Emergence of Policies

An agent-based study

R. Klein

TU Delft

Emergence of Policies

An agent-based study

by

R. Klein

to obtain the degree of Master of Science
at the Delft University of Technology,
to be defended publicly on Friday May 12, 2017 at 12:30 PM.

Student number:	4048016	
Project duration:	October 6, 2016 – May 12, 2017	
Thesis committee:	Dr. ir. I. Nikolic,	TU Delft, supervisor
	Prof. dr. ir. P. Herder,	TU Delft, chairwoman
	Dr. P. Bots,	TU Delft

An electronic version of this thesis is available at `http://repository.tudelft.nl/`.

TU Delft

Preface

Preface…

R. Klein
Delft, April 2017

Summary

Contents

1
Introduction

The policy process is a complex, non-linear process (Morçöl, 2013). Over time, researchers have attempted to codify this process. A policy cycle has emerged in some parts of the literature (Bridgman and Davis, 2004). Different theories were devised to try to explain and understand what happens during the policy process (Sabatier and Weible, 2014). This process is complex as it can encompass hundreds of different actors interacting with each other. It is also a process that can happen on different time scales. It is different in every political arena considered, may it be the health or the transportation industry. This process will also be different from one country to another varying with the types of institutions and the legislative process. Finally, the policy process deals with the beliefs of the agents present in the political arena. These beliefs can widely vary from one actor to another regarding similar topics (Sabatier and Weible, 2014).

This thesis present attempt at conceptualising and simulating this complex policy process and more specifically the process of policy emergence. This introductory chapter outlines the basic literature related to the policy analysis in section 1.1 and the issues arising with the conceptualisation and simulation of policy emergence in section 1.2. It then introduces the research approach and the objectives of the work presented in this report in section 1.3. It is completed by an outline of this report in section 1.4.

1.1. Policy Analysis

Policy analysis is a discipline that originates in the 1940's. It however only took off in the 1960's (Walker, 2000). Different models emerged from the study of the field. They started with models based on rational thinking with a linear approach to the policy process. They slowly evolved into more complex models acknowledging the non-linearity of the process and the irrationality of the actors taking part in the policy process. The study of policy analysis also looked at different case studies to ground into reality the theoretical findings.

For the purpose of this thesis, four theories are of paramount interest. These theories are widely used nowadays to try to explain the policy emergence process. These four theories are all outlined in Sabatier and Weible (2014). They are the three streams theory, the feedback theory, the advocacy coalition framework and the diffusion theory. These theories are chosen because of their centrality in the field of policy analysis and because of their potential to outlined the complex dynamics of the policy emergence process. Addittionally, and this will be shown throughout this thesis, they are compatible with an agent based modelling approach. Furthermore, most of the assumptions taken within these theories are validated through the use of numerous case studies. This help keep the focus on the work performed in this thesis and avoids any questions on the validity of the policy making theories used.

1.2. Policy Emergence

Currently, the study of policy emergence is mostly conducted through qualitative studies. These studies focus on specific cases (Ackrill and Kay, 2011; Birkland, 2004; Bloemraad et al., 2008; Cairney, 2009; Dolšak and Sampson, 2012; Hoberg, 1996; Hochschild and Weaver, 2010; Ingold, 2011; Kim, 2003; Mazarr, 2007; Mettler, 2002; Pierce, 2011; Travis and Zahariadis, 2002). For such case study, the researcher adopts a certain lens to analyse what has occurred. These lenses are shaped based on the varying policy making theories. This approach to analyse the process of policy emergence is limited in several aspects.

Using a qualitative approach, it becomes more complicated to analyse and compare the same case studies but in different legislations or with different institutions. Such an approach limits the analysis that can be performed by the researcher. Another problem relates to the policy making theories themselves. As these theories are very qualitative, and not fully formalised, the analysis will lack the sort details that could be obtained through a more quantitative study. These are details such as which actors spoke to who and what were the impacts of such discussion on the overall process. The qualitative approach provides a fundamental understanding of the overall events, but lacks the clarity of a quantitative analysis. Finally, and maybe mot importantly, the qualitative approach is a static analysis. Using such an analysis, it is impossible to test different scenarios with different events or agents to see whether the outcome could have been impacted by a different set of circumstances. It is also impossible to check whether the proposition of different instruments to the actors present in the system would have led to a different outcome.

It is for these reasons that it is important to attempt to conceptualise and simulate these policy making theories. The resulting model would yield an innovative approach to look at the policy emergence process. It would also allow researcher for additional insight in this process. Additional tests could be performed and tests on changing outcomes could be conducted.

1.3. Objectives and Research Approach

This section presents the objectives of the thesis along with the research approach that will be used to reach these objectives. There are two main objectives. The first one is to produce a conceptualisation that encompasses the four policy making theories considered (three streams theory, feedback theory, advocacy coalition framework and diffusion theory). This conceptualisation should be able to reconcile as many concepts as possible from each of the theories within one main framework.

The second objective is related to the modelling. The aim is to adapt this conceptualisation, through a formalisation, into an agent based model for the three streams theory and the advocacy coalition framework. A thorough analysis should be made of the results obtained from this model to verify that the behaviours expected from the policy making theories can be found within the results of the model.

1.3.1. Research Question

Following these objectives, it is possible to formulate the main research question. This question is to be answered by the work performed in this thesis. It is given as follows:

How can the emergence of policies be simulated using policy process theories within an agent based framework?

To complement this research question, three sub-questions are formulated:

1. What parts of the different policy making theories can be integrated into an agent based model?
2. How can we translate both the specifics and the assumptions of the theories into an agent based model?
3. What use can the model provide for political scientists?
4. What are the advantages of an agent based model versus a more qualitative analysis? Can they be complementary models?

1.3.2. Method

The first research questions are answered through a literature study. This extensive review will go over the different policy process theories in question. The aim is to gain information on the behaviours of the actors within these theories. It will therefore be important to obtain an overall understanding of each of the theories but also to get information on the details that help specify how each of these theories work. To gain a better understanding of the theories, it will also be important to look at different case studies in which they are used. Following the literature study, it will be possible to construct a joint conceptualisation of the different policy making theories fulfilling the first objective of this thesis.

The second method is the agent based model. This model will be built using the programming language Python. Before the model is constructed, a detailed formalisation will have to be produced to specify how the behaviors in the conceptualization should translate into quantitative reasoning. This formalisation will be directly resulting from the conceptualisation.

Finally, to verify the model and examine its usefulness, several experiments will be designed. These experiments will outline the assumptions made to test the model's behaviour. The results of these experiments will be analysed and be extensively discussed. The aim will be to confirm that the different concepts and behaviours expected from the policy making theories in the literature can be outlined by model outputs. To perform this task, the policy emergence model will have to be coupled to a technical model. This model is an agent-based forest fire model which is built as an aid to clarify the inner-operations of the policy model. It should not be considered as an actual case study.

1.3.3. Scope

The scope of this work is limited to the conceptualisation and creation of a model to study policy emergence based on several policy making theories. The work will not look into the validation of these policy making theories in and of themselves, though it will look at the validity of their translation into an agent based model. The aim is only to try to reproduce expected behaviours from the model. Furthermore, the different policy making theories were chosen because they are considered to be sufficiently validated. They are also widely used in the literatures for different analyses and case studies.

1.3.4. Scientific relevance

There are several aspects why this work is innovative and relevant scientifically. The first reason for this work is to attempt to grow the tool kit that policy scientists can use to analyse different cases. Currently most of the case studies are analysed using qualitative methods. The approach provided here would also allow them to use more quantitative methods. This method could also be generalised to look at more case studies and compare case studies on the same topic but in different countries.

The second aspect relates to the use of agent based models. This growing modelling discipline has been unter-utilised used within the context of policy emergence. The work presented in this thesis will therefore help grow the agent based model ecosystem.

Finally, the work presented here can also be used for prospective policies. Current approaches of the evaluation of policy instruments tent to only focus on the technical and implementation phases to assess their policy instruments. The model proposed here will also allow researcher to consider the political aspects of the introduction of a new policy instrument, increasing the chances of having a successful instrument.

1.4. Structure of this thesis

This thesis is composed of three main parts. The first part look into the literature related to the background of policy emergence. In this part, chapter 2 first looks at the field of policy analysis. Four different policy making theories are considered there along with a model that is widely used in the literature to describe the behaviours of actors in the policy process. chapter 3 then introduces complex modelling and agent based models. Finally, in chapter 4 a reflexion is performed on the current limitations of the policy making theories surveyed and how these could be enhanced using agent based models.

The second part of the thesis deals with the model. In chapter 5, the conceptualisation of the model is detailed. It goes over the general approach and then the approach used for the different policy making theories that are considered for the model. chapter 6 details the model validation that was performed using experts in the field of policy analysis. Finally, in chapter 7, the model implementation is outlined. In this chapter, the technical model to which the policy emergence model is coupled is explained.

The third part of this thesis deals with the results from the model. In chapter 8, an explanation is provided on what type of model exploration was performed and what experimentations are considered. In chapter 9 the results are presented. They are then analysed and compared to the expected results. Finally in chapter 10, this thesis is concluded with a discussion before the conclusions are drawn.

I

The Background

2

Policy Analysis

The field of policy analysis originates from operations research and system analysis (Enserink et al., 2013; Walker, 2000). It slowly evolved from the 1940's until the 1960's into policy analysis. In the early days, policy analysis was mostly the study of cases (Heclo, 1972). Researchers looked at famous cases such as the Cuban missile crisis and analysed the decisions that were taken (Allison et al., 1971). The field then evolved into a field where policy analysis is for public policymaking. By that, it is meant that policy analysis is the use of methodologies or tools that are meant to help within the framework of policy making. Nowadays, the field has evolved in representing both aspects: case studies and tools and methodologies (Enserink et al., 2013). This thesis focuses on the latter part and does not look at a specific case study.

In the literature, several meaning are proposed for policy and policy analysis (Heclo, 1972). Policy is sometimes viewed as a form of a more generalized decision-making. Other times it is seen as a proposed course of goal-oriented actions within a given environment providing obstacles and opportunities (Friedrich, 1963). Ultimately, Heclo (1972) states that "the term policy need to be able to embrace both what is intended and what occurs as a result of the intention". Finally, Bots (2013) even argues that the objective of a policy analysis is to change the mind of people.

Overtime several models have been presented attempting to represent the process of policy making and policy analysis. Enserink et al. (2013) cites five of these models which can be considered as the models on which other models are based. The first one mentioned is a model based on rational thinking. The model argues that the actors present during the process of policy making are rational, that the process evolves incrementally in a closed and hierarchical setting (Lindblom, 1959). This model suggests a linear process where failure to achieve a policy can be blamed on not fulfilling one of the steps of the policy process. [These are not the same models.] This policy process is expressed by Fischer (1989) as using the following steps: agenda formulation, policy formulation, adoption, implementation and evaluation. Criticisms related to this model are mostly related to the assumption of rationality from the part of the actors. Later developments suggest that bounded rationality would be more appropriate.

The second model presented is the view that the policy making process is a political game. It assumes that the actors are autonomous but interdependent and must make political compromises. The entire model suggests a bargaining game between the different actors (Lindblom, 1965). This approach has been comforted by crises such as the Cuban Missile crisis mentioned above. It can also be seen in a lot of political spheres where politicians play a power game to get almost any policy through their respective institutions. The model suggests that the only way to get a problem solved or a policy adopted, the actors have to come to an understanding. If no understanding is achieved, then nothing will happen. This bargaining can be facilitated by brokerage efforts or arbitration for example (O'Toole Jr, 1988).

The third model assumes that the policy making is a discourse. The policies considered require a shared meaning between the actors. This can happen following a learning process. Such arrangements happen when different advocacy coalitions come together. This theory is the basis for the advocacy coalition framework that is detailed later on in this chapter (Jenkins-Smith et al., 2014). Failure to achieve progress within this model is due to the different coalitions not being able to get through to each other. Within the context of this model, Hall (1993) describes three orders for change of policies: first, second and third order. He states that first order changes are regular low level change affecting the setting of policy instruments. Second order changes are less frequent and relate to changes of the policy instrument itself. Finally, third order changes are rare and relate to major political events. He calls such event paradigm shifts which lead to large upset in the policies already in place. He argues that such changes are mostly due to the public and the policy makers while first and second order changes relate to policy learning from the part of bureaucrats.

The fourth model presented is the garbage can model (Cohen et al., 1972). The approach followed by this model is a messier approach where progress is the result of the opening of a policy window (where there is a coupling of the problems, policies and the actors). This approach is very fragmented and can be dependent on the informal networks of the different actors. This theory is the basis for the three streams model which is detailed later within this chapter. The success of policies within the context of this model relates to the ability for the three main streams (problem, policy and politics) to come together at the right moment.

The fifth and last model presented relates policymaking to an institutional process. Policies are considered to be reproductions of earlier solutions. This model is set within a set of formal and informal rules. This model is part of new institutionalism theory. Within this theory, Williamson (1996) differentiates between four layers of institutions: organisations, inter-organisational arrangements, formal institutions and informal institutions. The success of policies within this model is related to an abundance or lack thereof of shared institutional arrangements.

The policymaking process is a process that is complex. One of the approaches that is used in literature is that of Mayer et al. (2013). It uses a hexagon model to represent the different parts of the policy process. In Figure 2.1, it is possible to see that the six main features (research and analyse, design and recommend, clarify values and arguments, advise strategically, democratise, and mediate) are all inter-related. Although, it can be argued that there is a sequence of events, depending on the policy topic or the case, some of these steps will be modified or will take more importance than others. Walker (2000) also presents a set of steps that presents the policy analysis process although he clearly states that these steps can be skipped and there is a series of feedback loops between the different steps.

The aim of this thesis is however to study how policy emerges over time. For this reason,

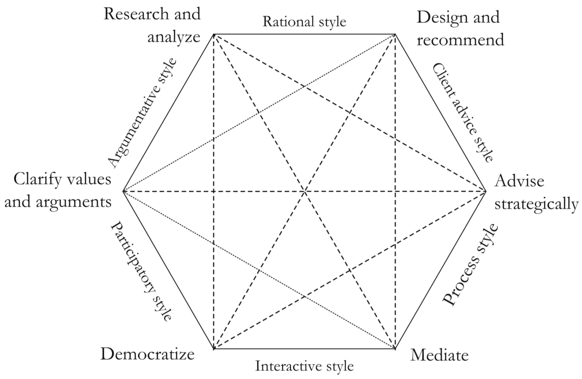

Figure 2.1: The activities in policy analysis and the policy analysis styles (Mayer et al., 2013).

not all parts of the policy process are of interest as will be shown in chapter 5. Furthermore, to better understand, several theories present in literature are looked into. These theories are related to the models presented above. The three streams theory is presented in section 2.1 followed by the feedback theory in section 2.2. The advocacy coalition framework is then explained in section 2.3 with diffusion theory in section 2.4. All these theories have in common the concept of policy entrepreneurs. The policy entrepreneurship models are described in section 2.5.

2.1. The Three Streams Theory

The streams theory is a framework which attempts to explain how policies are chosen at a high level, national or supranational, under a condition of ambiguity (Herweg et al., 2015; Kingdon, 2003; Sabatier and Weible, 2014; Zahariadis, 2007). This framework is a derivative of the garbage can model where it is assumed that there is no beginning and no end within the decision process (Cohen et al., 1972). In the garbage model, it is assumed that no one controls the policy process and the number of opportunity for a policy to rise. The agenda is set by the garbage content present in the cans. The cans contain three different streams: policy, problem and politics. A problem becomes of importance usually due to a focusing event. This leads to a policy window which occurs when all three streams are coupled (Mucciaroni, 1992).

The streams theory follows the same principle. It also contains three streams and has the concept of policy windows. The main difference relates to the definition of ambiguity. Kingdon (2003) provides three indicators for ambiguity: fluid participation, problematic preferences and unclear technology (Zahariadis, 2007). The fluid participation refers to the fact that policies but also policy makers come and go within organisations and governments. Problematic preferences refer to the fact that people do not know what they want. Their decisions are often forced by time constraints. The technology illustrates that policy makers are usually not fully aware of their responsibilities with respect to the larger organisation's or government's goals.

Similarly to the garbage can model, the streams theory identifies three streams: policy, problem and politics (Zahariadis, 2007). The policy stream is made of a sort of soup. In this soup, one can find policies that are devised by specialists. This stream is composed of a large amount of policies. However, only a few are ever considered by the policy makers.

Within this stream, these policies can also be recombined or arranged together to create new policies. The policies are selected by the policy makers based on different criteria such as the value acceptability, the technical feasibility and the integration (relating the different actors and the policy selected).

The second stream is the problem stream. It is composed of four main parameters: the indicators, the focusing events, the feedback and the load (Zahariadis, 2007). The indicators are policy specific characteristics that help the policy makers decide on the seriousness of a problem. Focusing events can help pick up specific problems. Such an event could be for example a train accident. This would lead politicians to pick up the problems related to train safety. Feedbacks relate to the fact that previous policy decisions might lead to new problems. Finally, the load relates to the fact that policy makers are unable to address a large amount of problems at once, they can only provide attention to several specific problems at once.

The third and last stream is the politic stream. Within this stream, the actors present in the decision making process are considered. This theory focuses on two main actor types: the policy makers and the policy entrepreneurs. The policy entrepreneur cannot make any decisions. His only strength is that he can convince the policy makers to make certain decisions. The policy entrepreneurs can be seen as lobbyists to the policy makers. They also operate to try to get the three streams to couple so that a policy window open. It is then their task to convince the policy makers to choose specific policies when the policy window is open. On the other hand, the policy makers are unable to affect the streams. They are only responsible of taking decisions. These decisions are influenced by their personal situation but also by the party to which they belong, by the policy entrepreneurs, by the general public mood and by time.

Three main assumptions should be taken into account when using the stream theory (Zahariadis, 2007). The first one is that the different streams are independent of each other. They do not interact with each other and operate in parallel. The second assumption relates to the policy makers. It is assumed that the policy makers have only finite attention or processing power. This means that they cannot consider multiple policies at once, instead they have to focus their attention on specific policies. This can be considered analogous to the load concept in the problem stream. Finally, the third assumption relates to the fact that policy makers are under strict time constraints. They have to decide on certain policy quickly before policy windows close. Their policy choices can be affected by this time constraint.

The streams theory has been used in multiple case studies. In Ackrill and Kay (2011), it was used to model the sugar reform in the European Union (EU). This application helps enlarge the work from Kingdon as the streams theory was originally devised with the United States in mind. Applying the model did require some adjustments like the decontextualisation of some concepts. Other concepts had to be reinforced as they are more present in the EU. This is particularly important for the policy spillovers which are very present in an institution like the European Commission. The streams theory has also been applied on emission trading in Germany in Brunner (2008) where it was found not to be sufficient to understand the case study, or to study the smoking ban in the UK in Cairney (2009).

Some questions do remain when considering the streams theory. The first one relates to the way the policy makers are considered. The current theory does not consider the in-depth psychology of the policy makers. It does not consider the fact that their decision could be affected by things as small as their popularity at a certain point in time or by irrational decisions (Mucciaroni, 1992). Furthermore, one could question whether the three streams being considered are indeed really independent in real life. Some academics disagree with this view. They argue that in some cases, the streams can be considered interdependent. Finally, some concerns also remains with respect to the verification and the validation of the hypotheses used to construct the theory. Considering this is a mostly qualitative method, one cannot use statistical tests to verify or validate the results of the theory (Bendor, 2001).

2.2. The Feedback Theory

Newly implemented policies are not implemented in a vacuum. They are usually preceded by other policies and supplemented by others. One can therefore expect that policies being implemented will have an impact on future policies and will be impacted by already existing policies. This is referred to as the feedback effect, (Mettler and Soss, 2004; Pierson, 1993). These feedback effects not only have an impact on other policies but can also have an impact on the decision making process, affecting the policy makers, the general public, as well as institutions and policy entrepreneurs.

In the theory, four main inquiries are used to describe the feedback effects (Mettler and SoRelle, 2014). The first one regard the meaning of citizenship. Some of the policies enacted by the policy makers can have a profound impact on what it means to be a citizen in a certain country. These policies can affect the status of citizens in the general public. This happens through policies which differentiate different types of citizens. These policies can be related to immigration or naturalisation. This can in turn shape the political landscape. For example, policies affecting the immigration process can favour certain political parties because of the large influx of certain population or alternatively reinforce opposing parties due to the rejection of these migrants by the local population.

The second one is related to the form of governance. These are policies that might lead to a reduction of the power the policy makers have. It can also lead to a change in the administrative arrangements for new policies. These policies can have an impact on how policy makers approach new policies or how they make their decisions on future policies. This is of course affected by whether the feedback effect stemming from these policies are negative or positive. For example, in the United States, the Social Security Administration, once unpopular, gained a favourable reputation. Once that happened, this administration was used to deliver other policies (Derthick, 1979).

The third inquiry concerns the power of groups. In the jargon used for the streams theory, one can consider these groups as being policy entrepreneurs. Although external groups are usually considered to originate entirely externally, in practice it can be demonstrated that most groups are actually established once a policy has been put in place. These groups will either try to defend the policies when new policies are being considered or will try to reduce its impact. New policies can also strengthen or weaken the position of the policy entrepreneurs.

The fourth and final inquiry relates to the political agendas and the definition of the policy problems. Some of the policies that are decided on by policy makers will ultimately affect what policies the policy makers will be addressing or will be allowed to decide on. New policy issues might be within the jurisdiction of the policy makers while other will move out. Some policy issues can also bring different types of coalition of policy makers to the table. Finally, new policies might affect the importance of some of the policies to the policy makers. They will want to create new policies right after or attempt to protect the existing policy at all costs by preventing new policies from being enacted.

There are different mechanisms that lead to the feedback effects mentioned above. Two are isolated in the literature: the resource effect and the interpretive effect (Pierson, 1993). The first effect is related to policies which affect the public monetarily. Some policies might increase the taxes while other provide subsidies to specific classes of citizens. These policies are likely to have a resource effect which means the public's participation will be affected in the successive public discourse. The interpretive effect relates to the rules that new policies establish. The way the new policies are designed and implemented will affect the public. Depending on how they are affected, their participation to the public discourse will be again affected.

The feedback theory has been used to attempt to explain real life cases. For example, this is the case in Jordan (2013) where feedback theory is used to study the welfare system. The theory was used in this case to explain the effect of welfare on consequent policies. This study was a comparison performed in different countries. Another case study is Mettler (2002) which studied the effects of the G.I. bill at the end of World War II. It explains why the G.I. bill had such a profound effect on the United States and provides a framework to study other policies.

2.3. The Advocacy Framework Coalition

The Advocacy Coalition Framework (ACF) is a theory of policy change (Moyson et al., 2014; Weible et al., 2009). It was developed initially by Sabatier and Jenkins-Smith (1993) to attempt to explain and simplify the complexity of the policy making process. The ACF sees the policy environment as split in different policy subsystems. These subsystems are considered separately from each other and can represent concepts such as security or health for example. In each of these subsystems, the actors are organised in coalitions. These coalitions are assembled with actors sharing similar beliefs. Within the subsystems, the coalitions attempt to influence each other. The ultimate goal is that these coalitions can influence the policy makers to change the policies based on their respective beliefs. The policy change is therefore a reflection of the dominant position in the subsystem. The principle of the ACF is summarised in Figure 2.2.

There are several assumptions that are needed to define what a subsystem is, according to Sabatier and Jenkins-Smith (1993). The first one states that the policy subsystem is the primary unit of analysis for understanding the policy process. The second assumption states that these same policy subsystems demarcate the actors on a given policy topic. Thirdly, the policy subsystems are considered to be semi-independent but can occasionally overlap. Fourth, the subsystems provide authority which can be used to alter the status quo. The fifth and final assumption states that the subsystems can undergo stasis periods, incremental change period or major change periods.

