP{1}POL{0}ELEC{0}MEDIA{1} +
SNE{0}IMP{1}POL{0}ELEC{1}MEDIA{1} +
SNE{0}IMP{1}POL{1}ELEC{0}MEDIA{1} +
SNE{1}IMP{0}POL{0}ELEC{0}MEDIA{1} +
SNE{1}IMP{0}POL{0}ELEC{1}MEDIA{1}
Number of Simplifying Assumptions: 6

sne * IMP * MEDIA + SNE * POL * MEDIA + sne * imp * POL * media

(Switzerland 11,Sweden 79) (Germany 11,Italy 86+Italy 11) (Switzerland 86)

Simplifying Assumptions SNE{0}IMP{0}POL{1}ELEC{1}MEDIA{0} +
SNE{0}IMP{1}POL{0}ELEC{0}MEDIA{1} +
SNE{0}IMP{1}POL{0}ELEC{1}MEDIA{1} +
SNE{0}IMP{1}POL{1}ELEC{0}MEDIA{1} +
SNE{1}IMP{1}POL{1}ELEC{0}MEDIA{1} +
SNE{1}IMP{1}POL{1}ELEC{1}MEDIA{1}
Number of Simplifying Assumptions: 6

SNE * imp * MEDIA + IMP * POL * MEDIA + sne * imp * POL * media

(Germany 11,Italy 86+Italy 11) (Switzerland 11,Sweden 79) (Switzerland 86)

Simplifying Assumptions SNE{0}IMP{0}POL{1}ELEC{1}MEDIA{0} +
SNE{0}IMP{1}POL{1}ELEC{0}MEDIA{1} +
SNE{1}IMP{0}POL{0}ELEC{0}MEDIA{1} +
SNE{1}IMP{0}POL{0}ELEC{1}MEDIA{1} +
SNE{1}IMP{1}POL{1}ELEC{0}MEDIA{1} +
SNE{1}IMP{1}POL{1}ELEC{1}MEDIA{1}
Number of Simplifying Assumptions: 6

SNE * POL * MEDIA + IMP * POL * MEDIA + sne * imp * POL * media

(Germany 11,Italy 86+Italy 11) (Switzerland 11,Sweden 79) (Switzerland 86)

Simplifying Assumptions SNE{0}IMP{0}POL{1}ELEC{1}MEDIA{0} +
SNE{0}IMP{1}POL{1}ELEC{0}MEDIA{1} +
SNE{1}IMP{1}POL{1}ELEC{0}MEDIA{1} +
SNE{1}IMP{1}POL{1}ELEC{1}MEDIA{1}
Number of Simplifying Assumptions: 4

Created with Tosmana Version 1.61

Tosmana Report

Algorithm: Graph-based Agent

File: C:\Users\judit\Documents\PA_IEG MSc\p34 Thesis\QCA\TOSMANA performing qca.xml

Settings:

Minimizing: 0

including: R

Truth-Table:

Case	SNE	IMP	POL	ELEC	MEDIA	Outcome
Belgium 86	0	0	0	0	0	0
Belgium 11, France 79	0	0	0	0	1	0
Switzerland 86	0	0	1	0	0	1
Finland 86	0	0	1	1	1	0
Sweden 11	0	1	0	0	0	0
France 11	0	1	0	1	0	0
Finland 11	0	1	1	1	0	0
Switzerland 11, Sweden 79	0	1	1	1	1	1
Spain 86, United Kingdom 86	1	0	0	1	0	0
Italy 11	1	0	1	0	1	1
Spain 11	1	0	1	1	0	0
Germany 11, Italy 86	1	0	1	1	1	1
Netherlands 11, United Kingdom 11	1	1	0	0	0	0
Germany 86	1	1	0	1	1	0
Netherlands 86	1	1	1	1	0	0

Result(s):

pol +	ELEC * media +	sne * imp * ELEC
(France 11+Belgium 11,France 79+Netherlands 11,United Kingdom 11+Sweden 11+Belgium 86+Germany 86+Spain 86,United Kingdom 86)	(Finland 11+France 11+Spain 11+Netherlands 86+Spain 86,United Kingdom 86)	(Finland 86)

Simplifying Assumptions SNE{0}IMP{0}POL{0}ELEC{1}MEDIA{0} +
SNE{0}IMP{0}POL{0}ELEC{1}MEDIA{1} +
SNE{0}IMP{0}POL{1}ELEC{1}MEDIA{0} +
SNE{0}IMP{1}POL{0}ELEC{0}MEDIA{1} +
SNE{0}IMP{1}POL{0}ELEC{1}MEDIA{1} +
SNE{1}IMP{0}POL{0}ELEC{0}MEDIA{0} +
SNE{1}IMP{0}POL{0}ELEC{0}MEDIA{1} +
SNE{1}IMP{0}POL{0}ELEC{1}MEDIA{1} +
SNE{1}IMP{1}POL{0}ELEC{0}MEDIA{1} +
SNE{1}IMP{1}POL{0}ELEC{1}MEDIA{0}
Number of Simplifying Assumptions: 10

pol +	ELEC * media +	sne * imp * MEDIA
(France 11+Belgium 11,France 79+Netherlands 11,United Kingdom 11+Sweden 11+Belgium 86+Germany 86+Spain 86,United Kingdom 86)	(Finland 11+France 11+Spain 11+Netherlands 86+Spain 86,United Kingdom 86)	(Belgium 11,France 79+Finland 86)

Simplifying Assumptions SNE{0}IMP{0}POL{0}ELEC{1}MEDIA{0} +
SNE{0}IMP{0}POL{0}ELEC{1}MEDIA{1} +
SNE{0}IMP{0}POL{1}ELEC{0}MEDIA{1} +
SNE{0}IMP{0}POL{1}ELEC{1}MEDIA{0} +
SNE{0}IMP{1}POL{0}ELEC{0}MEDIA{1} +
SNE{0}IMP{1}POL{0}ELEC{1}MEDIA{1} +
SNE{1}IMP{0}POL{0}ELEC{0}MEDIA{0} +
SNE{1}IMP{0}POL{0}ELEC{0}MEDIA{1} +
SNE{1}IMP{0}POL{0}ELEC{1}MEDIA{1} +
SNE{1}IMP{1}POL{0}ELEC{0}MEDIA{1} +
SNE{1}IMP{1}POL{0}ELEC{1}MEDIA{0}
Number of Simplifying Assumptions: 11

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