Some assumptions are also specified for the actors participating in these subsystems. The actors are considered to be rational. They can only process a limited amount of information. They are motivated by their own beliefs and can experience the so-called "devil shift". This is the belief that your opponent has more resources and is more powerful than you are. The belief system of the actors within the ACF is characterised in three parts (Sotirov and Memmler, 2012). The first and highest tier of this belief system is composed of

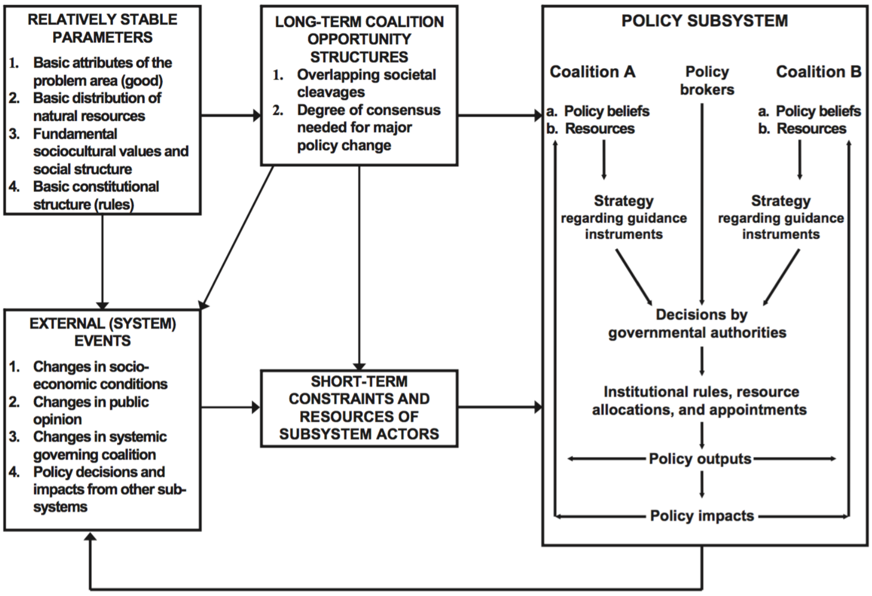

Figure 2.2: The 2007 advocacy coalition framework diagram, Weible et al. (2009).

the deep core beliefs. These beliefs are normative and ontological axioms. They are beliefs that will change only over very long periods of time if at all. The core beliefs are not specific and therefore apply to all policy subsystems. The second tier is composed of the policy core beliefs. These are beliefs that the actors have on specific policy subsystems. These are more likely to be swayed during argumentation with other actors or coalitions. Finally, the third tier beliefs are the secondary beliefs. These are more detailed and only focus on specific details of the policy subsystem. These can easily change depending on the desired outcome for the policy.

As mentioned earlier, the actors are placed together in coalitions within the policy subsystems. Decision for policy change are made between these coalitions. Several assumptions are provided by Sabatier and Jenkins-Smith (1993) about these coalitions. First, when a major controversy occurs, the lineup of allies and opponents tends to be rather stable over a decade or so. Second, the actors within a coalition will show substantial consensus on issues pertaining to the policy core, although less so on secondary aspects. Third, an actor (or coalition) will give up secondary aspects of its beliefs before acknowledging weaknesses in the policy core. Fourth, within a coalition, administrative agencies will usually advocate more moderate positions than their interest group allies. The fifth and final hypotheses states that actors within purposive groups are more constrained in their expression beliefs and policy positions than actors from material groups. Note that each of these hypotheses have been validated to different degrees (Sabatier and Jenkins-Smith, 1993).

Within the ACF, the actors might want to initiate change in the policies. This is usually done following four paths: external events, internal subsystem events, through negotiated agreements and policy-oriented learning. External events can be shocks or perturbations that are outside the control of the subsystem participants. They can also be a change in the political environments which will affect the policy subsystem. The internal events are events that occur within the boundaries of the policy subsystem. These are likely to influence the beliefs of the coalitions. For the negotiated agreements, nine prescriptions were defined by Sabatier and Jenkins-Smith (1993) as: a hurting stalemate, broad representation leadership, consensus decision rules, funding, commitment by actors, importance of empirical issues, trust, and a lack of alternative venues.

Policy-learning is one of the reasons for which change could happen. This usually happens incrementally over long periods of time. Policy-oriented learning serves as an enlightenment function for the different coalitions. Six hypotheses were specified for the policy-oriented learning by Sabatier and Jenkins-Smith (1993). First, policy-oriented learning across belief systems is most likely when there is an intermediate level of informed conflict between two coalitions. Second, learning across belief systems is most likely when there exists a forum that is prestigious enough to force professionals from different coalitions to participate and which is dominated by professional norms. Third, quantitative problems are more conducive to learning across belief systems. Fourth, problems involving natural systems are more conducive to policy-oriented learning across belief systems than those involved purely social or political systems because, in the former, many of the critical variables are not themselves active strategists and because controlled experimentation is more feasible. The fifth and final hypotheses states that even when the accumulation of technical information does not change the views of the opposing coalition, it can have important impacts on policy by altering the view of the policy brokers.

Heikkila and Gerlak (2013) also details the different phases of the policy learning process: acquisition, translation and dissemination. In the acquisition phase, the actor will attempt to gain knowledge about a specific policy. The actor will look for opportunity from its environment and seek information from other actors through group dialogue both formal or informal. During the translation phase, the actor will evaluate the knowledge he has gained and search for more internal information. In a way, this is the part where the actor interprets the information gained from the outside. Finally, in the dissemination phase, the actor will actively seek to disseminate the information gained. Heikkila and Gerlak (2013) mentions several two main products of policy learning: cognitive changes (of the beliefs of the actor) and behaviour changes related to changes in strategies or policies. Several aspect affect this policy learning. They are the structure of the network in which the actors operate, the nature of the connections that the actor has with other actors (social dynamics) and the level of technicality of the field in which this learning occurs. As mentioned previously, external factors can also have a serious impact on the learning process.

The ACF is widely used for case studies. An example of the ACF is used in a study of the changes in swimming and track and field athletics in the United Kingdom and in Canada (Green and Houlihan, 2004). The ACF helped understand the dynamics at play in the two countries and how it resulted in the observed differences. Case studies were also used to adjust the framework as a whole as shown in Leifeld (2013). In this case, the study was about German pensions. This study looked into the polarisation of the parties involved in a coalition leading to its split.

The ACF remains a framework that is being continuously researched on. Several of the hypotheses and the assumptions are not yet fully validated. This is due both because of time but also because some of these hypotheses are hard to effectively validate. The theory is currently reevaluated as shown in Gupta (2012), Ingold (2011), Sotirov and Memmler (2012), Witting (2012) and Weible et al. (2009). These different papers attempted to validate some of the hypotheses and assumptions made by Sabatier and Jenkins-Smith (1993). For this, they surveyed dozens of publications. They made some changes to the original hypotheses and assumptions based on these surveys. However, there still remains hypotheses that cannot or have not been validated maintaining the advocacy coalition framework as a work in progress.

2.4. The Diffusion Theory

According to Stokes Berry and Berry (1999), there are two ways that a policy can change. It can either change because of internal determinants or it can change because of diffusion. Internal determinants related to the fact that innovation is driven by the government due to political, economical or social factors.

The diffusion theory assumes that innovation and policies can be communicated through certain channels over time. This diffusion is usually studied when it happens between different governmental entities. Diffusion happens if the probability of adoption of a policy by one government is influenced by the policy choices of another government. Five mechanisms of diffusion have been identified in the literature.

The first mechanism is the learning mechanism. It is fairly similar to the policy-oriented learning presented in the ACF in the previous section. Government A will derive information about the effectiveness of a certain policy from government B. If they consider this policy to have been successful enough, they might decide to apply it for themselves.

The second mechanism is imitation. In this case, government A simply imitates the policy of government B. This happens because government A feels that the policy is worthy of adoption. The third mechanism is normative pressure. In this case, government A will adopt a policy from government B due to normative pressure. This can be because it sees that this specific policy is applied by a lot of other governments and they share the same normative values. This makes the policy interesting and worth looking into.

The fourth mechanism is competition. In this case, there might be a competition between two governments. One government might want to get an edge on the other and will implement a policy to get that edge. Two types of competition mechanisms are observed in literature: location-choice and spillover-induced competition. For location-choice competition, the government attempts to change the location of individuals who could go in any jurisdiction. In spillover-induced competition, the government adopts a policy in such a way that another governments policy's benefits are reduced.

The fifth and final mechanism of diffusion mentioned by Stokes Berry and Berry (1999) is coercion. This is a mechanism that occurs when a government forces a policy onto another. This can happen in the context of conflicts when a government will push the other to adopt a policy that might favour it for example.

Several methods have been devised to attempt to simulate these diffusions mechanisms (Stokes Berry and Berry, 1999). The first of which is called the national interaction model. This model simulates an entire society to see the spread of innovation through diffusion between the agents. Another is the regional diffusion model. In this model, the assumption is that the governments are influenced by other governments with which they share a border. In later versions of this model, this assumption was changed to include proximate governments also. The leader-laggard model is another model. In this model, the governments are classified in two main categories: the leaders and the lagers. The leaders are governments which are first to innovate while the lagers are governments that follow the leaders. Diffusion is then used to model the acquisition of the innovation between the leaders and the lagers. An important problem related to this model is that it is very difficult to validate as it is not always easy to fine which government is leading and which is lagging.

Diffusion of innovation is not only related to the concepts mentioned previously (Stokes Berry and Berry, 1999). Additional parameters need to be taken into account when modelling this theory. A special importance should be placed on the resources both economical and political. Certain policies might be pushed by entrepreneurs which little economical resources but with plenty of political one.

The diffusion theory has been used a lot in the United States to describe the state lotteries as shown in Caudill et al. (1995). It has also been used to describe interstate competition in Berry and Baybeck (2005). Case studies present in the United States provide for good examples as diffusion is more likely to occur between states. The states tend to share similar norms so it easier to adapt policies from neighbouring states. This theory has also been applied to Indian states as shown in Bussell (2010) with the study of policies related to communication technologies. Once again this theory applies well to large federal countries as their states tend to share some of their norms and values making policy diffusion more acceptable.

Finally, one of the flaws of this theory is that it tends to consider policies as single entities. This is however most of the time not the case. Policies are composed of different components that can sometimes be split. Not all components have to be adopted by a new government. The government can choose to adopt one part of the policy or none of it. This is not well reflected within the diffusion theory which tends to consider the policies as a whole.

2.5. The Policy Entrepreneurship Models

The concept of policy entrepreneur is widely encompassing and recurrent within the four theories presented. Several models have been developed to describe the actions of the policy entrepreneurs within the policymaking arena. Mintrom and Norman (2009) presents five such models. Mintrom and Norman also state that policy entrepreneurs within each of these models share specific elements. The first element mentioned is the display of social acuity. This display of social acuity is channeled in two ways: making good use of the policy network and understanding other actors in the model. The second element relates to the definition of problems. Policy entrepreneurs have to be interested with how problems are defined if they are to achieve any change in policies. The third element states that policy entrepreneurs have to be ready to build teams. This allows them to show that they have a certain level of support for their interests. The final element is the fact that policy entrepreneurs have to lead by example. By this, it is meant that policy entrepreneurs should attempt to reduce the perception of risk for other actors. This can be done through the use of pilot projects for example. Note that this might not be feasible for all topics.

Mintrom and Norman (2009) shows that these elements apply to the five models presented earlier on in the introduction. Some of most of these elements are mentioned in the different policymaking models in the literature. There is a special interest in two policymaking models regarding this thesis. These are the three streams and the advocacy coalition framework models. Each contains the presence of policy entrepreneurs but approached in a different way. Mintrom and Vergari (1996) compares the two approaches. There are some important differences between how the policy entrepreneurs are approached in both models. The first difference relates to the scope of the policy entrepreneur models. The advocacy coalition is a system that consider the entire policymaking community. The three streams approach is narrower as it considers only how policy entrepreneurs promote their ideas to the policy makers. The time-frame is also very different between both approaches. The advocacy coalition clearly considers long periods of time (several decades) where the policy entrepreneur beliefs vary slowly. The policy entrepreneurship considers much shorter spans of time where change happens quickly to grasp opportunities. Although these two approaches have differences, case studies show that both approaches can be used to study specific examples. This is done in Mintrom and Vergari (1996) where the education reform in Michigan is analysed using both approaches. Brouwer et al. (2011) shows a similar result but for the case of Dutch water management.

3
Complex System Modelling

3.1. Large Scale Socio-Technical Systems

3.2. Agent Based Models

Agent-based models (ABM) are a type of modelling method that uses autonomous agents. The agents used in ABM are independent agents that can take their own decisions. The agents' decisions are governed by simple rules and are backward looking. Each of the agents can assess the situation and communicate with the other agents present in the model, (Bonabeau, 2002; Macy and Willer, 2002; van Dam et al., 2012). The models are usually iterated in ticks. A tick represents a time t at which the agents can communicate with each other and perform all their actions. Once this is done, the model moves to the next tick. The time representation of the tick can be different in every model. In some model, a tick can represent five years of time while in others it can represent only a few seconds (Siebers et al., 2010).

Agent based models are used in a wide range of disciplines and for a wide range of topics (Helbing, 2012). These range from socio-economic to collective intelligence models while considering urban and regional development or coalition formation. Prior to ABM, modelling and simulation were rare in the domain of social and economic sciences. Having the ability to be used as a qualitative method, ABM can be used to model system in these domains, (Helbing, 2012; Macy and Willer, 2002).

There are several advantage to the use of ABM, (Bonabeau, 2002; Brailsford, 2014; Helbing, 2012). Agent-based models can help capture emergent phenomena. This is the result of the actions of the different agents. The collective results are different than the individual actions of the agents. These emergent phenomena are counter-intuitive. This makes them hard to model and it is one of the reason ABM is preferred in such cases. An example of an emergent phenomena is herd behaviour. The actions of different agents can, after some time, end up coordinating. In effect, the system is more than the sum of its parts (Helbing, 2012).

The second advantage of ABM is the fact that it can help provide a natural description of the system. In a lot of cases, ABM will seem to relate reality to the model more directly. This can be due to the fact that in the real world, humans are the ones making the decisions. Similarly, in an ABM model, it is agents that are making the decisions. Furthermore, other modelling methods will tend to use aggregate parameters which can be abstract and unrepresentative of reality. This goes further when once considers the visualisation that accompany ABMs. These can help the model and the results appear more believable.

The third advantage of ABM models is that they are flexible. The models being built can be modified fairly easily. The level of aggregation of the level can therefore be played with during the conceptualisation of the model. The flexibility of these models can also be related to the fact that it is easy to add or remove agents from the models.

There are also disadvantages to using agent based models, (Bonabeau, 2002; Helbing, 2012). These simulations remain models with all the disadvantages that accompany such models. The design and construction of such a model will depend on the person making the model. The right level of detail and aggregation needs to be pursued to obtain valid results. This is more an art than a science.

A second problem relates to the fact that these models tend to attempt to model humans. Humans cannot be modelled perfectly. Only limited part of their decision making process can be modelling in such models. This can affect the degree of accuracy of the results from the model. One should also be wary of the models built and the way their results can be interpreted. In some cases, it is more important to look at the results qualitatively while in others, it can be important to look at the results quantitatively.

Although ABM can be an appropriate method for certain models, the nature of the models will lead to large computing time. Because the ABM is modelling agents and each agents has to go through its rules for each tick, the computational efficiency of ABM can be low and the model run times can be long.

Finally, despite appearances agent based models are not meant to be used for prediction purposes. Instead, they are designed to help the modeller provide an explanation on the system being modelled or to provide additional understanding in the phenomenon being modelled, Sanchez and Lucas (2002).

There are examples of the use of agent based modelling for the emergence of policies in the literature. Once of which is the MAIA framework developed by Ghorbani et al. (2013). However, the model developed for this framework based on based on institutional analysis theory. This model does provide a clear approach on the design of the model.

3.3. Agent Based Models and Policy Analysis

4

Reflection

[A chapter reflecting on the different theories and ABM. This chapter will connect the first part of this thesis to the second.]

II

The Model

5

The Conceptualisation

This chapter aims at providing a complete overview at the conceptualisation that is realised from the policy making theories. This conceptualisation is used to formulate the different policy making theories into one common language that can later be used for formalise an agent based model. The chapter starts with the overall approach that is used to conceptualise this model. It details the different parts of the model that are used to represent the different policymaking theories. This is done in section 5.1. Details are then provided on the different actors in section 5.2. This section details the actors' attributes and actions. Finally, the external events are detailed in section 5.3.

5.1. Overall Model Approach

The conceptualisation approach is split into three main parts. First, the backbone is devised. This is the smallest possible model conceptualised that can still simulate the emergence of policies. It contains only a limited number of concepts found within the different theories. The second part consists of conceptualising the theories themselves. This is done in such a way that they can fit on the backbone. The aim is also to make this process modular, meaning that the modeller using this model should be able to use each of one of the theories on their own for research purposes. The modeller should be able to look at the three streams theory or the advocacy coalition. Additionally, (s)he should be able to add the feedback or/and the diffusion theory to both theories.

The approach taken for this conceptualisation is a cyclical approach which is preferred for an agent based model. This cycle can be split into two parts: the technical model and the policy emergence model. The technical model is a simulation of the system that is related to the policy emergence model. For example, in a policy emergence model related to health policies, the technical model could be a simulation of the health industry. Figure 5.1 illustrates this explanation. Overall this cycle can be approached in a similar method as a simplified policy cycle. The policy cycle is usually mentioned with the following steps: agenda setting process, the formulation of the policy, the implementation of the policy and the review of the policy Hill and Varone (2016); Hogwood et al. (1984); Lester and Stewart (2000); Palumbo and Calista (1987); Stewart Jr et al. (2007). The approach taken here consolidates some of these steps. The policy emergence model is the part where the agenda is set and the policy formulated. The technical model is associated with the implementation

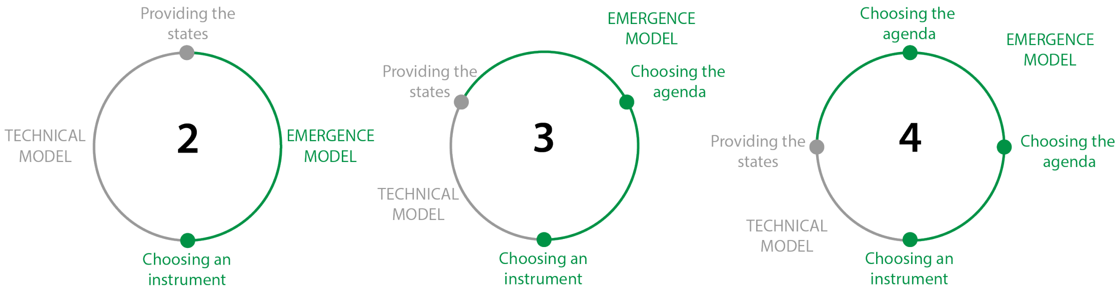

Figure 5.1: Policy process cycle as presented in the conceptualisation for a 2, 3 and 4-step cycle. In grey are the processes performed by the technical model, in green are the processes performed by the policy emergence model.

and review of the policies. These are considered out of the scope of this thesis and are not included in this conceptualisation.

The approach selected here is a modular approach that allows for the use of different levels of aggregation of the system considered by the author within the policy emergence model. The approach is outlined in Figure 5.1. For all variation of the model, the technical model is always the model that produces a number of inputs, called states, which define the current state of the world to the policy emergence model. The policy emergence model uses these states to produce a certain policy instrument. This policy instrument is chosen by the actors present in the model. In a 2-step model, the policy emergence model is only one step long. The actors just decide on a policy instrument that will need to be implemented in the technical model to solve the perceived problems. If the actors agree on an instrument, that instrument is implemented in the technical model. If not, the technical model runs without a new instrument in the next cycle.

Using this approach, it is also possible for the modeller to add steps to the policy emergence model if needed. A 3-step model can therefore be considered. In the first step of the policy emergence level, the actors first decide on what will be on the agenda. Once they have chosen the agenda, the actors choose an instrument that relates to what is on the agenda in the second step. This step happens at a lower level of aggregation. This allows more depth to the emergence process. This can be furthered by adding another step to obtain a 4-step model. In this case, in the first step of the technical model, the actors have to specify a first agenda. Having this first agenda, they can limit their number of issues considered for the next phase to the issues related to their obtained first agenda. A second agenda is then formulated based on the issues they can consider. In the third and last step, they choose an instrument based on the second agenda constructed. This approach can be extended to n amount of steps but it only increases the number of levels considered and hence the complexity of the model.

For the remainder of this report, the 3-step model is considered. The first step of the policy emergence model is called the agenda setting process while the second step is called the policy formulation process. The third step is the technical model. From now on, all models will assume this 3-step model except if otherwise stated. With this 3-step model, it is assumed that the models constructed are already at the subsystem level according to the ACF definition (Jenkins-Smith et al., 2014; McCool, 1998). This has for consequences that all actors that are included within the model have an interest in the issues being addressed. In turn, this leads to the fact that every actors can be part of a group throughout the model when the three streams theory or the ACF are being used. Note that the boundaries of the subsystem are not strict. The modeller can decide to introduce new actors or remove actors that are no longer participating in the system being simulated. This would be done through an external event.

Before the full model approach is presented, it is also important to introduce the belief tree. This belief tree is what constitutes the brain of the different actors present in the model. It is an attributed that all actors have and which is used to define their belief on the different issues. The belief tree structure is based on the three layered system that is used to describe the actor's belief in Jenkins-Smith et al. (2014). The number of layers is dependent on the number of levels that are considered by the modeller. In a 2-step model, the belief tree would only have two layers while in a 4-step model, it would require four. The reasoning behind this will become apparent throughout this section.

The representation of the tree that is used within this conceptualisation is shown in Figure 5.2. The top layer represent the principle beliefs of the actor. These are beliefs that are meant to only change over long periods of time and are unlikely to be affected by day to day problems. The second layer represents the policy core beliefs of the actor which are easier to change over time. As defined in Jenkins-Smith et al. (2014), the policy core beliefs "are bound by scope and topic" to the system considered. Finally, the third and bottom layer of the belief tree represents the secondary beliefs of the actors. The secondary beliefs tend to be associated with detailed issues for which the actors are more likely to change their minds over short periods of time. Secondary beliefs are the lowest beliefs in the tree. They are the beliefs on which policy instrument will directly act when being impelemented. The same belief tree structure is used for all actors. The difference between the actors is the values associated to the different issues present in the tree.

To further this explanation, if the modeller were to choose a 4-step model, then three would be composed of four layers as mentioned earlier. The highest beliefs in the tree would remain principle beliefs. The second level could be called the policy core beliefs 1 and the third level policy core beliefs 2. The lowest level would remain filled with secondary beliefs, as by definition, these are the beliefs that are impacted directly by a policy instrument. The two policy core levels would be at a different level.

Note that depending on the level of aggregation chosen by the modeller for the system, the deep core beliefs as highlighted in the literature Jenkins-Smith et al. (2014) could possible match with the principle beliefs. This shoud highlight the flexibility of the approach chosen but also the need for the modeller to choose the tree and its corresponding structure coherently with the system studied.

Within the conceptualisation, these different belief layers are associated to specific parts of the model. The principle beliefs are associated to what is called principle issues. These are very high level issues that the actors must consider. They are for example, and this will depend on the model considered, the economy, security or the environment. The policy core beliefs are associated to policy core issues. These are intermediate descriptions of the system which outline large swath of the model but a level lower than wide ranging issues used for principle issues. Finally, the third layer is composed of the secondary issues. These are very low and detailed issue that can be considered to be the parts of the model. In the case of public transportation, this could be the use of a metro or the use of car infrastructure. Secondary issues are the ones on which policy instruments will act. It is therefore important that the secondary issues be modifiable through these instruments. Following

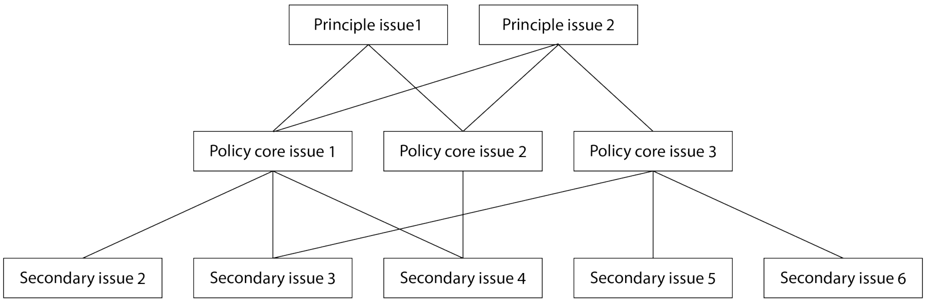

Figure 5.2: Conceptual representation of the belief system tree hierarchy. Note that not all possible causal relations are illustrated.

the example, there could be an instrument to encourage increased metro ridership or an instrument to encourage the use of personal vehicles to travel. The first instrument would boost the first secondary issue while the other instrument would boost the other issue.

Another concept that is added to the belief tree is the concept of causal relations. Actors will have a certain perception on how specific issues on the different layers of the belief tree affect other issues on other layers. These causal relations are only present between issues of differing layers as shown in Figure 5.2. These are based uniquely on perception of the actors and might not exist in the real life. This represents the perception of the actors on how the world works. These causal relations are crucial for the actions that the actors can perform and this illustrated in a subsequent section.

Each of the issues included in this tree will ultimately be associated with three parameters for each actor. The first one is the state of the issue. This describes the perception of the actor for the current state of that issue. For each actor, these states are obtained through actors that have a direct access to the unfiltered states of the world calculated during the technical model simulation. Each actor's perception of these states will therefore be affected by their personal policy network. The second relates to the aim of the actor. This aim defines what the actor is looking to achieve with respect to that specific issue. It represents what the actor would like the states of an issue to be at to be satisfied with the situation. Finally, a preference percentage is associated with each issue. This preference percentage is calculated on a layer per layer basis in the belief tree and is dependent on the gap between issue state and issue aim, and the causal relation which define which issue affect which other issue. It is the parameter that will tell the actor which issue to advocate for to other actors.

It is important to understand that the structure and the level of the analysis chosen for the belief tree are entirely decided by the modeller. The modeller must include in the belief tree structure only issues that (s)he believes are relevant to the case and can are important for the actors to have a belief on. Furthermore, the modeller must consider the level of aggregation at which (s)he is interested in working at. Very low level of aggregation models will lead to secondary issues being very detailed issues. This could for example lead to the choice between different types of trees in a model related to the tackling of air pollution. This is opposed to a model set at a higher level of aggregation where the secondary issues will only relate to the the choice between a park or the addition of cycling paths to tackle air pollution.

The use of the belief tree is the principle vector of policy learning within the model. It can be used to address the concept of policy learning in the literature (Hall, 1993; Hoberg, 1996; Howlett and Ramesh, 2002; Meijerink, 2008).

The rest of this section is dedicated to the approach taken for the different policy making theories. First the backbone is presented. This is the smallest model possible considering the policy emergence process. Then the policies themselves are each presented. Finally, an optional concept is mentioned. This concept can be added to the ACF.

5.1.1. The backbone

The backbone model is the smallest policy emergence model possible. It is not based on any policymaking theory in particular but does include specific concepts from some of these theories. The aim with the backbone model is to have the process of policy emergence with the smallest number of actor types and interactions possible while setting the infrastructure for the other policy making theory components. For this reason, only a few concepts are being considered. Only three types of actors are selected: policy makers as they are the only actors with decision making power, external parties and the electorate. Only one external party is considered. This external party is the only link between the technical model and the policy emergence model. Within the backbone model, the interaction between the actors are limited to passive interactions. This is the case for the influence of the electorate on the policy makers where no direct interactions between the electorate and the policy makers are required to lead to changes in the beliefs of the policy makers. The different steps are now explained.

The first step is to update the policy makers with the current states of the world. This happens before the agenda setting process. The external party, a concept detailed later, acts as the media, government agencies or research institutes with access to data about the technical system under review. It can therefore provides the states of the world from the technical model to the policy makers without distortion. The external party also provides the states to the electorate. The policy makers are then passively influenced by the electorate based on the electorates' beliefs. This action has for effect to pressure the beliefs of the policy makers into having similar beliefs as their respective electorate.

Then the agenda setting process starts. Each policy maker chooses an issue that they believe is most important within the policy core beliefs. This choice is made based on the preferences associated with each of the issues in their belief tree. Using the policy makers choices, one issue is chosen for the entire system. This issue is chosen as the one being the most widely accepted amongst all policy makers. This issue is the agenda. Note that within the backbone model, there are no actor interactions.

During the policy formulation process, the policy makers are again the only actors present. Each policy maker chooses one policy instrument which they deem best to impact their secondary beliefs based on the issue that is on the agenda. Then the policy instrument that most of the policy makers find adequate is selected system wide. This is again obtained through the calculation of the preferences of all instruments. If this policy instrument is chosen by enough policy makers based on a predefined decision rule, it will be implemented in the technical model. This marks one cycle of the backbone model. In the next cycle and once the technical model has run with the implemented instrument, the states are once again communicated to the external party which conveys them to the policy makers and electorate. It continues then as explained.

All policy instruments present in the model are specified prior to the simulation by the modeller. The modeller can decide what effect each of these instruments will have on the issues in the belief tree according to the technical model used. The perception of the effect from the actors can however be widely different depending on their affiliations and the way they garner their information. The policy instruments specified can have an impact on different secondary issues at the same time. Note that, at the beginning of the model, not all the policy instruments need to be known by all actors. Some can remain hidden from the actors until they are either considered to be discovered (think of technological progress) or they are introduced to the actors through diffusion-like processes.

5.1.2. Policymaking theory modules

To better represent the different policy emergence theories outlined in the literature, different policymaking theories can be added to the backbone model. The theories considered are the three streams theory, the advocacy coalition framework (ACF), the feedback theory and the diffusion theory (Jenkins-Smith et al., 2014; Mettler and SoRelle, 2014; Stokes Berry and Berry, 1999; Zahariadis, 2014). These theories are designed in a modular way. Each theory can be used alone if required for the research of the modeller. The three streams theory and the advocacy coalition framework can never be used at the same time for consistency. However, the feedback theory and diffusion can both be used at the same time and in combination with either the three streams theory or the ACF. The diffusion theory is a theory that affects the super-system while the feedback theory affects what happens within one system. This is detailed in this section.

Before each of these theories can be introduced, it is important to introduce several concepts that are recurrent in all four theories: the policy entrepreneurs, the policy network, the affiliation network and the super-policy network (Brouwer et al., 2011; Ingold, 2011; Mintrom and Norman, 2009; Mintrom and Vergari, 1996). Policy entrepreneurs are a new type of actor that is added to the model. They are meant to represent lobbyists and activists. The aim of entrepreneurs within a policy emergence context is to influence the beliefs of the policy makers in the entrepreneurs' interests. The actions performed by the entrepreneurs and the way these entrepreneurs behave depend on the theories considered. Additionally to the entrepreneurs each of the policymaking model contains several different external parties. These external parties reflect the media but also research institutions or/and governmental agencies. These external parties have access to the unfiltered states from the world. This is not the case for the policy makers and policy entrepreneurs. They gather their view of the world (states) based on different external parties and their affiliations to these external parties. Although external parties have direct access to the states of the world, depending on their interest in the issues present in the technical model, entrepreneurs will only gather specific issues' states and while ignoring others.

The policy network, shown in Figure 5.3, is the network that spans the entire model and that connects the policy makers, the policy entrepreneurs and the external parties. This network is composed of undirected links representing the level of awareness that actors have of one another. This network affects the actions that the actors can perform and the impact of these actions. This network can also be used to represent the lack of connection between different actors. In some cases, actors are not aware of other actors present in the network or simply do not have any connection to them. The network links also require active maintenance from the part of the actors. This means that actors not engaging with each other will see their mutual awareness diminish over time. The policy network also

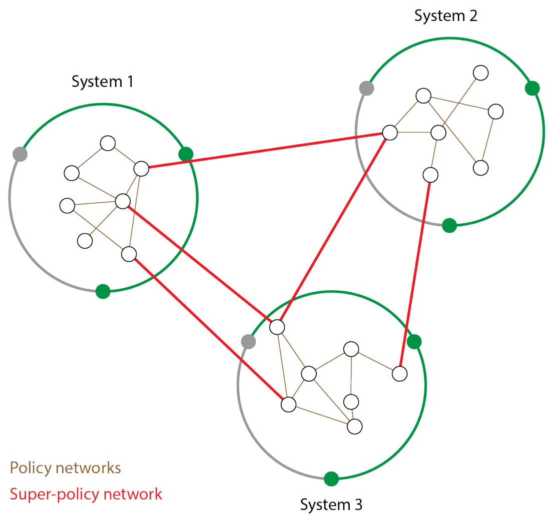

Figure 5.3: Illustration of the policy network and super-policy network for a three systems each using 3-step models.

introduces the conflict level aspect between the different actors on specific issues (Jenkins-Smith et al., 2014). The conflict level influences whether actors are likely to speak to each other. Three levels of conflict levels are identified for each issue between each actor: low, average and high.

Added to this policy network is the concept of the affiliation network. The affiliation network is a higher level network that connects the actors based on their political affiliations. This network also affects the actions of the actors and helps represents different families of actors which share similar beliefs on the world. For example, actors not sharing the same affiliation can be made to interact less with one another.

Finally, the super-policy network concept is included. This is a mirror of the policy network but at the system level. It connects agents present in different systems. This network is only used in the diffusion theory when different systems can influence each other. This super-policy network is illustrated in Figure 5.3. The super-policy networks connects actors in different systems in the same way the policy network connects different actors within one system. It can for example be populated with systems representing major cities around the world. Each of these systems has its own policy emergence process which can be influenced by other systems through diffusion mechanisms.

The super-policy network is composed of directed links. They are four types of directed links: friendly, dominant, competitive and coercive. The size of the network is sparser than the policy network with a larger proportion of inactive links. Furthermore, as is shown in Gray (1973); Walker (1969), geography is an important factor when considering diffusion mechanisms. The links of the super-policy network therefore have an additional attribute which is the distance between the two actors geographically. This distance will affect the impact of any of their actions. Distant actors being part of two distant systems will have a much lower impact on each other than actors present in close-by systems. This distance attribute can be temporarily changed when external events such as Mayor's conference brings actors to the same geographical location, increasing the potential for impactful actions.

The three streams theory Using the different concepts presented above and present within the backbone model, it is possible to conceptualise a model that represents the three streams theory (Kingdon, 2003; Zahariadis, 2007). In three streams theory, the agenda settiing and policy formulation processes are more complex than the mechanics outlined for the backbone. The agenda can no longer be only composed of only an issue and the policy formulation can no longer look only at an instrument. The new approach must considers the three streams: politics, policy and problem. For this, the actors must first be allowed to choose between a policy or a problem in both steps. Once their first choice is obtained, they can look for the associated problem or policy. To allow such choice, several elements have to be modified or added to the model. First, the issues present in the belief tree are qualified as problems within the three streams approach. Second, a set of policies is added to the agenda setting step. These are devised by the modeller. These policies are conceptualised in a similar way to the belief tree. Each policy has a certain impact on specific issues at the same level of aggregation (the policy core issues) in the belief tree. Based on this impact, a preference can be set by the actor. The impact is subjective and will vary for each actor. This impact belief can also be influenced by other actors. A similar structure is established at the policy formulation step. The instruments are similar to the policies with subjective impacts. The problems are now the secondary issues in the belief tree. The instruments that can be chosen are limited to the instruments which are related to the policy on the agenda. These parent-children relations between policies and instruments are defined by the modeller and are not subjective.

This approach attempts to imitate the streams approach. The agents will choose whatever they find most pertinent between the policies and problems. The pertinence is defined based on calculated preferences. If they find a policy most pertinent, they will choose that and, de facto, open a policy window. They can then select an associated problem and start influencing other agents based on their selection. This happens both in the agenda setting step and the policy formulation step.

Throughout both steps, actors which have chosen a problem first will be able to influence other actor's beliefs on that problem. Actors that have chosen a policy first will influence other's actors belief on that policy. The actors interacting here are the so-called action actors which are the policy makers, the policy entrepreneurs and the external parties. There respective sets of actions are slightly different. This is detailed later on in this chapter. In the agenda setting process, once all these actions have been performed and similarly to the backbone, the policy and the problem that received the most interest amongst policy makers are placed on the agenda. For the policy formulation, once again each actors picks up a problem and an instrument related to the ones that have been chosen during the agenda setting stage, but at a finer resolution (lower level of abstraction). They can then interact to influence each other's belief. At the end of this round of interaction, the policy makers decide if an instrument can be implemented. This happens if the threshold to implementation has been reached amongst the policy makers.

Added to the individual actions and as mentioned in the literature, the actors present in the three streams theory can build teams (Brouwer et al., 2011; Mintrom and Norman, 2009). These teams are groups of actors of similar beliefs assembled to better influence other actors. These teams are short lived groups that can be a mix of policy makers, policy entrepreneurs and external parties. They are created with different actors that have a similar goal regarding a specific issue. If their attempt to convince other actors fail, then the groups will disperse. This approach represents the relatively short lived teams that come together to pass or block a specific bill or executive order for example.

The advocacy coalition framework The steps used within the ACF model are closely related to the ones in the backbone. The actors considered are similar to the three streams theory: the policy makers, the policy entrepreneurs and the external parties. The states of all the actors are updated at the beginning of the model. Based on these states and on their respective aims, each of the actors can calculate their preferences for the issues in their respective belief trees. Each actor selects to advocate for the issue (s)he most prefers. For the agenda setting, they can then influence each other. At the end of this round of interaction, the policy makers select the agenda based on the issue that has been most selected. For the policy formulation, similarly to the backbone, each actor assigns a preference to an instrument based on the issue on the agenda and his/her own beliefs. After a round of interaction, the policy makers decide whether a policy instrument can be implemented or not.

However, there is a major addition compared to the backbone model for the ACF: coalitions. Besides individual interactions, the actors are also placed into coalitions (Mintrom and Vergari, 1996). Within the ACF, the actors do not group into teams but instead are grouped into coalitions. Coalitions are long-term entities to which actors are added based on their principle beliefs for the agenda setting and policy core beliefs for the policy formulation. Due to the nature and inertia of these higher level beliefs, these coalitions are very stable and only vary over long periods of time. Within the model, actors are added by default to coalitions with which they have most similar principle beliefs. The actions they then perform are influenced by the coalition in which they are. Furthermore, and because these coalitions are more stable, the policies and problem they advocate for coalition-wide might be different than the ones they would advocate for on a personal level. Note that the coalitions might be different in the agenda setting and the policy formulation processes.

The feedback theory The feedback theory model acts on a different part of the model than both the three streams and the ACF models. Each policy instrument introduced by the modeller can be associated with a specific feedback effect that will have an effect on the structure of the model. These effects are not necessarily known to the actors when they make their choice for a policy instrument. Once a policy instrument has been decided on and is implemented, then the effect is introduced in the model in the next tick or over a predefined period of time. Such effect can lead to a change in the provided resources for specific actors or the removal of certain issues from the decision making power of the actors present in the model. The different categories of effects are presented in Mettler and SoRelle (2014). This feedback model can be turned on and off by the modeller for experimental purposes. Note that without the three streams and the ACF models, the impact of the feedback model will be limited as only a very limited number of actors are present in the backbone model.

Three feedback effects are conceptualised: the meaning of citizenship, the power of groups, and the political agendas and the definition of the policy agenda. According to Mettler and SoRelle (2014), the meaning of citizenship feedback effect affects the number of people in some of the sectors of the electorate. The impact of a policy instrument with such a feedback will therefore be a change in the composition of the electorate. The expectation is that will have an impact on the influence that the electorate has on certain policy makers and an impact on the distribution of resources to the actors. The power of groups feedback process is one that affects the policy entrepreneurs. Depending on their affiliation, which is in this case related to the implemented policy, the policy entrepreneurs will have a rise of decrease in the resources their receive throughout the policy emergence process. The exact value and which policy entrepreneurs are impacted the most can be specified by the modeller within the feedback effect of the policy instrument. The political agenda and the definition of the policy agenda feedback mechanism affects what is considered to be within the public realm or the private realm, Mettler and SoRelle (2014). Conceptually, if a specific policy instrument has for effect to privatise elements of the system, then some policies and/or problems will have to be removed from the model. The opposite is also true. This feedback effect therefore affects what policies and problems can be considered within the scope of the model.

Diffusion theory The diffusion theory is an add-on theory that can be added on top of the backbone, the three streams theory or the advocacy coalition framework. It allows to connect different systems together to see whether they have an impact on each other. This is greatly affected by the different links that are present in the super-policy network. The interactions occurring in the diffusion theory happen after the intra-system interactions but before the choice of the agenda for the agenda setting and before the decision on the implementation of an instrument in the policy formulation step. These actions are provided below depending on the link between the agents. They are related to the different diffusion processes outlined in the literature (Stokes Berry and Berry, 1999).

1. Friendly: This type addresses the learning and imitation diffusion mechanisms. Within the context of this type, the actors will behave in the super-policy network similarly to the way they are behaving in the policy network. The actions are similar so as to engage in policy learning.
2. Dominant: This type addresses the normative pressure diffusion mechanism. For this type of diffusion, the actors from system 1 will actively influence the beliefs of actors of system 2. This is done on an issue per issue basis. These actions are more aggressive and different from the friendly actions.
3. Competitive: This type addresses the competitive diffusion mechanism. The competitive type will see a reverse type of action where actors from system 1 will look at actors from system 2 and change their own beliefs on the state of the world. This will have for effect that will attempt to introduce policy instruments related or stronger than the ones implemented in system 2.
4. Coercive: This type addresses the coercion diffusion mechanism. The coercive type is a stronger from of the dominant type where actors will force actors in another system into specific beliefs on specific issues.

The diffusion theory does not mention any possibility of groups as seen in the three streams theory or the ACF. All actions are performed by singular agents. If there is a need for teams or coalitions, it would then be advised to change the level of aggregation of the actors and include them all into one system.

5.1.3. Optional additions

One additional concept is currently considered to be added to the model. Additional concepts could later be added.

The policy broker The policy broker is often mentioned in the literature in relation to the ACF (Ingold, 2011; Ingold and Varone, 2011). Policy brokers are actors which are also policy makers or policy entrepreneurs but which are elevated to the role of broker based on their political resources and the size of their policy network. The policy broker is granted with additional actions that allows him/her to connect actors that have little trust or that did not know existed together. This can allow greater changes in the system. The addition of policy broker can only be done when the ACF model is present in a simulation.

5.2. The actors

There are different actors present within the model as mentioned throughout this chapter. The first actor is the policy maker. The policy maker decides on which policies to implement and can also influence other actors within the model. The second actor being considered which is mentioned within the three streams theory and the advocacy coalition framework is the policy entrepreneur (Jenkins-Smith et al., 2014; Zahariadis, 2014). The policy entrepreneur's main task is to push issues for which (s)he has an interest in. This does not exclude policy makers from being policy entrepreneurs at specific time within the policy process. This is why the policy maker's actions are very similar to the policy entrepreneur actions. The electorate is also considered as a category of actors. Finally, external parties are also introduced. The external parties are composed of all actors that have a direct access to the true states of the world. They help define the political balance and influence policy makers. Similarly to policy makers, the external parties can also be policy entrepreneurs on occasion. They therefore also have similar actions.

5.2.1. The policy entrepeneurs

The policy entrepreneurs represent all actors present in the real world that are not considered to be policy makers or external parties(government agencies or research institutes) and which are involved in the policy emergence process. This category can contains for example lobbyists, non-governmental organisations but also governmental bodies. The attributes and actions of the policy entrepreneurs are presented within this section.

Attributes The policy entrepreneurs have several attributes which are outlined below:

- System: This defines which system the actor is part of. This is only required when the diffusion theory is included.
- Belief tree.
- Affiliation: This represents the political affiliations of the entrepreneurs. Only a limited set of affiliation is present in the model.
- Resources: The amount of resources that a policy entrepreneurs has at its disposition is related to its power. These resources are an aggregate representation of the political resources which the policy entrepreneur might have as well as its financial and human resources that it has available to advocate for a certain issue (Ingold, 2011; Jenkins-Smith et al., 2014; Zahariadis, 2014). The resources are assigned based on

the affiliation of the policy entrepreneur. This is related to the representation of the electorate with the same affiliation. These resource can then be used to interact with other agents. The amount of resources defines the impact these interactions.
- Advocacy: Policy entrepreneurs choose to advocate for a specific issue in the backbone and ACF or for a specific problem/policy combination in the three streams theory. This is for the agenda setting and the policy formulation. These issues are obtained from their respective belief trees.
- Group: Within the three streams approach, the entrepreneur can join a team. Within the ACF, (s)he can join a coalition. If none of these theories are used in that specific simulation, this attribute is not available to the actor. Upon joining a group, the actor will gain a belonging attribute. This attribute is associated to how close in belief the entrepreneur is to the group. It helps define the amount of resources which the actor will provide the group for group actions and the amount that will be retained for individual actions. This belonging is calculated depending on the difference between the state of the actor and the state of the group in general.

Note that power is not a property that is considered within the model. This is because power can be implicitly derived from the amount of resources allocated to the actors and their centrality within the policy network. The definition of power is a topic considered to be a discussion which is outside the scope of this work (Room, 2015).

Actions The policy entrepreneurs can perform several actions. All these actions are detailed below in the order in which they are usually performed for each step. Because actors have a certain number of actions they can perform, a rule was devises to choose which action is selected and when does one actor stop performing additional actions.

Actors have a limited amount of resources which limits the number of actions they can perform. They therefore will stop performing actions once they have run out of resources. Resources are distributed for each step based on the entrepreneurs' affiliations. As for which action they perform, this is dependent on the grade assigned to each action. Each actor will investigate the impact of all actions they can perform on all actors. This impact is based on what they expect is the belief of their fellow actors. After estimation of all possible actions, the actors will go through with the action that is at the top of their list grade wise. It is possible that, due to discrepancies between the expected impact and the real impact, the action have a different impact that the actor had planned. This is due to the partial knowledge which actors have of other actor's beliefs. After performing an action, the actor performing the action and the actor influenced will both gain a certain amount of knowledge one each other's beliefs.

1. Select a issue/problem/policy: Before they can undertake any action, policy entrepreneurs have to decide what to advocate for. In the three streams they choose a policy/problem combination as explained before. In the backbone and ACF, they choose an issue for the agenda setting and an instrument for the policy formulation. These are decided based on the preferences in the belief tree of each actors. These preferences are calculated based on the urgency of an issue.
2. Networking actions: The entrepreneurs can perform networking actions. A small proportion of the resources of the actors assigned each step is dedicated to such actions. These actions are mostly related to the maintenance and growth of their policy network. This is because it is in the interest of the actors to have a developed network.

The strength of the network links is represented as the amount of awareness actors have of other actors in the system (Heikkila and Gerlak, 2013). Actors can only communicate with other actors if their connecting link has an awareness value higher than zero. The actors can spend resources to maintain their links with other actors. They can also spend resources to grow their network with other actors which they are aware of in the network but do not have an active link with. There are two strategies which the actors can use for their networking actions. They can either aim to get the largest network possible or they can focus onto a strong but smaller network. This strategy is specified by the modeller and is static throughout.

(a) Strategy 1: Largest network - Following this strategy, the actor will focus on links with a low level of awareness and reinforce them minimally. Then the actor will look into inactive links to activate them. Then, if resources are left, the actor will strengthen the active links (s)he already has.

(b) Strategy 2: Focused network - Following this strategy, the actor will focus on reinforcing links with an average or lower level of awareness and reinforce them strongly. Only if all active links are strong will the actor look into extending the network with the activation of inactive links.

3. Individual actions:

   (a) Individual Framing: The action of framing can be performed by entrepreneurs that wish to influence the way other actors understand the world. This is done by influencing the way actors understand causal relations in the belief tree of other actors. The action of framing can be done on all actors at once (blanket framing, representing political ads for example, or any other means of addressing the entire political sphere) or on specifically chosen actors representing, for example, a meeting with an elected official, or a concreted effort to affect them specifically (for example encouraging people to call their representative's office). The efficiency of this framing action is dependent on the awareness level between the two actors, the amount of resources spent and the different in belief between the two agents.

   (b) Influence on aim and state parameters: Similarly to framing, the entrepreneurs can also influence the beliefs on the issues of other actors. This is done in a similar way. However, now it is the perception of the world that can be influenced (the state of an issue) or the aim that the actor has for a specific issue. This is again dependent on the awareness that the two actors have for each other, the resources spent but also on the conflict level that these two actors perceive they have on a specific issue and their different in belief. The conflict level is calculated as the perceived difference in the aim of two actors. If this difference is high, the conflict level will be qualified as high. If it is negligible, the conflict level will be qualified as low. The influence of an actor over another will be different depending on the conflict level. As explained in Jenkins-Smith et al. (2014), high and average conflict levels will encourage actors to engage while low conflict levels will not.

4. Team actions (within the context of the three streams theory): To increase their influencing power, the entrepreneurs will attempt to build or join teams. There are therefore several actions that are related to teams. When in a team, the team is assigned a network of its own. This network is made of all links between actors in the

team and actors outside of it already existing. The awareness chosen is the highest awareness amongst all possible links that actors had with actors outside of the team. Note that teams as entities have an amount of resources, a team leader, a number of team members, an issue and an issue type. The resources are obtained based on the actors present in the team and their level of belonging to the team.

(a) Joining a team: Before starting a team, an agent can check whether he can join a team. The conditions for joining a team is whether (s)he has similar beliefs with the current issue being advocated for by the team and a large aim-state gap for this same issue.

(b) Starting a team: To start a team, an entrepreneur will look around for other actors. Performing that action will cost a small amount of resources. The actor will look for agents that have a large aim-state gap and which share his belief on the issue he is advocating. Once the entrepreneur is confident that enough actors match that requirement, he will formally ask them to join his/her team. When doing so, the agent might find out that his beliefs of other agent's belief was wrong. If that is the case, the team will not be started. Only partial knowledge will be exchanged between the actors. There are two possibility when creasing a team:

   i. Method 1: The similar beliefs are relatively wide apart. However, these beliefs have recently changed due to an external event. Because of this large change, the requirements for the creation are lowered and the agent can create a wide team to address the change in states or aims of an issue.

   ii. Method 2: The actors share similar beliefs. In this case, the definition is strict.

(c) Disbanding a team: There are several reasons for which a team could be disbanded. The first one is if the leader of the team changes the issue for which (s)he is advocating. In that case, the team has no more reason to be and it is disbanded. Furthermore, at a constant interval, the criteria for the creation of the team will be checked (method 2 criteria). Each actor that does not meet the criteria will be removed from the team and if less than three members remain, the team will be disbanded.

(d) Leaving a team: The action of leaving a team is determined passively by the belonging parameter level of an actor. If any actor has a low belonging level, this will mean that they do not identify with the issue advocated for by the team and will therefore be removed from the team.

5. Diffusion actions (within the context of the diffusion theory): There are different actions that are performed by the actors within the context of the diffusion theory and through the super-policy network. The resources used for all actions in the super-policy network are different than the resources used within one system through the policy network. They are assigned separately from the other theories and depending on the status of a system compared to another. The action chosen amongst all possible actions for any actor is the action that will yield the most impact.

   (a) Friendly type actions: For this type of diffusion, the actors can perform individual framing, aim influence and state influence actions in the super-policy network similar to what happens in the policy network.

   (b) Dominant and coercive type actions: For these types of diffusion, the actors of one system will impose their aim parameter for the issue they advocate on the actors of another system. The difference between dominant and coercive here is the impact of this action, coercive action will mean that the aim is virtually imposed on the actor of the other system while dominant will lead to a large change but not a total change. The impact of these actions will depend on the trust between the two actors.

(c) Competitive type actions: For this type of diffusion, the actors present in system 1 will look at the states perceived by the actors in system 2. They will then adjust their aims with respect to the observed states through the spending of some of their resources. This is meant to display a need for these actors to reach the same state as the ones in the second system.

5.2.2. The policy makers

As mentioned earlier, the policy makers are closely related to policy entrepreneurs. Within this model, policy makers are policy entrepreneurs that can perform additional actions related to the creation of the policy agenda and the decision on the implementation of policy instruments at the end of the policy formulation process. The policy makers are the only actors with decision making power (Zahariadis, 2014).

Attributes The policy makers have the same attributes as the policy entrepreneurs.

Actions The policy makers can perform all the actions that policy entrepreneurs can. Additionally, they can perform two additional actions. They can create the agenda and select a policy instrument for implementation.

1. Agenda creation: At the end of the agenda setting process, all policy makers come together with what they advocate for. A tally is then made. For the policy streams, the problem and policy with highest support are placed on the agenda. For the ACF, the issue that has the most support is placed on the agenda for the policy formulation process.
2. Policy instrument selection: Similarly to the agenda creation, at the end of the policy formulation process, all policy makers come together with the policy instrument they support. A tally is then made of how many policy makers support each policy instrument. Depending on the threshold (majority or unanimity), if the threshold is met, the policy makers decide to select the policy instrument at the top of the tally for implementation in the technical model.

5.2.3. The electorate

The electorate represents the voting general public. The electorate is implemented as several actors for which, each actor corresponds to one sector of the electorate. In turn, one sector of the electorate corresponds to one affiliation. The aim is to represent the overall political balance that is present in the case being studied.

Attributes The electorate has slightly different attributes than the policy entrepreneurs. Note that there is as many electorate actors as there are affiliations. The electorate helps define the balance of power which is measured into the amount of resources that is provided to policy makers sharing the same affiliation. The attributes of the electorate are outlined below:

1. System: This defines which system the actor is part of. This is only required when the diffusion theory is included.
2. Belief tree: This tree uses the same structure as the belief tree of policy entrepreneurs, policy makers and external parties. It does not contain preferences and there are no causal relationships within the tree. Each issue only has a aim and state parameter. This is because the electorate does not perform any actions on the system that require such causal relations. The only actions that the electorate peforms are aim influence on other the policy makers.
3. Affiliation: This represents the political affiliations of the entrepreneurs. Only a limited set of affiliation is present in the model.
4. Representation: This attribute defines the amount of the total population is represented within this part of the electorate in percentage. This helps defines the overall resources for the affiliation associated policy makers. All electorate representations must add up to 1.

Actions The electorate actor can only perform one action. It can influence the policy makers' aim parameter for each of the issues. Each electorate influences their affiliation associated policy makers on all of the issues present in the tree. They help shift the aim of these policy makers slightly towards the aim of the electorate. This is a very slow process but is nonetheless present.

5.2.4. The external parties

Within the context of the model, the external parties are the only actors that have direct access to the true states of the world. They are also entities that can willingly influence the perception of the electorate, the policy makers and the policy entrepreneurs similarly to normal policy entrepreneurs. This comes within the purview of framing of the issues. Such external parties can be considered to be, for example, media organisations (Birkland, 2004; Cook et al., 1983; Kosicki, 1993; McCombs and Shaw, 1972; Van Belle, 1993; 2000), think tanks or other foundation with motive to influence the model actors. The impact of the different external parties will be related to the resources they have. Overall, the external parties are conceptualised in a similar fashion as policy entrepreneurs but with less or different possible actions.

Attributes The external parties have the same attributes as the policy entrepreneurs.

Actions The external parties play two roles in the model. The first role is a passive role where they transmit the states of the world to the different actors present in the model. This action is impacted by affiliation of the actors they interact with and is based on their interests in the different states.

The second role is a more active and influence prone role. Two actions are then considered. The action that has the highest impact on the other actors is the one that will be selected by the external party for implementation.

1. Electorate influence: The external parties can influence the aim of the issues of the electorate. This is done system wide and depends on the amount of resources that

the external party is ready to use.

2. Blanket framing: The external parties can also perform blanket framing actions on all the actors present in the system (excluding electorate as they do not possess causal relations in their belief tree). This influence the causal relations in the belief tree of the actors. The impact of the action is dependent on the resources spent.

5.2.5. The policy brokers

Within the context of the coalitions, the policy entrepreneurs or the policy makers can become policy brokers (Ingold and Varone, 2011; Jenkins-Smith et al., 2014). They keep the same attributes and actions as normal entrepreneurs or policy makers but can also perform additional actions. The aim of policy brokers can differ depending on their self interest. However, in most cases, policy brokers are either neutral facilitators or can be play an advocacy role (Bardach, 1998). For each actor, this is defined by the modeller as an input. Policy brokers are selected as policy entrepreneurs that have wide ranging network with other entrepreneurs in the different coalitions. They also need to have vast resources compared to other actors. The role of policy brokers is to use their large networks to help other actors interact with each other despite the fact that they did not have a direct link (Henry et al., 2011).

Attributes The attributes of the policy brokers are the same as the one that the policy entrepreneurs have except for one additional: policy broker behaviour. The behaviour of the policy broker is defined as either being a neutral facilitator or play an advocacy role to attempt to influence other actors on specific issues. Depending on the chosen behaviour, the policy broker will have access to a different set of actions.

Actions For neutral policy brokers, the additional action that the broker has is the ability to place two actors within his network in direct contact temporarily. Conceptually, the link between the two actors joined by the policy broker gains the same level of trust as the link between the policy broker and the actors he is connecting. This increase is temporary. The aim of such action is to increase the speed of policy learning and potentially a consensus between different actors or coalitions. The policy broker needs to spend resources for such an action.

For advocacy type policy brokers, they can also put in contact actors within their network. However, the policy broker will first check that one of these two actors share his beliefs on the particular issue he is advocating for and that it is that actor that will be influencing the other. The aim in such a behaviour is to have a selective policy learning behaviour where only beneficial information to the cause of the policy broker is disseminated.

5.2.6. The teams

Although the teams are not actors for say, they behave like actors in the model. They are therefore outlined in this section. Teams are temporary entities composed of actors having similar beliefs as mentioned before.

Attributes The teams have similar attributes to some of the actors. They are detailed below:

1. System: This defines which system the actor is part of.
2. Team leader.
3. Resources: The amount of resources that a team has is dependent on the belonging level of the actors which are part of it. Each actors gives a part of its resources to the team which is proportional to how close he feels with the team on the issue the team is advocacting for. These resources form the entire amount that the team has at its disposition.
4. Advocacy: The policy or problem that a team advocate for is the same as the one that team leader has. A team can only advocate for a policy or a problem at a time. This is taken as the first of those that the team leader has chosen.
5. Members: This is the list of all actors being part of the team.

Actions Teams can perform a range of actions similar to the actions that the other active actors can perform. These are detailed below. Note that for a certain amount of resources must be assigned by the modeller from the total amount available for each of the two types of actions.

1. Intra-team actions: The team can perform actions on itself in the interest of increasing team cohesiveness. Three actions are then of interest: blanket framing (a framing action on all actors in the team at once), aim influence and state influence. These actions were explained above. Such actions use the resources of the team. Which action should be decided is chosen based on the expected impact from each of the actors. The highest graded highest amongst all actors is the one that is selected and implemented.
2. Inter-team actions: The team can also perform actions on individual actors or other teams. These actions are individual framing, aim influence and state influence. These actions use the resources of the team and exploit the overall policy network of the team. Similarly to intra-team actions, all actions possible on all external actors are graded. The action with the most impact on the issue advocated by the team is then implemented. These actions are calculated based on the partial beliefs of the different members of the team on the actors outside of the team.

5.2.7. The coalitions

Coalitions are very different from teams (Mintrom and Vergari, 1996). They are not constructed the same way and no actor can leave a coalition. Coalitions are created based on similar principle beliefs in the agenda setting phase and policy core beliefs in the policy formulation. The modeller choose one principle belief for which (s)he judges the coalition should be formed around. Then, the actors with similar beliefs are grouped together in coalitions. The amount of coalitions present in the model is then dependent on the threshold that the modeller considers to be similar belief. Using a lax definition will lead to only a few coalitions while using a strict definition of similar belief will lead to a fragmented system with numerous coalitions. The belonging level of the actors is calculated after they have been assigned to a coalition. Changes in coalitions are unlikely considering the change in principle beliefs is limited. When joining a coalition, the members of the coalition will all exchange their beliefs so that they understand where everyone stands with respect to the issue advocated by the coalition.

Attributes The coalitions attributes are given as:

1. System: This defines which system the actor is part of.
2. Team leader.
3. Resources: The amount of resources that a coalition is obtained in the same way as for the teams, based on the belonging level of its members.
4. Advocacy: The issue a coalition is advocating for is the same as the one of its leader.
5. Members: This is the list of all actors being part of the coalition.

Actions Actors present in coalitions can perform inter or intra-coalition actions. The same actions as for teams can be performed for intra- and inter-coalition actions. The difference here is in assessing which action should be carried through. For coalitions, it is the leader of the coalition that decides which action should be carried out based on his own beliefs and his own impact estimation.

5.3. The external events

The external have an important place within the model. They can help influence the results. External events designed by the modeller can impact any part of the model. Depending on the external events placed, the amount of resources per actor will change or there will be an addition of several policies within the model. The list of class of external events is extensive. The idea behind external events is that if the modeller can think of a specific situation from a case study for example, it should be translated into a model external event. A list of potential external events is presented below. Note that the external events presented below could also be combined or triggered at the same time. This list is not exhaustive:

1. Election: This will have an impact on the representation attributes of the electorate which has a spill-off effect on the resources of the policy maker, policy entrepreneurs and external parties.
2. The introduction of a new issue: This would allow actors to have access to a new issue within their belief tree which they can advocate for.
3. Resource shift: A change in the resource distribution within the model could be designed. This could help represent a power play within the model.
4. Policy network shift: Due to some unknown force, there would be a change in the awareness level of all actors turning some active links inactive and vice-versa.
5. Affiliation network shift: The weights used to describe the relations between the affiliation could be modified.
6. Introduction of a new actor: This would introduce a new actor along with its associated policy network links, beliefs and other attributes.
7. Understanding shift: This would introduce a large change in the causal relations of the different actors present in the model.

6
Model validation

The validation process is required to build confidence into the conceptualisation that has been devised. The reasoning behind this approach relates to the difficulty in validating the model produced from this work but also in the importance of validating the concepts being taken from the literature. This chapter first presents the process and scope that was used to validate the model in section 6.1. The chapter then goes over the different parts that were addressed within this validation. The approach taken is discussed in section 6.2 , the three streams theory in section 6.3 and the advocacy coalition framework in section 6.4.

6.1. Process and Scope

The validation method used is a validation by experts. This method was found to be the most appropriate method to validate the work that was done to convert concepts and assumptions from the literature into agent based model concepts. Contact was established with several leading researchers in the field of policy making sciences, each specialising in one of the theories used in the model, as well as in efforts to use computer simulations for theoretical policy sciences analysis. A summary of the conceptualisation was sent to them before an one hour interview was organised. The researcher interviewed were: Professor Paul Cairney from the University of Stirling in the United Kingdom, Professor Nikolaos Zahariadis from the Rhodes College in Memphis, Tennessee, and Professor Christopher Weible from the University of Colorado Denver. Additionally, written feedback was also provided on the conceptualisation summary by Dr. Karin Ingold from the University of Bern in Switzerland.

It is important to understand that the scope of the validation is not in any way to validate the policy making theories. As was mentioned earlier, the aim of this work is merely to use widely accepted policy making theories and attempt to appropriately translate them into modelling concepts that can be used in an agent based framework. The aim of the validation was therefore to establish a common understanding with these researchers in such a way that there understanding of specific details of these policy making theories were adequately considered for the model. The aim was also to press on aspects of the theories which are incoherent or which require considerably more detail to be used within a modelling framework.

6.2. Validation of the Approach

One of the topic addressed during the validation is the approach taken with the model. This is related to two main assumptions: it is possible to combine the different policy making theories and the policy cycle can be approximated as a 3-step process within the context of the present work.

As expected, there was pushback from each of the researchers on these two assumptions. Prof. Cairney argued strongly against the use of a policy cycle at all and noted that even Sabatier mentioned that the use of a policy cycle to explain policy emergence is hopeless. However, there was an understanding that for modelling purposes and specifically for an agent based model, reverting to a more linear approach of the policy cycle was required. Prof. Weible also argued about the use of this form of the policy cycle, no objections were raised on using only two steps: agenda setting and policy formulation.

Prof. Cairney also pushed back on the combination of the policy making theories. At the time of the interview, it was proposed that the model could combine the three streams theory approach for the agenda setting process and the advocacy coalition framework for the policy formulation process or vice versa. The reasoning behind such an approach was mainly that because some of the theories' concepts had been merged (consider the use of a belief tree within the three streams theory), this was technically feasible. Prof. Cairney argued that using both of these theories together within one model was ill advised as the two theories were contradictory as presented in the literature. Prof. Weible also noted that the combination of these two theories would disregard the difference in time scales that is inherently present in the two theories. In the literature, the ACF is considered to be a long term process with policy learning occurring over decades and coalitions that can last just as long. The three streams theory, on the other hand, works on a shorter time scale.

As a result from these discussions, some changes were performed on the approach taken for the model. The 3-step policy cycle approach was kept intact. Although there can be arguments made against the policy cycle approach, and with the fact that the policy emergence process is messy and non-linear, these descriptions are not constructive enough to provide details on alternative methods to approach the policy emergence process. This is especially striking as when using an agent based approach, there is a need for a structured approach to the system that needs to be modelled. Finally, it is important to note that, as Dr Ingold mentioned, Herweg et al. (2015) suggests that using the agenda setting and policy formulation fit well with a more formalised version of the three streams theory.

Changes were however made on the combination of the three streams theory with the advocacy coalition within one simulation. It was decided that it would make no sense to simulate both theories at the same time in different parts of the policy cycle. Although it is still technically possible to combine both theories, all experiments performed in the model will not combine both theories but will be constituted only of one theory at a time. This does not apply to the diffusion and feedback theories which can still be combined with both the three streams theory or the advocacy coalition framework.

6.3. Validation of the Three Streams Theory

The approach used for the three streams theory was mostly discussed with Prof. Zahariadis considering a lot of his research is related to this theory (Zahariadis, 2003; 2007; 2014).

Comments were targeted mostly at the concept of policy window and whether such a policy window would be observable within the three streams theory. This is also related to the selection of the problem and/or the policy by the actors present in the system. At the time of the interview, the three streams theory was using an approach where, during the agenda setting the actors would select a problem and during the policy formulation the actors would select a policy. However, and this was noted by Prof. Zahariadis, this is not how the policy window is described in the literature. The approach that was used only allowed for problem driven policy windows. It made it impossible for actors to first chose a policy and then proceed to the selection of a problem based on that policy.

Following this discussion, a considerable change was performed on the approach chosen for the three streams theory conceptualisation in the model. To better represent the policy window, it was decided that during both steps in the policy cycle, the actors would select a problem and a policy. They could decide to select first a policy or a window based on their beliefs of what is currently most important. These changes are aimed at better representing the aspect of the policy window where actors choose a problem or a policy only considering their own beliefs.

Additional comments related to the three streams theory approach were linked to the transparency with which the modelling assumptions are made. Prof. Zahariadis insisted on the importance of reporting on all assumptions made as they can have a major impact on the behaviour obtained from the model.

Comments were also made on the approach considered for the introduction of external events in the model. The conceptualisation originally argued that external event (a crisis) would lead to a larger amount of resources for the actors in the system which have to deal with this crisis. Prof. Zahariadis argued the opposite, stating that an external event would lead to a constriction of the resources available to the actors. However, this should also be accompanied by a relaxing of the threshold that define consensus between the actors. The reduction of actions allowed, along with the larger threshold for the acceptance of a policy instrument, should then lead to the faster adoption of policy instruments to deal with the external event. The approach to the external event modelling was subsequently modified to fit with this approach.

6.4. Validation of the ACF

Feedback on the advocacy coalition framework was mostly discussed with Prof. Weible considering a lot of his research is related to this framework (Jenkins-Smith et al., 2014; Nohrstedt and Weible, 2010; Sabatier and Weible, 2014; Weible et al., 2009). The feedback provided on the ACF was mostly related to the importance of documenting the concepts that are transferred into a model. This effort would be useful to understand how many of the concepts are modelled so as to represent the messiness of the policy emergence process. A comment was also made on the term deep core belief that was used throughout the conceptualisation to represent the highest belief of the actors. However, strictly related to the deep core definition that is provided in the literature, the belief level considered does not match with what a deep core belief is. The term was therefore changed to principle belief which illustrates a lower level of belief than deep core beliefs.

Overall the feedback obtained through this validation was positive and encouraging. Most of the conceptualisation was considered appropriate within the scope of the work performed here. Some elements had to be modified such as the approach of the three streams theory and the combination of the three streams theory and ACF within one policy cycle. However, this lead to a more coherent approach to the four policy making theories and should make the approach presented in this thesis more robust.

7
Model Implementation

Once the model has been conceptualised and the conceptualisation validated, it is time to implement this approach into a programming language to be able to perform simulation. For this an additional step is also performed, the formalisation, which is presented in Appendix A and Appendix B for the policy emergence model and the technical model respectively. This chapter presents the implementation of the model using the programming language python and a forest fire model. This chapter first explains the reasoning behind the used of Python in section 7.1. The general approach that is use for the model implementation is then shown in section 7.3. The forest fire model is presented in section 7.2. The external parameters that are used are detailed in section 7.4 and are followed by an explanation of the verification that was performed in section 7.5.

7.1. The Use of Python

Python is a programming language that dates back to 1991. It is an open source language that is used widely around the world and which is becoming increasingly attractive within academic fields. Within the context of agent based models, Python is a fairly new language. The programming software of reference for such models is NetLogo and uses a subset of the Java language.

Several reasons can be used to justify the use of Python instead of NetLogo for the model implementation within this report. The first relates to the flexibility that is inherent to the use of Python. Considering Python is widely used for other applications than agent based modelling, a lot of tools can be used with the language. A large number of file inputs can also be used with Python. The potential of Python is virtually limitless and is much less restricted than what NetLogo can do. This is particularly important for this policy emergence model. This model requires a large amount of inputs. It might be easier for a researcher to use a different file to introduce the inputs to this model. Furthermore, the technical model will not always be in Python. In some cases, the technical model will be created before the policy emergence model. It will therefore be important that both models be able to talk to each other. Python allows for more flexibility on that front compared to other more restricted languages.

Regarding the coding of the model itself, Python is a more suitable language to use considering the data structure that is required to model the agent's belief systems. Python also allows for more flexibility considering the size of the model being considered. Python is used because of the ultimate sharing objective of this project. The aim is to widely share the model that is built such that other researchers be able to add modules, provide feedback or make modifications to the model. Python makes such an effort easier. as it is a more widely known programming language.

There are however drawbacks to the use of Python, mostly related to the logistics around agent based modelling. The coding of an agent based model follows a certain framework. It usually consists of the following steps: initialisation, step (where one time step is run at a time) and data collection. Although this framework is perfectly implemented in NetLogo, it is almost entirely absent from Python. In recent years, one effort has been made to present an agent based framework in Python. This was done by Project Mesa[1]. They have developed a Python agent based framework that allows for the construction of simple agent based models which perform the critical steps of an agent based model but also allows for the live display of the results on the browser.

The model coded in this thesis uses the framework originally developed by the Mesa Project and builds on it extensively. The basic structure was kept but aspects such as network functionalities or behaviour space introduction were added along with the addition of the possibility to use an extensive input file to simulate different types of experiments. This lead to some limitations such as the loss of live browser visualisation or inputs through a graphical user interface. Such functionalities are still possible and can be added at a later stage but are not considered to be within the scope of this thesis.

7.2. The Technical Model

Although the policy emergence model is detailed throughout this report so far, to test it, there is a need for a technical model. This technical model is what the agents will choose policy instruments for and will therefore try to influence. The technical model requires to be coupled to the policy emergence model. The technical model chosen is a simple model. For later studies, different models can be coupled with the policy emergence model such as public transport models or health care system models.

The technical model chosen is a forest fire agent based model. This model is a classic simple example of agent based modelling. The model selected was obtained from the mesa-project but was adjusted for the purposes of the experiments with the policy emergence model. The forest fire model is a model that contains several hundred cells. Each cell can take several states. Depending on these states, there is a certain probability that a fire might occur for specific cells and spread to neighbouring cells. Each of the cells can take one of six states:

- Empty cell: The cell is left empty and can therefore not burn.
- Thin forest: This is a low density forest patch which has a low probability of burning. Thin forests become thick forests after a certain period of time.
- Thick forest: This is a high density forest patch which has a high probability of burning.
- Burning: This is a temporary state. After this state, the cell will immediately take the burnt-out state. Note that this process can be affected by fire-fighters as mentioned later on.
- Burnt-out: This is a burnt patch that will ultimately regrow into a thin forest or remain

[1] `https://github.com/projectmesa`

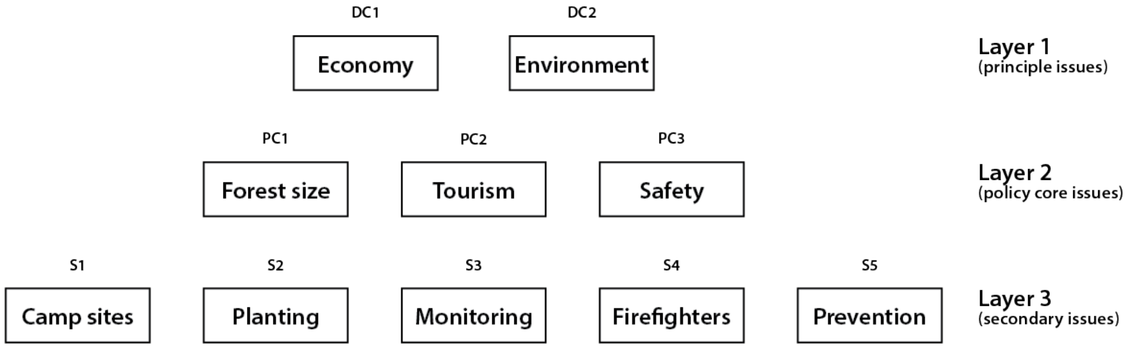

Figure 7.1: Belief tree used for the forest fire technical model.

empty over time.

- Camping site: This is a cell filled with a camping site. Such a cell has a high probability of burning. Camping sites help tourism and can only be built through measures from the policy makers.

There are several additional elements to the model. Fire-fighters are present within the model. They can reduce the impact of a fire and instead of leading to a burnt-out cell, they will extinguish the fire which leads to a thin forest cell.

To integrate the forest fire model with the policy emergence model, several steps are undertaken. The first one is to create a belief tree for the agents. It is from this belief tree that the agents will select the issues and problems they advocate for. The instruments provided by the modeller all impact the secondary issues presented in the tree. They impact the current perceived states of these issues. The belief tree constructed is shown in Figure 7.1. The first layer of the tree, with the principle issues, is composed of the economy and the environment. The second layer, the policy core issues, is composed of the forest size, the tourism and the safety. Finally, the third layer of the tree, which uses the secondary issues, is composed of the camp sites, the planting of more trees, the monitoring of the cells, the amount of fire-fighters dispatched, and the prevention of fires. Each of these issues is associated with specific parameters within the model.

Additional information on how each of the states for these variables are calculated are provided in Appendix B. It is accompanied by a full formalisation of the technical model and the effect that policy instruments have on the model. Note that in the case where the modeller would consider a different technical model, this entire formalisation would have to be built from the ground up again. This part is model specific and will therefore only apply to the issue studied. On the other hand, the policy emergence model will remain the same. In most cases, the technical model will already be present. The modeller will have to build a belief tree based on that model along with providing instruments and devising a plan to calculate the states for the policy emergence model.

7.3. The General Approach

The agent based model built here can be split in three main parts: the technical model, the bridge between the technical and the policy emergence model and the policy emergence model.

The technical model can be any model describing a certain system. To allow for the policy emergence model to be coupled to this technical model, a bridge is needed such that the variables outputs from the technical models are formatted appropriately as input for the policy emergence model. This bridge is represented in the model as the truth agent. This agent contains all the values of the states for each of the issues present in the belief tree of the agents. These states are directly calculated from the technical model on an interval [-1, 1]. The manner in which the states are calculated can be tuned by the modeller to represent specific parts of the technical model which the agents will be able to reflect upon and choose instruments for.

The overall models runs as follows. First, the model initialisation happens. In this step, the different agents specified by the modeller are created. Their belief tree aims are populated according to inputs from the agents. It is also at this stage that the instruments that the agents will be able to use are imported into the model. The forest fire model is also initiated with the creation of the cells and a certain distribution of states of the cells. The initialisation can be influenced by the inputs provided by the modeller for different sets of experiments.

After the initialisation, the agent based model begins. It is roughly split in fourt parts: the tick initialisation, the agenda setting, the policy formulation and the end of tick procedures. The tick initialisation sets up the steps. The technical model is run and the instruments, if any are agreed on, are implemented. The states of the systems are calculated and fed to the truth agent. Using the truth agent and the agent's own aims, all of the agents can then update their preferences.

Then comes the agenda setting. In this step, the agenda have for task to decide what will be on the agenda. They decide on an issue that a majority of them consider to be important. Depending on the policy making theories being used, the steps will be different but the outcome will mostly remain the same: the agenda. After the agenda has been obtained, the agents move to the policy formulation which is considered to be a separate political arena from the agenda setting. There they have to come to an agreement about a policy instrument to be implemented. Once the agents have interacted, and regardless of whether they have an agreement on an instrument, the model moves to the end of tick procedures where the network awareness parameters are updated and the data is collected for the analysis of the specific tick.

At this point, the model has performed one tick and returns to the tick initialisation. This repeats until the total number of ticks specified by the modeller has been reached. A tick is meant to represent two weeks for both the forest fire model and the policy emergence model. More detailed information on all of these steps are provided in Appendix A.

The approach presented here assumes two agent based models coupled to each other. For each step in the overall mode, the forest fire model also only advances by one tick. This means that each cells within the model are allowed to change state only once. Then the model proceed to the policy emergence part. This is arbitrary. In other models, there might be a need to run the technical model several steps forward for each step that the policy emergence model goes forward. Furthermore, the coupled models might not even be both agent based models. In this case, for every step, there might be a need to run a full simulation of the technical model to calculate the states for the truth agent.

7.4. The Model Parameters

There are a number of exogenous parameters that can be used to simulate different types of behaviours in the model. There are three main types of exogenous parameter with respect to the full agent based model: parameters related to the technical model, parameters related to the bridge between the two model and parameters related to the policy emergence model.

The parameters related to the technical model relates to the tuning of the forest fire model. They define the initial values for that model but also the time between different events. The parameters used for the bridge relate to the calculation of the states for the actors and the impact of the instruments. For specific instruments certain maxima or minima can be set to avoid having unrealistic results within the technical model or to make sure that the states will remain within the [-1,1] interval.

There are many more external parameters that are related to the policy emergence model. Each policy making theory has its own set of parameters that can help define everything from the belief tree inputs to the strategy that an agent will choose when selecting a team in the three streams theory. These parameters are wide ranging and all have default values. They can however be modified by the modeller so as to make the model more geographically specific to the system being studied or to the actors being modelled. These parameters help make the model appropriate for different policy network behaviours which will vary depending on the case study. The full list of parameters that can be changed is presented in details in Appendix D.

7.5. Model Verification

An extensive and rigorous verification process was conducted alongside the writing of the code for this model. The verification was done in parallel due to the size of the model and the impossibility to do all of the verification at the end only. The main method of verification was a verification through `print` functions. For almost all of the lines of code in the model, the `print` function was used to check whether the expected outcomes were seen from the different operations. A lot of this `print` function infrastructure still remains in the comments of the code and can be uncommented to perform additional verification checks.

Several categories of checks were performed for this verification. The first ones are related to the forest fire model. It was checked that the states calculated from the technical model never went above one or below minus one. A warning still remains in the code in the cases of this happening. A check was also performed on the implementation of the instrument which is also considered to be part of the technical model. It was made certain that they were implemented appropriately and led to changes in the technical model.

The second checks were performed on all parts of the code that included the belief tree. This is considered to be the most important part of the verification due to the fact that the choice of the wrong index does not break the code but instead introduces errors in the simulation. For example, if the indexing of the causal relations in the partial belief tree of the second actors are mistaken for another causal relation, the code would still run but provide erroneous outputs. The use of the belief tree was therefore extensively verified through the checking of the indexes selected in all lines of code that used the belief tree. Some of the infrastructure used for this verification still remains in the code at this moment.

These verification impacted most parts of the code from the preferences calculations to the instrument selection and the actions implementation.

The third checks that were performed were on the actions grading, selection and implementation. Several verification checks were performed there to make sure the actions were graded appropriately, the right action was selected and the right action was implemented by the right agent on the right agent. The action selections comes back throughout the model in different forms. Several times, actions are performed from one agent onto other agents for causal relations and issues. This happens both in the agenda setting and formulation processes. Restrictions are required for the policy formulation step where the causal relations considered are restricted (only actions on causal relations related to the item on the agenda can be performed). For these actions, the verification was fairly simple as the number of actions were limited by the number of issues, causal relations and agents in the model. A more crucial verification was the actions performed in teams. For such actions, all of the agents in the team perform actions on all of the agents outside the team. This can lead to a grading list of actions of several hundreds of entries. It is then important to pinpoint which action is which performed by whom and on which agent. This was extensively checked to make sure the appropriate actions were performed. If incorrect, the code would once again still work but the policy learning would be greatly affected.

Additional verification steps were taken when considering the networks. The policy network awareness and awareness decay mechanics were verified. The shadow networks used for coalitions and teams were also checked. An extensive verification process was also conducted to make sure the appropriate data was saved from all the potential outputs from the model. The code that was constructed for the inputs in the case of experiments was also verified to make sure the change inputs was appropriate for each of the runs. The overall verification process is presented in more details in Appendix C.

III

Results and Reflection

8

Exploration and Experimentation

Once the model has been constructed, it is possible to look into how this model will be used. The first task for this is to select endogenous parameters that will be recorded. The different parameters of interest will be used to analyse and discuss the results. They are presented in section 8.1. Before experiments are conducted, it is important to understand whether the model behave in a specific manner when using extreme variable. This is looked at in the exploration phase in section 8.3. Then it is possible to perform different experiments to attempt to display concepts that are present in the literature and that should be expected in the model. This is shown in section 8.4. Finally, limitations are expected from these experiments and they are outlined in section 8.5.

8.1. The Endogenous Parameters

The model produces and uses a large number of endogenous parameters. A lot of these parameters can be used to analyse the model. Considering the model is split in several parts, these parameters can be categorised in different parts as well. Furthermore, for the analysis and the discusssions, there is only a need of a certain set of these parameters depending on the aim of the modeller in the analysis. A modeller that looks at the policy network behaviours, will have little interest in parameters linked to policy learning.

The first set of parameters relate to the technical model. These are the parameters that defined what is in the forest fire model. It encompasses parameters such as the number of cells in each of the state (thick forest, empty, thin forest, ...). It also considers the coefficients that can be affected by the agents in the model such as the probability for a camp site to catch on fire or the probability that a burning cell with be extinguished. Note that some of these parameters are initially set by the modeller but because they are modified by the agents afterwards, they can also be considered endogenous.

The second set of parameters is related to the emergence model itself. These are mostly parameters that are derived from the decisions of the agents. This is the case for the agenda which is composed of an issue or a policy and a problem for the three streams theory in particular. It also contains the selected instrument at the end of the policy formulation and the truth belieftree which is composed of the raw states directly obtained from the technical model.

Then come the parameters related to the agents. There are several of these parameters with the most important being the belief tree of the agent. This belief tree contains both the beliefs of the agent but also what the agent thinks are the belief tree of the other agents present in the model. These trees are also referred as the partial knowledge trees. In the case of the three streams model, these belief trees are supplemented with belief trees on the policy and instruments. Each of these also have two parts: own belief tree and partial belief trees. The agents need to have a perception of the belies of the other agents' beliefs on the impact of the policies and the instruments to be able to interact with them. Each of the agents also has a certain amount of resources based on their affiliation and the current political representation within the system. Then, for the three streams theory and the ACF, the agents will have a specific belonging level if they are part of a team and when they are part of a coalition. This belonging level can help understand the dynamics of the teams and coalitions and their political power within the model.

There are also a number of parameters related to the policy network. This policy network is there by default but not necessarily fully populated by links. This will vary on awarenes for each of the links. Note that right now, the policy network is randomly generated which makes it an endogenous parameter. In the future, it is in the interest of the modeller to have it as an exogenous parameter to better represent a case study. Separately, for each issue in each links, the agents will have a certain conflict level. This conflict level might also be different from agent A to agent B and from agent B to agent A. In the case of the three streams theory and the ACF, shadow networks are also sporadically created between teams and coalitions, and the agents that are not in these teams and coalitions. These network possess the same behaviour and parameters as the normal policy network.

Finally, there are parameters related to the teams and the coalitions for the three streams theory and the ACF. For teams, these parameters are the amount of resources, the time of creation, the members and the issue being advocated for. Each of these parameters, when studied, can help understand the network dynamics at play. It can also provide insight in why a certain instrument was chosen over another. For coalitions similar parameters are present.

To be able to focus the analysis of this model, not all parameters are being considered as potential output. A selection has to be made such that the analysis can focus on specific aspects of the model. Within the scope of this thesis, the aim is to show that the broad concepts present in the literature are present in the model. The parameters of interests are therefore limited. All model parameters are used along with the agent's own belief tree for each of the models. For the backbone+ model, network parameters such as awareness and the agents on both end of the links are also outputed. Then for the three streams theory and the ACF, parameters of resources, issue and members are selected. The rest of the parameters are not considered to be of interest. The entire list of the parameters present in the model is in Appendix D.

The selection performed here is very specific. Different modeller with different aims can have a different parameter interest which would result in a very different list. The model is complex enough to allow very different analysis depending on the focus of the modeller.

8.2. The Forest Fire Model

The first tests that are performed are performed on the forest fire model alone. These tests are necessary to understand the behaviour of the forest fire model as a stand-alone agent based model. They will help understand the behaviour of the model and better understand what the impact of potential policy instruments that the agents will introduce are.

A sweep of of the all the parameters available in the forest fire model is performed. This is done through 100 experiments with each 200 ticks. The parameters considered are:

1. The thin forest burning probability
2. The mulitplier coefficient between the thin forest burning probability and the thick forest burning probability
3. The time for the growth from thin to thick forests
4. The time between burnt cell and thin forest and empty cell
5. The percentage between empty cell and thin forest when a cell is past burnt

For each of these parameters, the combination of the parameter chosen is obtained using a Latin Hypercube Sampling[1] function. This allows for a statistically representative sample without having to run millions of simulations.

8.3. The Model Exploration

To be better able to understand the behaviour of the model and to check whether the model can break in extreme situation, a model exploration is performed. For this exploration, a set of parameters is given extreme values unlikely to happen in reality. The parameters selected vary depending on the model being considered. For the model exploration, the aim is to set these parameters to extreme values to observe whether the model results are as expected and to see if any parameter could break the model in a significant way.

The number of agents that is being considered within the model exploration but also for the experiments later on is 31. The distribution is given as follows: six policy makers, six external parties and 18 policy entrepeneurs. Note that it was chosen to have three policy entrepeneurs per policy makers. The distribution of agents is kept constant to simplify the comparison between the different models. This set of agents also leads to a reasonably sized policy network and an appropriate distribution of the affiliations within the model.

Due to the nature of the model and the nature of agent based models, a warm up time is sometimes necessary. The warm up time is the time it takes for the model to get to a certain state where one considers the models to be close to a state comparable to reality. This is particularly important within the policy emergence model for the beliefs of the agents. The actions of the agents are eminenetly driven by their knowledge of other agent's belief. If the model were to be started without start up time with empty partial knowledge, it could then take upwards of 1000 ticks for the model to reach a state where all the agents have a certaina mount of knowledge on all the beliefs of the other agents. This kind of warm up time is too long to be considered practical for any experiment considering that a run is chosen to be 500 ticks only. Alternatives are available to drastically reduce the warm up time but none of these alternative are perfect. The main aim of these alternatives is to populate the partial knowledge of the different agents as close to what they would be in reality. This can be done through several methods like statistically distributing the partial knowledge for each issue based on the actual beliefs of the agents and skewed depending on the affiliation of the other agents. It can also be populated randomly with number on the interval [-1, 1]. The method used here was to assign the partial beliefs as equal as the real belief of the agents but with a certain amount of uncertainty, a random number within $\pm$ 1 of the value. The quality of these partial belief initialisation methods and of the warm up time could be

[1] `https://cran.r-project.org/web/packages/lhs/lhs.pdf`

studied on its own depending on the method to observe what the effects of different partial belief initialisations are.

The parameters considered are as follows:

1. For the backbone:
   (a) The belief tree profile: for each affiliation a certain profile is designed. For the normal case, this profile is random. For a real model, the belief tree would require modeller input using the belief of real agents collected through surveys or interviews. For the exploration, three cases are considered. First every issue aim and causal relation is set at 1, for the second case, they are set to -1 and for the third case to 0.
   (b) The affiliation weight: the weights are varied between 0 and 1 according to varied combinations. The aim here is to see what impact a change of weight has on the dynamics in the model and on the policy learning overall compared to the base case scenario.
   (c) The affiliation distribution: the distribution of the affiliation is changed such that in one case, all affiliations have the same power but in another case, only two have a lot of power. The aim is to display the impact of resources on the policy learning and ultimately the agenda chosen by the policy makers.
   (d) The electorate influence. This coefficient is by default set to 0.001. To see whether the influence is working as intended and if these values have unexpected consequences, the coefficient will be set to 0 and to 1 in different sets of simulation.
2. For the backbone +:
   (a) The resources potency parameter: the resource potency parameter affect the effect of action. It is set to 1 and 100 to see what impact a lot of powerful action have on policy learning.
   (b) The resources weight action: this coefficient defines the amount of resources in percentage that an agent can spend for every action performed. It is set to 1 and 100 to see whether a lot of small actions lead to a different outcome that one action per agent per tick.
   (c) The awareness decay coefficient: this coefficient is set to 0 and 1 to observe the changes in the policy network dynamics and the impact on the other parts of the model. if there is no link decay or a large amount of decay.
   (d) The conflict level coefficients: the coefficients are all raised to 1 to see if what the impact of the conflict level is on the actions and the overall policy learning occuring in the model.
3. For the three streams:
   (a) The team creation threshold - gap: the gap required to created a team is set to 0 and 1.5 which are considered to be two extreme values which would show a constant creation of teams or no creation of teams at all.
   (b) The team creation threshold - state: the different in states between agents is varied from 0.1 to 1.5 simialrly to the change in the gap.
4. For the ACF:
   (a) The coalition threshold is set to 0.1 and 1.5 to check the impact of this threshold on the fragmentation of the political arenas in different coalitions.

Each exploration model is run for 500 ticks. This corresponds to about 18 years of simulation in the real world if one considers that 1 tick refers to 2 weeks. Furthermore, to avoid having to look at repetitions which would require a large amount of time, the random generator used is set to the same seed for each of the exploration simulation. This allows for an easier comparison between the models. In the future, provided more powerful computers are available, it would be important to not set a fixed seed for the random generator and have a small number of repetitions for each input set. Statistical analysis could then be performed to get a better sense of the obtained results.

8.4. The Experiments

After the exploration, experiments can be run with the different models. For each experiment a set of inputs must be chosen. The parameters considered are the same as the one shown for the exploration. For each of these parameter, an acceptable range is set. For the belief tree three profiles are proposed. Then using the Latin Hypercube Sampling[2], it is possible to get a statistical representative design space as a combination of all these inputs. A set of 50 input data sets is chosen initially. This should be raised in the future to have a better sample of the design space considering the number of exogenous parameters.

The input sets used are shown in the following list per model.

1. For the backbone model:
   - (a) The belief aims (three profiles):
     - i. Profile 1:
       - A. Affiliation 0: Large values for the issues, large values for the causal relations.
       - B. Affiliation 1: Exact opposite of affiliation 1
       - C. Affiliation 2: Low values for the issues, low values for the causal relations
     - ii. Profile 2:
       - A. Affiliation 0: Low values for the issues, large values for the causal relations.
       - B. Affiliation 1: Exact opposite of affiliation 1
       - C. Affiliation 2: Low values for the issues, low values for the causal relations
     - iii. Profile 3:
       - A. Affiliation 0: Large values for the issues, large values for the causal relations.
       - B. Affiliation 1: Exact opposite of affiliation 1
       - C. Affiliation 2: Low values for the issues, large values for the causal relations
   - (b) The affiliation weights:
     - i. Affiliation weight 1-2: Interval 0.7-0.8
     - ii. Affiliation weight 1-3: Interval 0.8-0.9
     - iii. Affiliation weight 2-3: Interval 0.9-1.0
   - (c) Affiliation distribution:
     - i. Affiliation 1: Interval 25%-50%
     - ii. Affiliation 2: Interval 25%-50%
     - iii. Affiliation 3: Calculated based on the other two

[2] https://cran.r-project.org/web/packages/lhs/lhs.pdf

   (d) Electorate influence on the policy makers: Interval 0.01-0.10
2. For the backbone+ model, use what is already being used for the backbone model plus:
   (a) Resources potency parameter: Interval 1-10
   (b) Resources weight action: Interval 0.05-0.20
   (c) Awareness decay coefficient: Interval: 0.01-0.10
   (d) Conflict level coefficient
      i. Conflict level [0]: Interval 0.7-0.8
      ii. Conflict level [1]: Interval 0.8-0.9
      iii. Conflict level [2]: Interval 0.9-1.0
3. For the three streams model, use what is already being used for the backbone+ model plus:
   (a) Team creation thresholds:
      i. Gap in belief: Interval 0.6-1.0
      ii. Closeness of problem: Interval 0.2-0.7
      iii. Closeness of policy: Interval 0.2-0.7
4. For the ACF model, use what is already being used for the backbone+ model plus:
   (a) ACF threshold: 0.15-0.55

Throughout all of the experiments, during the policy formulation for all models and the agenda setting for the three streams model, the agents can select an instrument or a policy. These instruments and policies are specified by the modeller. For the backbone, bacbkone+ and the ACF models, the instruments to not varry throughout the runs. They remain as specified by the modeller. For the three streams theory, both the policies and instruments are influencable by the agents. They are set up in a belief tree like structure. Only the initial beliefs of the agents on these policies and instruments have to be specified by the modeller. The partial belief of the agents for the policy and instrument tree are obtained the same way as they are for the main belief tree for consistency.

Now using these inputs, several experiments can be simulated. Each experiment has a different type of external event with experiment 0 being the base case with no events. The aim of these experiment is to observe how the model responds to external events such as a change in the political representation or a switch in the beliefs of specific actors present in the model. Each of the experiments are presented below. Each simulation is performed with 500 ticks once again and there are no repetitions with a fixed seed for the random number generator.

8.4.1. Experiment 0 - The base case

Experiment 0 is the base case, no external events are included in this simulation. It will be used as a benchmark simulation to see the changes caused by the external events.

8.4.2. Experiments 1 to 4

The first few experiments look into the suddent changes of the understanding of the technical model by the different agents. This is done through the change of causal relations within the belief tree of the agents. The causal relations' sign is flipped for all causal relations linking the principle beliefs and the policy core beliefs in the agent's trees. To look at the propagating effect of such changes, several external events are designed. In the first experiment, this change in causal relation is applied on all agents at tick 200. For the second experiment, it is only performed on the policy makers. For the third only on the external parties and for the fourth only on the policy entrepreneurs.

8.5. Limitations

There are several limitations to the approach provided in this chapter. The first one relates to the exogenous parameters. The list of parameters that can be changed is extensive. The modeller has access to a large set of parameters that can affect all aspects of the model in small or large ways. These parameters can affect the strategy of agents but also the number of agents and he can decide to have each agent with a different belief tree. This means that an impossible number of experiments can be run with the model. It is therefore important for the modeller to focus on a specific aspect and try to maintain most of the parameters constant so as to be better able to explain the behaviours observed. This could also be a risk as the parameters left unchanged could be the ones responsible for specific behaviours. Furthermore, a full study of all parameters currently contained in this model is beyond the scope of this work. This is due to the model complexity and the time expected to be needed for such a study.

Considering the number of endogenous parameters, it is also important to note that the modeller cannot record all of these parameters. The amount of data produced by the model is tremendous. Selecting the full belief tree as an output can lead to output files ranging from dozens of gigabytes to several hundred per run. This is greatly affected by the number of agents chosen in the model but also the size of the original structure of the belief tree. This problem becomes even more accute when considering the three streams model where the policy and instrument beliefs trees can also be recorded. It is therefore also important for modeller to appropriately consider the variables of interest.

9
Results and Analysis

9.1. Technical Model Results

What needs to be shown in the graphs and analysed:

1. A graph from one experiment with all the states - (statistical of several runs if possible) for experiment 0

9.2. The Agenda Setting Process

What needs to be shown in the graphs and analysed:

1. A graph to show the influence of the electorate on the policy makers - Plot all four models on one graph for one run, experiment 0 and for a representative and clear issue
2. A graph that shows a causal relation for all policy makers - Plot all four models on one graph for one run, experiment 0 and for a representative and clear causal relation

What can be obtained from Figure 9.2:

1. Proof of the electorate influence on policy makers - this is a fairly strong influence, in this case 0.008 every tick.
2. The agents with most changes in beliefs are weak agents that can easily be influenced.
3. The lack of change of agenda and then instrument - stable system
4. Stable states - no difference between the different actors mostly - the affiliation difference matter very little it seems.

What can be obtained from Figure 9.3:

1. Convergence of all the policy makers. But to what point? Is this related to the affiliation distribution for this specific experiment and how does that compare to other experiments?
2. Specific changes in the causal relations - there is a tendency throughout the model to have either causal relation actions or aim actions but rarely both in the same quantity. What parameter influences that?
3. Make a comparison of the three models, show that at the end, the results are fairly similar. (Look into the coalition dynamics at the PF level? Could it be that the results are similar because of coalition lack of dynamics (small coalitions).

What can be obtained from Figure 9.4:

1. Explain what the different instruments are and the different policies

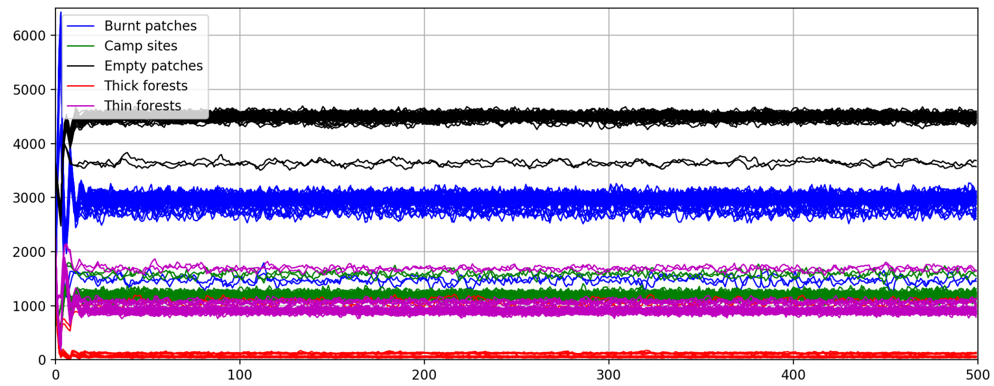

Figure 9.1: Results from the forest-fire model showing the number of cells in the different states for 50 runs in experiment 1. The results are shown only for the backbone but are similar for the backbone+ and the ACF.

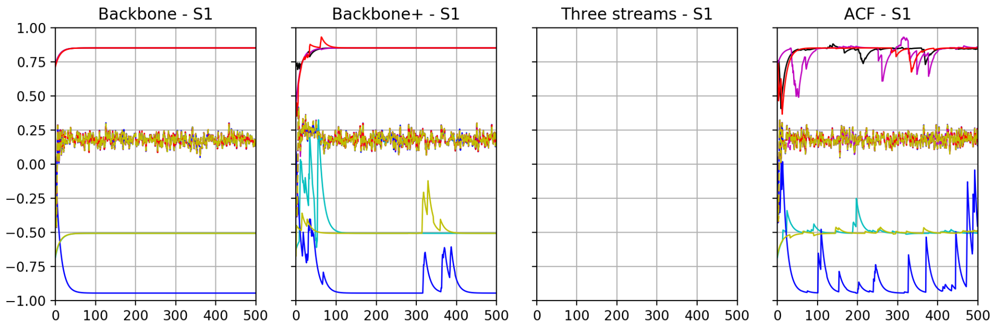

Figure 9.2: The first secondary belief of all policy makers for all four models. The full lines represent the aims while the dotted lines represent the states. This is plotted for the base case.

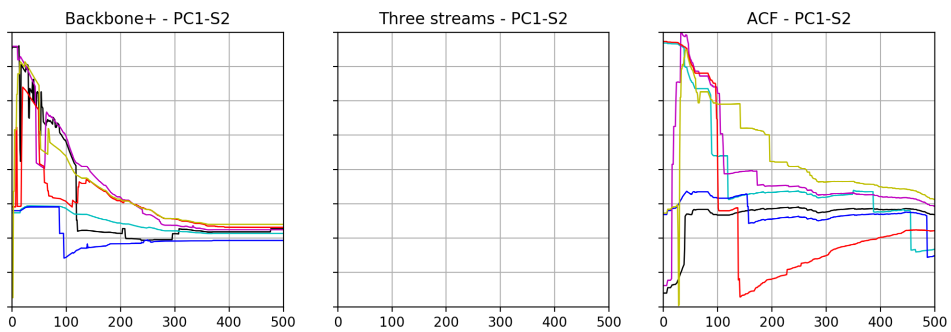

Figure 9.3: The causal relation linking PC1 and S2 for all policy makers present in the model.

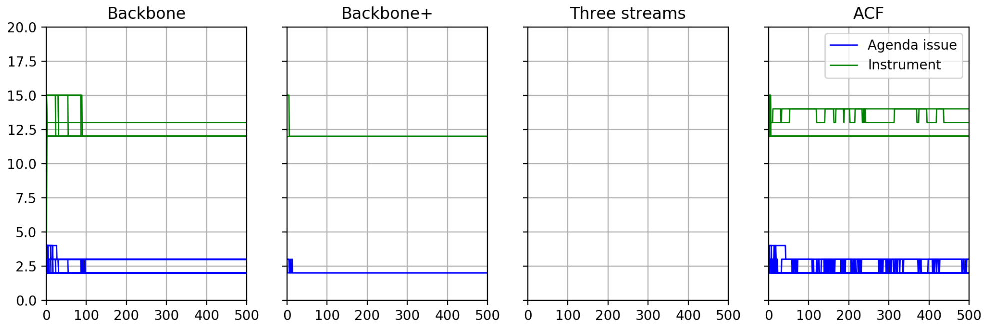

Figure 9.4

2. Explain why they are being chosen
3. Make a comment on why the model is so stable and there is very little change.
4. Make a comparison of the three models.

What still needs to be shown from the results obtained so far:

1. Exploration results - showing the impact of the different extreme values (if any)
2. The impact of one dominant agent on policy learning and instrument choices (study of several results with same beliefs tree type per model).
3. Impact of coalitions compared to normal models on the agenda outcomes.
4. Impact of different profiles for the belief trees to justify the use of a scenario analysis approach - check per type of model.
5. Impact of the external parties on the electorate
6. Study of the network evolution for different cases and discuss.

9.3. The Policy Instrument Selection

9.4. The Policy Learning

9.5. The Network Impact

9.6. Team Dynamics

9.7. The Coalition Dynamics

9.8. The Partial Knowledge

10 Discussion and Conclusion

To conclude this work, it is important to reflect on the initial research question formulated in the introduction. It was given as: "How can the emergence of policies be simulated using policy process theories within an agent based framework?". The research sub-questions also helped established a direction for the research performed in this thesis. These questions are answered here with additional discussions. In section 10.1, the relation between the policy making theories and agent based modelling is discussed in relation with the first sub-question. The second sub-question is addressed in section 10.2 with an explanation of how these policies were integrated together and into an agent based model. section 10.3 details an answer on the usefulness of the model brought up in the third sub-question while section 10.4 looks into the limitations of this model following sub-question four. The main question research question is then answered in section 10.6. This thesis is completed by a small section highlighting the work that still needs to be done in section 10.5.

10.1. The Policymaking Theories and ABM

Research sub-question 1 is given as:
What parts of the different policy making theories can be integrated into an agent based model?

Agent based models are composed of several specific parts. They are populated with agents which each have their own interaction rules. The agents are created in a space that is surrounded by the environment. This environment can have an impact on what is happening in the model through inputs. Finally, the simulation in an agent based model happens over time. All of these elements can be used to assimilate the policy making theories into an agenda based model.

There are several parts of the policy making theories that relate to the agent aspect in an agent based model. The first obvious one is related to the actors that are naturally part of the political arena mentioned in the different theories. These actors can be easily assimilates as agents. Furthermore, the teams as mentioned within the entrepreneurship model and the coalitions in the advocacy coalition can also be considered as actors with different properties than other agents in the model.

Agent based models are composed of agents that can each have their own rules that they follow. This fits well with the different theories that are present in the literature on how the actors operate in each of the policy making theories. The policy entrepreneurship is used in the literature to provide a framework of the class of actions that the actors can perform. This is mostly used in the context of the three streams theory. The same can be said of the advocacy coalition theory that is used to define what and how actors act in and out of their coalitions within the advocacy coalition framework.

The environment is also an important aspect of agent based models. It interact with the model itself through inputs. These inputs are the results of external events or simply are the outcome of another model which is not part of agent based model. This, once again, fits appropriately within the context of policy emergence and all of the policy making theories. The policy emergence process does not happen in a vaccuum. It is heavily impacted by external events occuring frequently throughout. It is also impacted by the current state of the world. Both external events and the states of the world can be used as input for the policy emergence model.

Agent based models processes occur over time. This is also the case for the policy process which vary from several weeks to several decades depending on the case being considered but also depending on the policy making theory studied. This time aspect needs to be taken into account when designing an agent based model.

Finally, and maybe most importantly for a policy emergence model, agent based models can simulate emergence. Because the sum of the behaviours of all the agents in an agent based model is larger than the sum of each of the agent's behaviour, emergence pehnomena can be observed in such simulation. This is of particular interest when looking at the policy emergence process. The aim of the model conceptualised and produced in this thesis is to observe such emergence process in the policy context. It is therefore fitting to use an agent based model for that.

10.2. From Theories to Model

Research sub-question 2 is given as:
How can we translate both the specifics and the assumptions of the theories into an agent based model?

To be able to construct the model, a lot of assumptions had to be made starting for the formulation of the conceptualisation from the literature, and then from the conceptualisation to the formalisation (which was use to code the model). These assumptions were necessary due to the lack of details within the different policy making theories and due to their highly qualitative aspects.

These assumptions help turn a qualitative approach into a quantitative and operational model. The first of these assumption and the most controversial one is the assumption that the policy process can be modelled as a policy cycle. This assumption is made mainly with the structure of an agent based model in mind which requires a cyclic structure. It is also made because some literature does argue that one of the possibilities of representing the policy process is through a policy cycle (Bridgman and Davis, 2004; Jann and Wegrich, 2007; Wyner and Benn, 2011). The policy cycle type chosen here is unlike any policy cycle mentioned in the literature as it is ultra simplified into two main parts: the part for the policy emergence and the part where the policy has been implemented and the world reacts to it. The first part of this cycle is the one of interest for this work. It can be divided in an unlimited amount of parts with decreasing level of aggregation. However for simplicity, the model presented in this report only considered two steps which are called the agenda setting and the policy formulation phases. Although commented upon, this approach was validated through expert interviews. This is mostly related to the fact that the two steps selected for this thesis (agenda setting and policy formulation) are close to the literature when it comes to policy cycles.

The second important assumption that was made relates to the way the agents' belief system was constructed. This belief tree presented in the conceptualisation is an extrapolation of the belief system that is presented within the advocacy coalition framework literature (Jenkins-Smith et al., 2014). This tree was constructed with several aspects in mind: first the agent's belief must hinge on a gap between what they see as reality and what they seek to achieve. This is considered as the main driving factor for agents. Second of all, these agents must have an understanding of what is happening in the real world regardless of whether this understanding is indeed correct. This resulted in a belief tree with causal relations linking the different echelons of the tree. An additional assumption that was made, and which is not based on the literature, is that this belief tree approach can also be used for agents within the three streams theory, the diffusion theory and the feedback theory. This is required to operationalise the model and is welcome as it allows for the agents to all be based from the same structure for all policy making theories considered.

Finally, multiple small assumptions were made regarding the actions that the actors can perform. The literature does not specify or formalise what type of actions the actors perform. They mention that actors performing networking actions, they work to gain credibility and work to create coalitions (Mintrom and Vergari, 1996). There are mentions of actors performing reframing actions without specifying how or on who. Assumptions were therefore made to specify these loosely defined actions from the literature. Three main actions were devised such that they impact the different parts of the belief tree. A framing action will impact the causal relations belonging to the tree. Agents can also influence each other's belief and understanding of the states of the world directly. All of these actions were devised in the aim to recreate the policy learning behaviour that the ACF theorises happen over long periods of time.

The conceptualisation resulting from all these assumptions is a model that can accomodate the four policy making theories chosen for this thesis. Most of the concepts mentioned in all of these four theories are present. This is further documented in Appendix F. Furthermore, the four theories can be simulated using one common approach.

10.3. The Model Usefulness

Research sub-question 3 is given as:

What use can the model provide for political scientists?

The model can provide considerable insight into the process of policy emergence in any one case study and can be used as a formidable tool for political scientists. The first important point is the ability for the researcher to test different types of scenarios. This can be done through the use of external events. The number of possible external events is only bounded by the eents that occured in the case study. The researcher can therefore study the impact of these external events. (S)He can also build scenarios with different successions of external events. This freedom in the use of external events will allow a more in depth analysis of the system and how it responds to external events than a simple qualitative study. This is the first advantage of this model.

This model also allows the modeller to compare different policies and instruments. The aim here is not to test the impact policy A versus policy B but to gauge the response of the political arena to the introduction of a new policy in the system. Depending on the policy network and the resources distribution in the political arena, the selection of that policy instrument will vary. Although, one cannot expect a prediction, the modeller would certainly be in a position of looking at the behaviours in the model. For example, what effects did the policy network or the policy learning had on the resulting instrument. This approach would be more adequate for a post analysis of a case study to try to learn from mistakes.

The number of parameters present in the model allows for the representation of different institutions and different legislative processes. This is an important aspect for researchers that want to compare different countries which have adapted drastically different policy instruments for similar case studies. The model can help understand at what point the differences in the specific situation of each country led to the differences in the policy emergence process.

Because of its complexity and its potential total amount of outputs, the model can also provide an in-depth understanding of policy emergence dynamics. The researcher can look at which agents have more impact on other agents over time and understand why that situation occured. There is also the possibility of studying the policy network dynamics. This can be done at the overall network level but it can also be done at the team and coalition levels. At this level, temporary networks are created for the teams and coalitions to interact with the agents not included within them. The researcher can look through these network to analyse the impact of the teams and coalitions.

Finally, the model allows for the tracking of the policy learning for each of the actors. As each agent has a record of his perceived belief of the other agents, it is possible to track how the policy learning is evolving and for what issues or causal relations within the belief tree. This could provide particularly interesting insight in the propagation of knowledge within the model if these partial knowledge trees are appropriately intialised.

10.4. Model Limitations

Research sub-question 4 is given as:
What are the advantages of an agent based model versus a more qualitative analysis? Can they be complementary models?

Despites all its positive aspects, there are limitations to the model. These limitations are mostly related to the complexity of the model and as a consequence, the required inputs. The main limitation is related to the amount of required inputs for the agents. There are two main ways for a modeller to approach the selection of inputs for the belief trees of the agents and the policy network. The first one would be to model the real world as is within the policy emergence model. This would consider using the same number of agents as in the real political areana, conducting interviews with the actors to populate the belief trees and obtaining an deep understanding of the policy network. This is a process that is expected to take a lot of time. It could even take more time than conducting an actual qualitative study of the case at hand. Furthermore, the size of the model resulting from such an approach could result in a staggering amount of data to be processed and analysed. However this approach provides researchers with a ready-made infrastructure that corresponds with their choice of theory. This should save them the time and effort of conceptualising, formalising and coding a new model.

The second approach would be destined to a less novice researcher in modelling or programming. This method would still require an extensive analysis of the actors and their network. However, the researcher could then use this data to produce a model that is comparable in proportions to what is visible in reality. For example, the number of actors representing a certain political party will be proportional to the number of seats they have in that specific legislature. The beliefs would also have to be approximated to a lump of actors being represented by one agent. The same would also apply to the policy network. This approach is something that would require an understanding of reducing a large number of actors into a limited number of agents. Just as modelling is, this is more of an art than a science. In this case, this is a problem. The resulting model would however be smaller and more manageable. The results and analysis could also be of more interest than the full model.

The second limitation relates to the size of the model and the number of parameters that one used in the model. Although the number of parameters is an asset, it is also a limitation of the model. The researchers using the model will need to have a deep understanding of what each of these parameters does if they wants to change any of them. Furthermore, the setting of these parameters might need to be tweaked depending on experiments performed or case studies being looked at. This is a complicated and time consuming step that makes such study cumbersome. This is also particularly important for the initialisation of the partial knowledge. How these partial knowledge belief trees are initialised has a very real impact on the subsequent proceedings in the model. This is due to the fact that all agent actions are performed based on partial knowledge.

The third and last main limitation relates to the data analysis. Considering the amount of data that can be outputed from the model, this step of the simulation will either require a complex graphic user interface or a programmer that can process the data in graphs that can be understood by the researcher. The researcher will also have to pinpoint his interests to be able to limit the output data to a manageable size.

Overall the limitations are related to the model size and complexity. This calls into question the use of this model against the use of a more traditional and qualitative method for case studies. The choice here has to be made by the researcher. The model might be more appropriate for the comparison of case studies dealing with the same industry or field but in different countries. This could help try to understand why similar or different outcomes emerged in these different countries. For single case studies, the simple fact of gathering the data for this model would be sufficient to perform a qualitative study already. In most cases, this will be sufficient for the researcher. In cases where it is not, then the model could also be used. It is also possible for the modeller to use both, starting with a qualitative study and use this data to further his/her research with a quantiative analysis.

Depending on final result outcomes, add something about the model being dependent on external events.

10.5. Further work

The work presented in this report was just a preliminary test of the integration of the different policy making theories together into one model. This work is far from being finished. The entire list of what the author has thought about for further work is outlined in Appendix E. The first two main aspects are the implementation of the diffusion theory and the feedback theory. These two theories are not yet present in the Python code which only currently includes the three streams theory and the advocacy coalition framework.

Due to the overall amount of parameters but also to the computational efficiency of the code, not all possible parameter studies were performed within this work. This analysis would be required for further work to better understand the impact of each of the parameters present in the model and whether they were appropriately conceptualised.

An important part of the formalisation which has yet to be introduced in the Python code relates to the states selection by the external parties. It was theorised that the external parties will not necessarily be interested in all states but will focus on specific states related to their core interests. For example, a NGO concerned by the environment will be less likely to be interested in states related to education. This approach of selective information still needs to be implemented. It is expected to have a major effect on differentiating the states that each of the agents perceive in the model. This should lead to drastically different results compared to the results presented within this report. The resulting model would be more dynamic

Throughout this report, the partial knowledge belief initialisation has been mentioned as an issue. This initialisation is what defines the warmup time. It can have a large impact on the results of the model. It would therefore be important to conduct a thorough study of how these partial knowledge trees should be initiated. It would be important to know if a fully random set of values is more effective than a distributed set of inputs depending on affiliation of the actors and the issues considered.

Currently the policies and policy instruments are being specified as inputs by the modeller. There are however ways to extend this approach into an endegenous approach where it is the agents that create the policies they want to consider. An approach similar to the one presented in Taeihagh et al. (2009) could be used for this. This would be added as a module to the current model and could use the already developped agent based model developped in Taeihagh et al. (2009).

It would also be important to perform a full fledged case study. In the work presented in this thesis, the case selected is minimal and not grounded in reality. It would be important to use acurate and real inputs and test the model in such an evnironment with all external events that occured. This type of study would be able to validate the approach taken to see whether the model can be used to reproduce what a qualitative study would have done.

10.6. Conclusions

[This is related to answering the main research question]

A

Emergence Model Formalisation

This chapter presents the formalisation of the concepts outlined in the conceptualisation. This chapter first presents the different key parameters needed to shape the simulation. It is followed by an explanation of the overall model cycle, the backbone model and the intermediate model. The three streams model is then formalised followed by the advocacy coalition framework model. The chapter is concluded with the diffusion module, the possible addition of policy brokers, and the additional required algorithms.

[What should be done about agent motivation and the tracking of agent motivation?]

A.1. Parameters

This section presents the different key parameters that are present within the model.

A.1.1. The system and subsystems

The overall model is composed of two main parts: the system (Sys) and the technical model ($Tech$). The system is presented in this chapter. The technical model is the real world simulation that feeds the system with inputs and which uses the system's output as inputs for its world simulations. If the system has no output, then the world simulations can be performed unchanged.

The system is populated with a set of subsystems given as $sSys = \{sSys_1, sSys_2, ..., sSys_n\}$ and where $sSys \subset Sys$. These subsystems represents various separated geographical retions where policy emergence is observed. These subsystems are separate but can be linked through concepts developped in the diffusion theory (see section A.8). Each subsystem is populated with a set of agents with a specific policy networ, a specific affiliation network and a specific electorate. They also each have an agenda. The system itself has a certain pool of modeller-defined policy instruments that can be used in any of the subsystems by the agents. Furthermore, to connect the subsystems, a super-policy network is created between agents of different subsystems. Finally the belief tree is a system wide component. The way it is populated will differ from subsystem to subsystem and from agent to agent.

A.1.2. The agents

The model is composed of five types of permanent agents and one temporary agent. These are divided in two main categories: the agents considered as they have to spend resources to perform actions and the agents that are passive as all the actions they perform happen regarldess of resources or of the situation. One agent fits in both categories.

Active agents The active agents are the policy makers, the policy entrepreneurs and the external parties. Note that the external parties also have a passive role in which they provide the states from the truth agent, to the policy makers, the policy entrepreneurs and the electorate. This is however considered to be a passive action as it happens every cycle regardless of resources. Furthermore, both the policy makers and policy entrepeneurs can get temporary upgraded to policy borkers in which case they can perform additional actions. This is detailed later on.

The active agent's attributes are given as follows:

1. The *active agent* is represented as an 9-tuple given by `agent = (ID, subsystem, type, beliefTree, affiliation, advocacy, resources, coalition, team)` where `ID` is the unique ID of the agent, `subsystem` is the subsystem ID in which the agent is present, `type` is the choice of agent type, `beliefTree` is the agent's personalised belief tree, `affiliation` is the political entity the agent identifies with, `advocacy` is the list of the issues the agent is supporting, `resources` is the agent's resources (a relative value), `coalition` is the coalition ID to which the agent is a member of, and `team` is the team ID to which the agent is a member of.
2. A *type* corresponds to a choice of agent. This can either be a policy maker, a policy entrepreneur or an external party. Depending on the choice selected, the behaviour algorithm will be different impacting the actions performed by the agent. The use of the parameters specified for the agent will also be affected leaving some unused.
   The policy makers are the only agent present in the model that can decide on what is to be placed on the agenda. They also have the responsability to choose what policy instrument will be adopted. The policy entrepeneurs are agents that can influence the policy makers but do not have decision making power. The external parties are agents that report the state of the world to the other agents. They can also influence the electorate and reframe issues for policy entrepeneurs and policy makers. They are the representation of the media industry or institutions within the model.
3. The *belief tree* is made of two main parts: the agent's own belief tree structure and values and the belief trees of all other agents and their values based on the agent's perceived knowledge of their beliefs. The entire *belief tree* structure is therefore a list of belief trees which is as long as the number of agents in the model. The details of the tree structure itself are provided later on.
4. The *advocacy* is represented as a 4-tuple `(prob_as, pol_as, prob_pf, prob_as)` where `prob_as` is the problem chosen by the agent during the agenda setting process, `pol_as` is the policy chosen by the agent during the agenda setting process, similarly `prob_pf` and `pol_pf` are the problem and policy selected by the agent during the policy formulation process. Note that some of these might not be used depending on the theories considered at any point. As is explained later, the backbone does not require agents to choose a policy for the agenda setting process but this parameter is required for the three streams approach.
5. The *resources* is represented as a value. Resources are distributed to the agents based on their affiliation and on that affiliation's representation within the model. These resources are used by the agent to perform influencing actions on other agents.

6. The *team* is represented as a 3-tuple given by `(team ID, belonging, strategy)` where `team ID` is the team to which the agent belongs, `belonging` is the agent's feeling of belonging in a team and `strategy` is the agent's strategy when wanting to create a new team. The *belonging* value relates to the amount of resources an agent is willing to commit to his team. This is calculated based on the difference between his belief and the average belief of the team leader for the specific issue for which the team is assembled. This parameter is not active when the agent is not part of a team and is therefore set to 0. This means that 100% of the agent's resources will be used for his own actions. There are two *strategies* that can be used to create a new team. The first is that the agent will create the largest team possible incorporating all agents he meets and that matches specific requirements in his team. The second consists of limiting the size of the initial team by only creating a team with the first few agents that match the requirements to start a team. These strategies are futher explained later on.
7. The *coalition* is represented as a 2-tuple given by `(coalition ID, belonging)` where `coalition ID` is the coalition to which the agent belongs and `belonging` is the agent's feeling of belonging in the coalition. The *belonging* value relates to the amount of resources an agent is willing to commit to his coalition and is calculated similarly to the belonging value for teams.

Passive agents The passive agents are the truth agent and the electorate. Both types of agents only perfom passive actions.

The truth agent: There is only one truth agent within the model. This agent helps make the link between the technical model and the agents within the model. It gathers all the states of the world and provides it, as it is, to the external parties. Only one truth agent is present per subsystem. The only attribute of the truth agent is the belief tree. This is a different one that for the active agents. It only contains the overall similar structure without any causal relations. It only contains the states for each of the issues.

The electorate: The electorate represents the voting public within a subsystem. There are as many electorate agents as there are affiliations in the model per subsystem. The role of the electorate is to influence the policy makers in their aims. The following defines the attributes of the electorate.

The *electorate* can be given as a 6-tuple written as: `electorate = (ID, subsystem, affiliation, beliefTree, representation)` where `ID` is the unique name of the electorate, `subsystem` considers in which subsystem it is, `affiliation` is its associated affiliation, `beliefTree` is the associated belief tree of the electorate and `representation` is the percentage of the total population which this electorate represents within the model. The addition of all *representation* parameters must be equal to 100 when added up together. The `representation` parameter affects the amount of resources received by the policy makers.

The belief tree of the electorate is similar in structure to the one of the truth agent. It only contains the issues.

A.1.3. Belief tree

The belief tree is composed of two main parts: the issues and the causal relations. The issues are categories in three layers: the deep core issues, the policy core issues and the

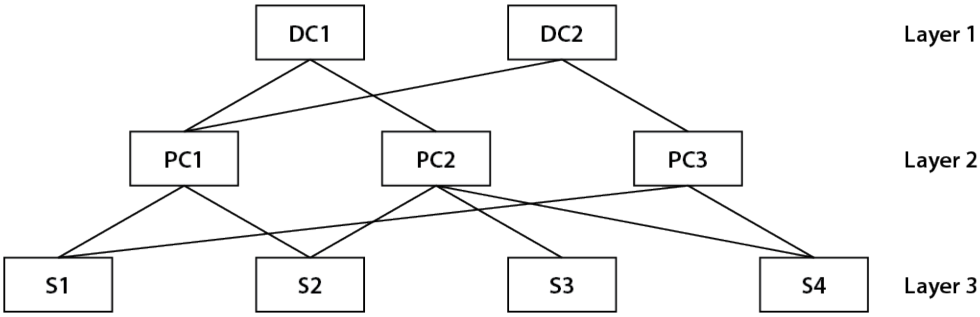

Figure A.1: Example representation of a belief system with the different layers and several links between the layers.

secondary issues. Secondary issues are linked to policy core issues through causal relations while policy core issues are linked to deep core beliefs through different causal relations. The overall representation of this tree structure is shown in Figure A.1.

Each issue is categorised by four parameters: the state, the aim, the preference and the awareness. The state defines the view of the agent of a certain i sue as it is in the real world. This view does not have to match reality and can be influenced by other agents. The aim shows what the agent would like to see hapenning in the world. The preference which is a derived parameter, defines the importance that the agents places on the different issues. It is calculated depending on the state of the issue, the aim of the agent and the causal relations linked to this issue. The sum of all preference weights on any single layer of the belief tree have to be equal to 1. Finally, the awareness represents the fact that agents are aware of a specific issue or not. It can take the value of 0 or 1. If an agent is not aware of an issue, it will not consider it in any calculation as if it did not exist. The belief tree structure also contains causal relations. These links the issues on the different layers of the structure. These are the representation, in the agent's mind, of how each of the issues are related to each other within the technical model and which issues affect which other issue.

Based on these initial explanations, it is possible to specify the belief tree structure as follows:

$$belief tree = [own_{tree}, others_{tree,n}] \tag{A.1}$$

where n represents the number of agents present in the model.

To further specify the tree of the agent considered, the following can be said:

$$\begin{aligned} own_{tree} &= [issues_k, causal\ relations_l] \\ issues &= [state, aim, preference, awareness] \end{aligned} \tag{A.2}$$

where k defines the number of issues present in the belief tree structure and l the number of causal relations.

And it is also possible to specify the structure used to saved the perceived knowledge of the belief of the other agents:

$$\begin{aligned} other_{tree} &= [issues_k, causal\ relations_l] \\ issues &= [state, aim] \end{aligned} \tag{A.3}$$

Note that there is no need to calculate the preference of other actors. This is because that is not used within the decision making process of the agents to select a specific action to perform.

In both cases, the issues are specified with deep core issues first, policy cores following and ending with secondary issues. The causal relations are specified in the following example order: DC1-PC1, DC1-PC2, DC2-PC1, DC2-PC2, PC1-S1, PC1-S2, ... The state, preference and causal relation parameters are then specified on the interval of [-1, 1]. The preference is a percentage based parameters and is therefore calculated to be a number on the interval [0, 1].

A.1.4. Policy network

The policy network represent the links between the different agent within a single subsystem. The attributes for these links are given below:

1. A *policy network link* is represented as a 7-tuple `link = (agent1, agent2, trust, trustDecay, conflictLevel, temp1, temp2)` where `agent1` and `agent2` are the agents at the end of a link, `trust` is the trust value, `trustDecay` is the decay value at which the trust diminishes per time interval, `conflictLevel` is the conflict level characterising the relation between two agents for specific issues and *temp1* and `temp2` are the parameters used for when an agent is in a team or a coalition.
2. The *trust* value can take three main values. For -1, there is no knowledge for both actors that they know they exist. This means that they cannot network together without external introduction from a third party. For 0, the actors have no connection but know each other exist. Any positive integer relates the value of trust between the two agents. The trust is given on the interval $]0,1]$. Note that trust is relative amongst all links. The policy network links between policy makers can never be -1 as policy makers are public figures. Furthermore, a link cannot be downgraded to -1, it can only start at -1. As the trust decays over time at a specific rate, there are several actions or events that can lead to a growth or stop the decay in the trust between two agents. This is detailed later on.
3. The *trust decay* is represented by a 3-tuple `(value, initial, time)` where `value` is the current value of decay which changes depending on the interaction of the agents, `initial` is the initial value of the trust decay that is a set value set by the modeller initially and `time` is an integer stating the amount of time intervals left before the value returns to its initial value.
4. The *conflict level* parameter is determined for each agent for each issue's aim and state. Note that the conflict level between two agents will be difference depending on which agents is considered as the conflict level is obtained based on the perception of another agent's beliefs. The conflict level is therefore given as a 2-tuple for each link: `(agent 1, agent 2)`. Then for each agent, the conflict level is defined per issue for the state and then for the aim. The conflict level is then calculated using:

$$\begin{aligned} aim\ conflict\ level_{n,n_m} &= |A_n - A_{n_m}| \\ state\ conflict\ level_{n,n_m} &= |S_n - S_{n_m}| \end{aligned} \tag{A.4}$$

   where A is the aim, S is the state, n is the agent for which the conflict level is calculated and n_m is the perceived belief of agent n on agent m for that specific issue.

The resulting value is then formatted into a coefficient to be used in the grading of actions as is shown later on. When the result obtained is between 0 and 0.25, the conflict level is considered to be low, the coefficient is then set at 0.75. When the result obtained is between 0.25 and 1.75, the conflict level is considered to be medium, the coefficient is set to 0.85. Finally for a result higher than 1.75, the conflict level is considered high and the coefficient is set to 0.95. Note that the coefficients values can be varied by the modeller during experimentations.

5. The *temporary* parameter is only used when one of the two agents joins a team or a coalition and is given as a 3-tuple by: `type, trust, conflictLevel`. The `type` refers to whether the agent is in a team or a coalition. The `trust` is calculated as follows. Assume there is a link between `agent1` and `agent2`, and that `agent1` enters a team. Then the trust parameter of the links of all agents within the team with `agent2` are considered and averaged into one value. This value then becomes the temporary trust parameter for the link. A similar behaviour is considered for the `conflictLevel` parameter. However, it is not an average that is done but a case by case consideration. If one of these agent has an `average` conflict level then it is chosen. If this is not the case but there is a `high` level of conflict, that is taken next and then the `low` level of conflict is considered.
   The temporary parameters are either related to `agent1` because it joined a team or a coalition or `agent2`. This means that if both agents join a different coalition, then they will use a different trust level depending on which agent is communicating with the other and considering their presence in a team or a coalition. Furthermore, this will only happen if the agent is communicating on behalf of his team or coalition. In the case of direct agent to agent interaction, then the original trust value is used.
   Note that the *temp* parameter is wiped every cycle and reconstructed at the beginning of the team action cycle. This is done to more easily update the trust and conflict level parameters without the need for additional calculation and the need to consider the trust decay parameter.

A.1.5. Super-policy network

This network is modelled on the policy network model. However, it consists of connections only connecting agents which are in different subsystems. The parameters used are similar to the policy network parameters. The *temporary* parameters are however not used as coalition or teams are not considered on cross-subsystem communications.

A.1.6. Affiliation network

The affiliation network is a network that looks at the political affiliation of the different actors. Its links are represented as a 3-tuple given by `(affiliation1, affiliation2, affiCoef)` where `affiliation1` and `affiliation2` are the affiliations that are connected by the link and `affiCoef` represents the influence that an actor with an affiliation 1 can have on an actor with affiliation 2. The *affiliation coefficient* is given on the interval $[0,1]$.

A.1.7. System network

The systems network is a network similar with the affiliation network. It is however composed of directed links between the different systems. This network is exclusively used in the context of the diffusion theory. Each link is composed of a 3-tuple write as: `system1,`

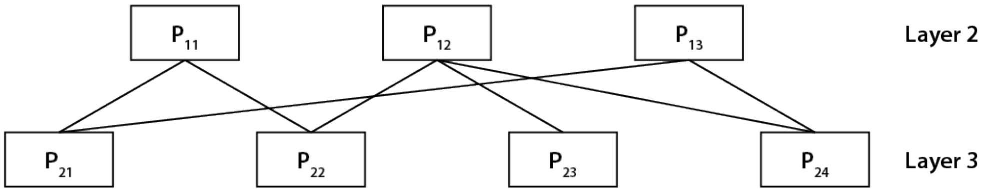

Figure A.2: Policy pond representation with the two levels of aggregation.

`system2, type)` where `type` defines the nature of the relationship between the two networks. It can be friendly, dominant, competitive or coercive. More details are provided later on in this chapter.

A.1.8. Policy pond and policy instruments

The policy pond is related to the three streams theory. This pond contains all possible policies which the agents can choose from. Within the scope of this work, there are two types of policies within this pond. They are differentiated by their aggregation level. The main difference between these two types of policies is that the lower level of aggregation policies are then ones that can be implemented as instruments by the agents present in the model. They can therefore also contain feedback effects. The two policy levels are related with parent children relations as shown in Figure A.2. These relations can be objctive or subjective depending on the theory considered. They represent the amount of relation between the policies on the different level in percentage. The policies are then given as:

1. A *policy* is represented as a 5-tuple `(name, impact, change, awareness, feedback)` where `impact` is related to the impact of the policy on a specific issue, `change` is the objective change expected in the model due to this policy, `awareness` is related to the avalability of the policy for a specific agent and `feedback` is related to the expected model feedback from the implementation of the policy considered.
2. The *impact* of a policy instrument is given as a 2-tuple: `(issue, impact)` where `issue` defines which of the issues is affected and `impact` specifies by how much. For higher level instruments, the issues are the policy core issues while for the lower level instruments, the issues considered are the secondary issues. The values for the impact are subjective and can be influenced by the agents in the model.
3. The *change* due to a policy instrument is the subjective representation of the impact of the policy instrument. These are the actual changes that will occur in the model with the implementation of the instrument. They are defined by the modeller and cannot be influenced by the agents present in the model. The structure of the parameter is similar to the *impact* parameter. Note that it is for the modeller to normalise all changes of all policy instrument if these policies are policies that apply on different durations. The way the instruments are graded is the same for all and does not take into account the time over which the policy instrument is to be implemented.
4. The *awareness* parameter defines whether a certain policy instrument is known in a subsystem. It is therefore defined as a list of 2-tuple: `(subsystem, awareness)` where `subsystem` defines which subsystem is concerned and `awareness` defines whether this policy instrument is known in the subsystem by taking the value 0 or 1.
5. The *feedback* parameter defines what additional feedback can be expected from the measure. The feedback can be placed into three main categories: impact on the elec-

torate composition, impact on the knowledge of the belief tree, impact on the resource allocation for policy entrepeneurs. These are related to the feedback theory.
In the case of impact on the electorate composition, certain policy instruments will lead to changes to the `electorate.representation` parameter. This change in turn will lead to the recalculation of the resources attributed to the policy makers.
For the impact on the knowledge of the belief tree, it is the $issue.knowledge$ parameter that can be affected. Specific policy instrument can place certain issues out of reach of the decision making process. They would then take the *knowledge* value of -1.

A.1.9. Agenda

The *agenda* is a 2-tuple given by `agenda = (problem, policy)` where `problem` is the problem chosen to be on the agenda, `policy` is the policy chosen to be on the agenda. Note that there is one agenda per subsystem. Furthermore, the agenda policy is not required in all theories considered. The policy appears on the agenda only when considering the three streams theory. This is elaborated on later on in this chapter.

A.1.10. Teams

The teams are created following the three streams theory. They contain a number of agents that feel they share their beliefs for a specific issue. A team is therefore given as a 6-tuple written as: `(team ID, lead, members, issue, creation, resources)` where `lead` is the leader of the team (the agent that created the team), `members` is the list of members that are part of the team, `issue` is the policy issue that the team is advocating for, `creation` is the time at which the team has been created and `resources` consists of the resources at the disposal of the team to perform actions. The resources are calculated as the sum of all the members belonging level. It is therefore a number that can be above 1.

A.1.11. Coalitions

This will probably be updated later.

A.1.12. The external events

The external events that are considered are external events that affect the policy emergence model. External events that would affect the technical model such as a flood for a hydrological technical model are of no interest and considered out of scope of this report. However, the impact on the model such as a change in the electorate composition due to a high amount changes due to the flooding is of interest.

The following is a non-exhaustive list of potential external events which the modeller could use.

1. An election - this would create a change in the `electorate.representation` parameter which would in turn lead to different resources allocation for the policy makers.
2. The introduction of a new issue - a new issue could be introduced to the system or to a subsystem. This would affect the `agent.knowledge` parameter for all agents present in the model.
3. Resources shift - a shift in the resources distribution due to an external event could be modelled. The `agent.resources` parameter would be changed.

4. Policy network shifts - change in the trust parameter.
5. Affiliation network shift - change in the `affiCoef` parameter.

A.2. The model cycle

This is the cycle iterated through when the entire model is considered. Different theories are related to the different parts of the model and are mentioned below:

1. Tick initialisation:
   (a) *World simulation:* The technical simulation which is an exogenous party to the model or an internal technical model are run to provide inputs for the next step.
   (b) *Trigger of external events:* Any event that the modeller decides to implement are activated at this stage of the model cycle.
   (c) *Update of the truth agent:* The technical output is converted into normalised data fitting with the issues present in the belief tree. These are placed in the truth agent's S parameters.
   (d) *Electorate action:* The electorate influences the belief of the policy makers.
   (e) *External parties belief update:* External parties update their S for the issues for which they are interested in. They update with the truth agent's beliefs.
   (f) *All agents belief update:* The rest of the agents which are not external parties or the truth agents have their beliefs updated. The external agents share their beliefs with the policy makers and entrepreneurs. This sharing of information is affected by the affiliation of the different agents.
2. Agenda setting:
   (a) *Agent issue classification and selection:* Each agent ranks his deep core and policy core beliefs. The agent then selects an issue that he will advocate for in his policy core beliefs based on his ranking.
   (b) *Creation of the coalitions (ACF):* Agents are set up in different coalitions according to their deep core beliefs. This step only occurs within the context of the advocacy coalition framework.
   (c) *Deliberations (Backbone+/3 Streams/ACF):* All agents deliberate and perform their actions. The deliberations do not occur when considering the backbone model. The details for each model are provided in later sections.
   (d) *The policy makers rank the issues:* Each policy maker updates his preferences for his deep core and policy core beliefs. This is to take into account the effects of the deliberations and influencing from the other agents.
   (e) *Agenda setting:* The system calculates the systemwide grades of the issues chosen by the different policy makers. They are then ranked and the issue at the top of the ranking is selected to be the agenda. This constitutes the agenda with which the policy formulation process will work.
3. Policy formulation:
   (a) *Policy pool selection:* Based on the issue selected from the agenda, each agent can select a certain number of secondary issues they belief will have an impact on the issue on the agenda. Related to these secondary issues, they can determine a set of policy instruments that would have an impact on the issue on the agenda through their secondary issues.
   (b) *Policy instrument selection:* Each agent selects a policy instrument that he will be advocating for during the policy formulation based on the set of policy in-

struments available to them.

   (c) *Creation of the coalitions (ACF):* Agents are set up in different coalitions according to their deep core beliefs. This step only occurs within the context of the advocacy coalition framework.
   (d) *Deliberations (Backbone+/3 Streams/ACF):* All agents deliberate and perform their actions. The deliberations do not occur when considering the backbone model. The details for each model are provided in later sections.
   (e) *The policy makers rank the instruments:* Each policy maker upgrades their policy instrument preferences after the deliberation phase.
   (f) *The system decides if a policy instrument should be implemented:* The system checks if the consensus threshold is being met. If it is, the policy instrument is implemented into the world simulation and removed from the model.
4. *The model advances to the next time step:* The clock is advanced to the next tick. End of ticks actions are also performed.

A.3. The backbone model

The backbone model refers to the smallest model used to simulate the emergence of policies. This model does not contain any of the theories found in the literature and is built in two main parts. In the first part, the agenda setting part, where the policy makers grade the issues according to their view of the world and decide on a policy and a problem to tackle. Next, in the policy formulation process, these same policy makers select a policy instrument based on their beliefs. If they meet the number of policy maker threshold for implementation, the instrument is implemented. Within this backbone model, the agents do not communicate with each other. The backbone model also contains the electorate agents. These can influence passively the policy makers as is shown in the algorithms shown below. The electorate feature can be turned on and off depending on the experiment or verification that is being performed on the model.

A.3.1. The backbone policy cycle

The backbone policy cycle is presented below. The steps that were already mentioned in detail previously are not re-explained.

1. Tick initialisation:
   (a) *World simulation*
   (b) *Trigger of external events*
   (c) *Update of the truth agent*
   (d) *Electorate actions*
   (e) *External parties states update*
   (f) *All agents states update*
2. Agenda setting:
   (a) *Agents deep and policy core issues preference update*
   (b) *Agent issue classification and selection*
   (c) *Agenda setting*
3. Policy formulation:
   (a) *Agents secondary issues preference update*
   (b) *Policy pool selection*

   (c) *Policy instrument selection*
   (d) *The system decides if a policy instrument should be implemented*
4. *The model advances to the next time step*

A.3.2. Tick initialisation

This section presents the different algorithms required to appropriately initialise each tick in the model.

Agent beliefs update All agents must been updated on the different issues' progress based on the world simulation and the information that the external parties have gathered. These updates are based on the affiliations of the agents and the external parties they are communicating with. For each agent, the updated beliefs of the agents are given by:

$$S_{agent} := S_{agent} + \frac{1}{n}\sum_{i=1}^{n}\left(\left(S_{EP_n} - S_{agent}\right) \cdot affiCoef_n\right) \tag{A.5}$$

where S stands for the issue state, EP stands for external parties and $affiCoef_n$ is the affiliation related weight. The affiliation coefficient is the one that relates the affiliation of the agent and the affiliation of the external party selected.

Electorate action on policy makers How the electorate are updated from the truth agent has yet to be formalised and introduced in the code. Right now, the electorate is an agent with a static belief.

The policy makers are passively influenced by the electorate. Each electorate has a certain affiliation to which policy makers are also related. Each policy makers' issues will therefore be influenced by their respective electorate. This happens as a passive effect where the issue aims of the policy makers slowly progress towards the issue aims of the electorate. The gap is introduced in the equation to mark a sense of urgency. The equation to calculate the change in the aim of the policy maker is given as follows:

$$A_{PM} := A_{PM} + (A_{El} - A_{PM}) \cdot 0,001 \cdot |A_{El} - S_{El}| \tag{A.6}$$

where El stands for electorate and PM for policy maker. Note that this is only performed for the issues of the policy maker for agents with matching affiliations.

A.3.3. Agenda setting

This section presents the different algorithms that are used to set the agenda and obtain an issue at the end of this step.

Preference calculation update (deep and policy core issues) - Policy makers and entrepreneurs The preference parameter for the beliefs of the agents defines which issue the agent will want to address first. This parameter is calculated for all issues present in the belief tree. Within the context of the agenda setting, the preference is only calculated for the deep core and policy core beliefs.

To calculate the preference for all of the deep core issues per agent, the gap between the state and the aim is calculated for each issue. It is then normalised amongst all deep core issues to formulate the preference. The equation is given as follows:

$$P_i = \frac{|A_i - S_i|}{\sum_{j=1}^{n} |A_j - S_j|} \tag{A.7}$$

where j is defined at the number of deep core issues and i characterises the deep core issue being selected for the calculation.

For the policy core, a similar approach is being used. The main difference resides in the fact that there are causal relations that should also be taken into account. These causal relations are not always helping bridge the gap between the aim and the state of an issue. If they do not, they must then be discarded. To calculate the new preference, the gap for the issues is considered along with the impact of the causal relation on the gap of the issues on the above layer. Once again, all the preferences on one layer must be normalised. The resulting equation that can be used to calculate the preference is given by:

$$P_k = \frac{|A_k - S_k| + \sum_{j=1}^{n} |CW_j \left(A_j - S_j\right)|}{\sum_{l=1}^{p} \left[|A_l - S_l| + \sum_{j=1}^{n} \left|CW_{j,l} \left(A_{j,l} - S_{j,l}\right)\right| \right]} \tag{A.8}$$

The sums only include these terms if CW_j and $\left(A_j - S_j\right)$ have the same sign. If it is not the case, these terms are not considered. And where p is defined at the number of policy core issues, k characterises the policy core issue being selected for the calculation, j specifies the associated deep core and CW represents the weight of the causal relation.

Note that Equation A.8 also applies to the secondary issues but with everything considered one layer lower.

Selection of the issue (agent) For the selection of the issue for whith the agent will advocate for, the policy core issues are considered. All policy core issues are ranked based on their preference value as shown earlier. The highest preference is chosen for each agent.

Policy ranking and selection (system) (1) To constitute the agenda, an issue has to be chosen for the entire subsystem. For this two methods are proposed which can yield different results. The first method considers all the top issues as graded by the agents. They are affected by the normalised resources of the agents. The grade of each issue is the sum of all agent's resources which have chosen that issue as their top issue. Whichever policy has the highest grade becomes the policy that will be chosen for the agenda.

Policy ranking and selection (system) (2) The second method used for the ranking and selection of the issues is similar to the first one. The difference is that here all issues are taken from each agents. They are then weighted all together and not simply the issues at the top of the ranking of each agent. This approach is meant to represent a different approach to the power dynamics in the model. The grade for each policy is then obtained as:

$$rankingGrade = \sum_{i=0}^{n} \left(\frac{1}{P_{rank}} \cdot resources_n \right) \tag{A.9}$$

where n is the number of agents and P_{rank} is the ranking of the policy for that agent. The issue with the highest grade is then taken as the issue for the agenda.

A.3.4. Policy formulation

This section presents the different algorithms that are used within the policy formulation step.

Preference calculation update (secondary issues) - Policy makers and entrepreneurs Within the context of the policy formulation, the secondary issue preferences have to be selected. The equation and the procedure are very similar to the calculation for the policy core issues in the agenda setting. The main different is that only issues that are related to the issue on the agenda are considered within the belief tree. Any secondary issue that is not related to the issue on the agenda is discarded and considered to be irrelevant to the agents.

Once again, the equation used to calculate the secondary issue preferences are given by:

$$P_k = \frac{|A_k - S_k| + \sum_{j=1}^{n} |CW_j \left(A_j - S_j\right)|}{\sum_{l=1}^{p} \left[|A_l - S_l| + \sum_{j=1}^{n} \left|CW_{j,l} \left(A_{j,l} - S_{j,l}\right)\right|\right]} \tag{A.10}$$

The sums only include these terms if CW_j and $\left(A_j - S_j\right)$ have the same sign. If it is not the case, these terms are not considered. And where p is defined at the number of secondary issues, k characterises the secondary issue being selected for the calculation, j specifies the associated policy core and CW represents the weight of the causal relation.

Policy instrument pool construction At the beginning of the policy formulation, a pool of policy instrument needs to be established based on the agenda. For this pool, all policy instruments that have an impact on a secondary issue without preference 0 are considered. The agent will then be able to select any policy instrument for that pool and to promote it to other agents during the policy formulation process.

Policy instruments ranking and selection (agent) During the policy formulation step, the agents must chose their preferred policy instruments from a pool of preselected policy instruments. For this, the agents look at the preference of the secondary issue (calculated previously) and adjust this preference with the expected impact of the policy instrument. The equation used to calculate the grade of each policy instrument is given by:

$$G_i = \sum_{j=1}^{n} \left[impact_j \cdot \left(A_j - S_j\right) \cdot P_j\right] \tag{A.11}$$

where n is the number of impacts this policy instrument has, and j represents the secondary issue and the associated impact of the policy instrument on that issue.

Note that an instrument is only considered if its impact is of the same sign as the gap. If this is not the case, the instrument will be counter productive in the mind of the agent and should therefore not be implemented. The grade assigned is then 0.

Consensus check 1 - Unanimity This check consists of checking whether all instrument chosen as the top instrument by the policy makers are the same. This is done by checking the `agent.advocacy.polins` parameter. If this is the case, the policy instrument can be implemented

Consensus check 2 - Majority The majority check is similar to the previous. Here however, the check consists at counting how many time each issue in the `agent.advocacy.polins` parameter there are. If the count is larger than half the number of policy makers plus one, then the policy instrument can be implemented.

A.4. The backbone+ model

The section presents the backbone+ model. This model uses the backbone model architecture but adds the policy network along with individual agent actions. This backbone+ model is an artifact of the formalisation from the conceptualisation. In strict terms it does not address a single policymaking theory in itself but helps build to all four theories addressed in this report. The items that are similar to what was presented in previous sections are not re-explained. The additional parts are detailed.

A.4.1. The backbone+ policy cycle

Each agent has a certain number of actions that (s)he can perform. Within the cycle presented earlier, these actions can be performed at the deliberations stage. An algorithm is devised for the agent to decide which actions to perform. This is shown below in details. Note that the deliberations for an agent end after all its initial resources are exhausted. The deliberation phase algorithm is the same for the agenda setting process and the policy formulation process. The main difference is the set of options that are available to the agents in each of the phases. For the agenda setting process, both the issue selected by each agent is discussed, this means that agents can perform actions on the selected issue and the related causal relations. In the policy formulation process, the agenda is already set. Agents must first select a secondary issue they will advocate for and hence a policy instrument. The action then performed are all related to either the secondary issue selected or the causal relations that relate to this issue. Agents can therefore only perform actions on issues and causal relations that are related to the agenda policies and problems and to the policy instrument they have each selected.

1. Tick initialisation:
   (a) *World simulation*
   (b) *Trigger of external events*
   (c) *Update of the truth agent*
   (d) *Electorate actions*
   (e) *External parties belief update*
   (f) *All agents belief update*
2. Agenda setting:
   (a) *Agent issue classification and selection*
   (b) *Deliberations:*
      i. *Resources receival:* The agent receives its resources based on modeller-specific data.
      ii. *Policy network upkeep or maintenance:* The agents perform actions that will either renew or maintain a policy network link. A part of the agent's resources are spent for this process. Agents can have one of two strategies: largest network strategy and focused network strategy. The strategy used by each agent is chosen by the modeller.

   iii. *Individual belief actions:* These actions are the actions that have an impact on the belief of the other agents directly or indirectly. The agents use all their remaining resources to preform these actions. For the external parties, these actions consists of blanket framing and electorate influence. For the policy makers and entrepreneurs, these actions are framing, and influence on state and aim of the issue they advocate for. These actions and how which is selected is detailed later on.
 (c) *The policy makers rank the issues*
 (d) *Agenda setting*
3. Policy formulation:
 (a) *Policy pool selection*
 (b) *Policy instrument selection*
 (c) *Deliberations:*
   i. *Resources receival*
   ii. *Policy network upkeep or maintenance*
   iii. *Individual belief actions:* The actions here are similar to the actions during the agenda setting process. The main difference is that these actions are focused on the secondary issues instead of the policy core issues as these are the issues that the agents are advocating for.
 (d) *The policy makers rank the instruments*
 (e) *The system decides if a policy instrument should be implemented*
4. *The model advances to the next time step*

A.4.2. Backbone+ model related algorithms - networks

This section details all the additional algorithms that are required for the backbone+ model related to the policy network. There is 20% of the resources for the agenda setting process that is reserved for the agent to spend on network maintenance. The agents are allowed to five actions each time spending 4% of the total amount of resources for each action. The order in which agents are selected to perform their network actions is random.

The two strategies that can be used for the maintenance of the network of an agent are mentioned below:

1. Largest network strategy - the agent will look into increasing its network as much possible:
 (a) The agent first wants to keep all links active. Any link that is below 30% trust level will be targeted for action. The lowest, but still above 0, will have priority.
 (b) If all links are above 30% trust, the agent will look into introducing new links which had 0% trust. The priority is placed on the link with agents with the closest beliefs.
 (c) If there are still resources left after step 1 and 2 are complete, the agent will maintain the link with the lowest trust level in the network.
2. Focused network strategy - the agent will focus on maintaining a network of agent sharing its beliefs: (note that when it is stated similar belief, this relates to the problem that the agent is advocating for and no other issue)
 (a) The agent will look first for link where an agent with a similar belief (one of the agents has his belief within 0.2 of the other agent's aim belief) or higher belief level and with a trust which is lower than 70%. The agent will prioritise based

only on the trust level as long as the belief criteria is met.
(b) If no link qualifies, then the agent will seek to introduce new links in his network. The agent will select agents that have a similar belief or higher belief level.
(c) If both step 1 and 2 are met, the agent will look into maintaining a trust level above 70% for links still in service. The priority is put on the links with the lowest trust value.
(d) If all previous steps are met, then the agent will simply look for new links.

The actions described above are explained in more details below.

Maintaining the trust in a network An agent can increase the trust in a network link if he feels the trust level is too low. This trust maintenance is dependent on three main parameters: the resources spent and the affiliation of both agents. The total increase in trust for such an actions is calculated as:

$$trust := trust + resources \cdot affiCoef \tag{A.12}$$

where the $affiCoef$ is the weight related to the affiliation of the two agents. If they share the same affiliation, then it is equal to 1.

Establishing a new network link Agents can also establish links with other agents for which they know they exist. This action can only be performed when the `link.trust` parameter is equal to 0.

If this is the case, then the trust can be increased through the spending of resources. The new trust level is then calculated similarly to the trust maintenance but with a small malus to account for the initial investment costs. The equation is given as follows:

$$trust := resources \cdot affiCoef \cdot 0.5 \tag{A.13}$$

Seeking agents of similar beliefs Similar beliefs are defined on the aim of an issue being advocated for at the policy core level. There are several steps to seek agents with similar beliefs:

1. Seek all links with trust equal to 0 or higher and select their associated agents.
2. Select the aim parameter of the problem of the original agent.
3. For each associated agent, check its aim parameter for this same problem issue.
4. Calculate the difference of the parameter between the original agent and the associated agent for this issue.
5. Rank all differences from lowest to highest where the lowest is considered to be an agent of similar beliefs.

This ranking is impacted by partial knowledge of the original agent on the associated agent's beliefs.

A.4.3. Backbone+ model related algorithms - external parties actions

This section details all the additional algorithms that are required for the backbone+ model related to the actions of the external parties. Out of all the resources reserved for external parties, 50% of these resources are devoted to blanket framing while 50% are devoted to electorate influence. These are each spent in interval of 10% of the total amount of resources dedicated to these actions. This means that overall, each external party will perform five blanket framing actions and five electorate influence actions.

External parties - Blanket framing The external parties can perform framing tasks. The framing expressed by these parties is called blanket framing as it impacts all of the agents present in a subsystem at once. This framing is focused on influencing all of the causal relations related to the issue that was selected by the external party performing the action. Its impact is dependent on affiliation and on the resources that the external party is spending. For each causal relation, the external party checks the impact of performing a framing action for all agents present in the model. This is based on his partial knowledge of other agent's belief on the causal relation. The grades are calculated as follows:

$$\begin{aligned} G_{cr,m} &= \left|\left(CW_n - CW_{n_m}\right) \cdot affiCoef_n \cdot resources \cdot \frac{1}{agents}\right| \\ G_{cr} &= \sum_{m=1}^{agents-1} \Delta G_{cr,m} \end{aligned} \tag{A.14}$$

where cr is the causal relation selected, n the external party performing the framing, m the affected agent considered, $nagents$ the total number of agents and CW the causal weight.

The action on a causal relation for which the grade is the highest is then selected to be implemented. The causal relation of the affected agents are then given by the following equation:

$$CW_m := CW_m + (CW_n - CW_m) \cdot affiCoef_n \cdot resources \cdot \frac{1}{nagents} \tag{A.15}$$

Note that this time, the actual causal weight of the causal relation is used and not the perceived one.

Not yet sure how to address this action with the new grading options. The action chosen could be based on the number of agents that prefer the issue of the external party after the action has been performed. This would require counting the number of agents that have for main issue the issue of the external party and the number of them that have it as a seccond choice and so on. If the situation is improved, then that action is selected.

External parties - Electorate influence The external parties can influence all the electorate's aims directly. The external party will only select the aim of the issue for which he is advocating for. The external party performs the action in his head using the following equation and his full knowledge of the other agent's beliefs:

$$A_{El,i} := A_{El,i} + \left(A_{n,i} - A_{El,i}\right) \cdot affiCoef_n \cdot \frac{resources}{nEl} \tag{A.16}$$

where n is the external party, i is the issue and nEl is the number of electorates. Note that for this action, it is assumed that the external parties know the aim value of the each electorate for each issue.

Then the external party will proceed to evaluate the preference of the agent influenced based on his partial knowledge of the other agent's belief. This is done for all actions and the grade assigned to each action is the absolute value of the difference between the aim of the external party influencing and the new aim of the agent being influenced. All of these grades are then added for each agent. The grade that is the smallest means that the action lead to agents becoming closer to the external party. The acton is therefore chosen to be implemented.

For the action chosen, the same equation is chosen. Because the external parties have full knowledge of the electorate's beliefs, there is no partial knowledge used and the expected results of the action will be the same as the actual results.

A.4.4. Backbone+ model related algorithms - policy makers and entrepreneurs actions

This section details all the additional algorithms that are required for the backbone+ model related to the actions of the policy makers and entrepreneurs. For each round of actions, the agent can spend 10% of the total amount of resources reserved for the belief actions. This means taht the agent can perform ten actions in total. For each round, the agent considers all actions mentioned below. Each of these actions is graded and then the action with the highest grade is chosen to be implemented.

After each action has been performed by one agent, the model randomly selects an agent and performs all these steps again until that new agent has performed his action. This continues until all agents have spent all their resources.

The equation to calculate the grade of each action and the one used to implement the actions are different. The first difference is that one will use partial knowledge of the other agent's belief while one uses the actual beliefs. The second difference is the introduction of the conflict level for the grading of an action. This parameter stems from the ACF theory and is a parameter that is used to describe the likelihood of two actors discussing on a specific topic. For average level of conflict, they are more likely to talk to each other for example. This parameter is not used for the implementation of the actions. Finally, a parameter is used for purposes of experimentation. This parameter is used to help facilitate the influence of policy makers. This is because they are the decision makers and could therefore be considered prime targets to get issues faster on the agenda for the agents in the model. For this, the actions affecting the policy makers can be weighed up compared to the actions of the policy entrepeneurs. This parameter can be varied by the modeller during testing to see what affects most the policy emergence process. It should be situated on the interval $[0,1]$. It is once again only used in the grading equation and not for the implementation.

Individual action - Individual framing The different agents can attempt to influence the causal relation belief of other agents. This framing action is similar to the blanket framing action of the external parties but applies to only one agent. Within the context of the agenda setting process, agents can perform framing actions on all causal relations related to the policy core they have selected. For the policy formulation, the causal relations considered are the ones related to the secondary issues selected which are influenced by the policy instrument selected. The change in the causal relation is obtained as follows:

$$CW_{n_m} := CW_{n_m} + \left(CW_n - CW_{n_m}\right) \cdot resources \cdot trust_{n,m} \cdot actionWeight \tag{A.17}$$

where n is the agent performing the action, m is the agent on which the action is performed.

Once the estimated new causal relation is obtained, the difference between it and the old causal relation is calculated and set as the grade for this action.

If a framing action is considered to be the best possible action, the following equation is used to implement that decision:

$$CW_m := CW_m + (CW_n - CW_m) \cdot resources \cdot trust_{n,m} \tag{A.18}$$

Individual action - Aim change Similarly to framing, agents can attempt to influence the aim of other agents. This is can be done during personal conversation and is therefore impacted by resources, trust and conflict level. The equation to calculate such change is given below:

$$A_{n_m} := A_{n_m} + \left(A_n - A_{n_m}\right) \cdot resources \cdot trust_{n,m} \cdot conflictLevel \cdot actionWeight \tag{A.19}$$

where n is the agent performing the action, m is the agent on which the action is performed.

Once again, to provide a grade to this action, the potential new aim is compared to the former aim of the agent.

If this action is selected, the following equation is then used to implement that action:

$$A_m := A_m + (A_n - A_m) \cdot resources \cdot trust_{n,m} \tag{A.20}$$

Note that this action's set of possible issue is different between the agenda setting and the policy formulation processes. In the first, only the policy core issue which was selected by the influencing agent can be used for actions. During the second, only secondary issues related to the policy instrument selected by the influencing agent can be used for the action. This is also true for the next action, the state change.

Individual action - State change Finally, similarly to the framing and aim change, agents can attempt to influence the view of the world of other agents through direct interaction. This is the state change action. This is once again done similarly to the other actions, through resources and is impacted by the trust and the conflict level between the agents.

The change is given by the following equation:

$$S_{n_m} := S_{n_m} + \left(S_n - S_{n_m}\right) \cdot resources \cdot trust_{n,m} \cdot conflictLevel \cdot actionWeight \tag{A.21}$$

where n is the agent performing the action, m is the agent on which the action is performed.

The grade provided is the difference between the potential new state and the former aim of the agent.

If this action is selected, the following equation is then used to implement that action:

$$S_m := S_m + (S_n - S_m) \cdot resources \cdot trust_{n,m} \tag{A.22}$$

A.4.5. Partial knowledge updates

As mentioned previously, each agent has a certain perception of the beliefs of all other agents in the model on each of the issues state and aims, and on the causal relations. This perception is updated every time an agent performs another action with a fellow agent. Depending on the action performed, each of the agent will gain knowledge about the other agents belief with a certain amount of randomness.

For blanket framing actions, the belief will be shared with a ± 0.25 randomness on the actual value. For framing, state and aim influence actions, the shared belief is associated with a ± 0.1 randomness value.

A.5. Backbone model with three streams theory

This section presents the model of the backbone and the backbone+ model combined to the three streams theory. The three streams theory brings the notion of the coupling of the policy stream, problem stream and politics stream. In the model, this require the addition of several elements. For this, the policy pond is more extensively used. For this model, in both the agenda setting and the policy formulation, the agent can choose a policy from the policy pond and can choose a problem. The problems are based on the belief tree and are defined in preference based on the gap between aim and state for each of the issues presented in the belief tree. Each agent can then choose from both policies and problems. A similar approach is used for the policy formulation.

Furthermore, in the spirit of the policy entrepreneurship model, teams are also added to the three streams model. This teams are used to accelerate the policy learning within the system. These teams can perform similar actions to the actions that each individual actions can perform.

A.5.1. The three streams policy cycle

The new policy cycle used for the three streams theory is presented below. Only the additional parts are detailed.

1. Tick initialisation:
   (a) *World simulation*
   (b) *Trigger of external events*
   (c) *Update of the truth agent*
   (d) *Electorate actions*
   (e) *External parties belief update*
   (f) *All agents belief update*
2. Agenda setting:
   (a) *Agent issue classification and selection:* The agent can select from policies or problems their issue.
   (b) *Deliberations:*
      i. *Resources receival*
      ii. *Agent-Team actions:* Each agent can decide to join or start a new team depending on his belief and his choice of policy or problem. Teams are constituted of members that share their beliefs on a policy or a problem. Related to these teams, several actions are performed such that the team will disband in the required circumstances. This is detailed later on.

iii. *Team actions:* When an agent is in a team, he will participate resource-wise to the team. This allows the team to influence agents that are outside of the team such that they align their beliefs to the team's beliefs. The team will also perform actions on its own members in such a way that the agents will have more coherent beliefs.
iv. *Policy network upkeep or maintenance*
v. *Individual belief actions:* Needs details ... (added actions)

(c) *The policy makers rank the issues*
(d) *Agenda setting*

3. Policy formulation:
   (a) *Policy pool selection:* The way the policy pool is defined is different within the context of the three streams theory. This is detailed later on.
   (b) *Policy instrument selection:* Similarly, the policy instrument selection is different for this theory. This is also detailed later on.
   (c) *Deliberations:*
      i. *Resources receival*
      ii. *Agent-Team actions:* Needs details ...
      iii. *Team actions:* Needs details ...
      iv. *Policy network upkeep or maintenance*
      v. *Individual belief actions:* Needs details ... (added actions)
   (d) *The policy makers rank the instruments*
   (e) *The system decides if a policy instrument should be implemented*
4. *The model advances to the next time step*

A.5.2. Three streams actions related algorithms - Issue selection

As mentioned earlier on, the three steams approach provide a different method for the agents to select issues. This is detailed here for both the agenda setting and the policy formulation.

Agenda setting In the agenda setting, the agents can choose a policy or a problem. Depending on which they choose, they will then have to choose an associated issue. So if an agent selects first a problem, then he will have to look for a policy. The opposite is also true. Note that the first issue selected is the one that the agent will forcefully advocate for when creating or joining a team but also when performing individual actions.

The grade assigned to the problems are given by the following equation:

$$G_{prob,i} = (A_i - S_i) + \sum_{j=1}^{n} \left| CW_j \left(A_j - S_j \right) \right| \tag{A.23}$$

where i corresponds to the policy core considered and j the related deep core issues.

The grade assigned to the policies are given by the following equation:

$$G_{policy,i} = \sum_{i=1} (A_i - S_i \cdot I_i) \tag{A.24}$$

where i corresponds to the policy core affect by the policy selected and I is the impact expected from the policy.

Once all possible policies and problems have been graded, the agent will select the one with the highest grade. Then the process is repeated again but for the problems or policies to find the associated issue. This is done with only problems related to the policy selected if a policy was selected first or with the policies related to the problem selected if the problem was selected first.

Policy formulation For the policy formulation process, the steps are similar when choosing a policy and a problem. The grading is done using the same equations but at the secondary level instead of the policy core level. However, a difference occurs in the possible secondary problems to be selected and the policies considered. The problems considered are all the secondary issues that are related to the policy core that is on the agenda according to the causal relations of the agents within his belief tree. The policies considered are all policies that are children of the policy that is on the agenda.

A.5.3. Three streams actions related algorithms - external parties actions

The external parties can perform actions that are similar to the ones presented in the backbone+ model. Depending on whether they have selected a problem or a policy initially, they will have a different set of actions that they can perform.

For the external parties that have initially chosen a problem, the number of actions is numbered to two. They can perform blanket framing on all agents present in the model. This blanket framing uses the same equation as the one presented in the backbone+ model. It only is regarding the causal relations that are linked to the problem chosen. The action chosen is done in the same way as the backbone+ model. The external parties can also perform electorate influence actions on the aim of the policy core they have chosen as was shown before.

If the external party has chosen a policy first, then he can still perform two actions. The aim influence on the electorate is the same as before. They can also perform a blanket framing action on the impact of the policy they have chosen. The following equation is used for that:

$$I_m := I_m + \left(I_n - I_{n_m}\right) \cdot resources \cdot trust_{n,m} \cdot actionWeight \tag{A.25}$$

where n is the agent performing the action, m is the agent on which the action is performed.

This action can only be performed on all the impacts that are related to the policy which the agent has selected. The action that results in an expected change that will place the new impact closest to the external party impact is the one that is selected to be implemented. The equation used for the implementation of this action is then given by:

$$I_m := I_m + (I_n - I_m) \cdot resources \cdot trust_{n,m} \tag{A.26}$$

A.5.4. Three streams actions related algorithms - policy makers and entrepreneurs actions

Similarly to the actions performed by the external parties, the actions performed by the policy makers and entrepreneurs are slightly different in this model compared to the backbone+ model. For agent that have chosen a problem first, the number of action is numbered to three. They can perform state and aim influence actions on the other agents. They can also perform framing actions on the causal relations related to the selected problem. These are all graded similarly to the grading scheme used in the backbone+ model.

For the agents that have first selected a policy, three actions are also available. They can once again perform state and aim influence actions on all the policy core issues related to the policy they have chosen. They can also perform a framing action on the impact that policy has on the policy cores. This is done using the same equation as the one presented for the external parties. Again, all actions are estimated and their impact on the likelihood of the agent impacted choosing the policy of the agent performing the action is estiamted. The one that leads to the largest increase is selected as the action to be implemented.

A.5.5. Three streams actions related algorithms - Agent-team actions

The agent-team actions are all actions that each agent performs to either decide to join or create a team. It also consists of actions related to the disbanding of teams and the checking that the team requirements are still met. Each agent goes through all of these actions each tick. Each agent can only be part of one team at a time in the agenda setting process and the policy formulation process. Note that all actives agents can be part of teams. These are the policy makers, policy entrepreneurs and external parties. The following list presents the different actions that are taken in chronological order in which they are performed in the model. Each of these actions is thoroughly detailed later on in the section.

1. *Belonging parameter update:* If an agent is in a team, then its `agent.team.belonging` parameter is updated based on the latest beliefs.
2. *Leave a team:* An agent will leave a team of his own accord only for one reason: if the belonging level drops below 30%. If the agent leaves the team he was part of, the team must then be checked to see if it has enough members. If it has less than three members it will have to be disbanded and all agents present in the team are removed from it.
3. *Disband the team:* If the agent is the lead of the team, there is a possibility that he will disband the team. This happens when the policy issue the agent is advocating for changes and does not match the issue of the team anymore. This is not checked every tick but every five ticks. If they do not match, the team will be disbanded and all agents removed from the team. The requirements used to create a team are also rechecked every five ticks to see if the members should still be in the team. If the number of members falls below three during this review process, then the team wil be disbanded.
4. *Join a team:* If the agent is not in a team, he will first try to join an existing team. For each team considered, he will spend a small amount of resources to gather information. If the gap in his beliefs is above the required threshold for the issue that the considered team is supporting, and his state belief are closed enough to the team's leader state belief on that issue, then the agent can join the team.
5. *Create a team:* If the agent has not managed to join a team, then he has the possibility to create a team himself. For this the agents looks towards the agents to which he is connected and has trust. If the agent first chose a policy, then the agent will be able to start a team around that policy only. The same is true if the agent had chosen a problem. For each of these agents, the agent considers the gap in this issue along with the state to see if he shares beliefs with the other agents. Considering each agents

costs a little resources for both the agent searching and the agents he is interacting with. Then depending on the personal strategy of the agent, the agent creates a team with all the agents he has found or he creates a team once he has found a sufficient amount of agents. Note that the gap amount is dependent on the situation along with the state. This is detailed later on.

This formalisation is currently missing aspects where two teams could merge.

Start a team As mentioned earlier, the agent that wants to start a team has to look at different requirements. Two different cases have to be considered here: the case where the agent first chose a problem and the case where the agent first chose a policy.

If the agent first chose a problem then the first requirement is that for the secondary issue chosen, the gap between aim and state must be above a certain threshold. This threshold is 0.8 in general but can be set to 0.5 in cases where a change in the magnitude of the state from the previous tick is larger than 0.5 (in case of an external event). This must be the case for all agents if they want to join the team. The second requirement relates to the causal relation. For the agenda setting, it is the causal relation between the deep core issue with the highest preference for the starting agent and the policy core issue selected as the problem. For the policy formulation, the causal relation selected is the one relating the problem on the agenda and the secondary issue selected as the problem by the agent. All agents that want to join the team must be within 0.5 of the value of the causal relation for the agent starting the team

If the agent first choses a policy, then there is a small change in the requirements looked at. The agent still looks at the gap requirement. However the second requirement is now dependent on the impact that the policy has on the secondary issues selected as the problem by the agent that is starting the team. The impact on the associated problem should be within 0.5 for the other agents considered to enter the team.

If both of these requirements are met, then the agents qualifies to join the team. Note that for each agent contacted, the agent starting the team loses 2% of his resources and the contacted agent loses 1% of his resources. This is to justify the resources needed for the exchange of knowledge. Furthermore, the agent starting the team will initially assess the other agents based on his knowledge of their beliefs. This leads to the spending of resources. If his perception of the other agent's beliefs are not true, then the agent will not join the team but the resources will have been spent regardless. The resources are also used to gain some information on the beliefs of the other agents. Even though the other agents might not be interested, spending these resources allow the agent to gain knowledge of the beliefs of the other agent within a certain range. Through this exchange of knowledge the agent also provides his own beliefs to the agent being contacted.

The creation of the team requirements are then based on the strategy that the agent is using. The first strategy consists of starting a team with all the agents found that meet the requirements mentioned earlier. The team will then be composed of the maximum number of agents possible. The second strategy consists of starting a team once a certain number of agents has been established to meet the aforementioned requirement.

Upon the creation of a team, all agents that are part of the team are added to the member list. The lead agent of the team is the agent that started the team. Each agent's belonging level is also calculated based on a weighted average of the beliefs of the team on the state of the issue advocated for. Joining a team will also lead to no decay between the agents present in the team, effectively counting as an action the agents.

Join a team The agent can join a team if he is not already part of a team. For this, the agent will check the same requirements as when creating a team (gap and state requirements). This is done for the issue of the team he is approaching. For each team that the agent probes, 2% of his resources are spent. If the requirements are met, then the agent will join the team and add himself as a member of the team. The agent is allowed to spend 50% of his resources for such a search. Once these resources have been depleted or all team have been considered, the agent moves on.

Leave a team An agent can leave another team for one reason: because his belonging level is too low. The belonging parameter of the agent is checked on a tick per tick basis. If it descends below 30% then the agent will automatically leave the team. If the team remaining has 2 agents or less, it will be disbanded right away. Note that the belonging parameter is updated based on the perception of an agent on another agent's beliefs without full knowledge. This will artificially increase the life of teams.

Disband a team As mentioned earlier, a team will be disbanded if the policy advocated by the team does not match the policy advocated by the lead agent. This is checked every five ticks. The second reason for which a team will be disbanded is if the agents present in the team to not meet the team creation requirements anymore. This is also checked every five ticks.

Belonging level setting The belonging level in a team is used to measure how much resources an agent will be willing to provide for the team and how much he will keep for his own actions with other agents. This belonging level is entirely related to the issues being advocated by the team.

For the agenda setting, the following is done to obtain the belonging level:

1. The weighted total policy state of the policy being advocated by the team of all agent is calculated using:
$$S_{pol,weighted} = \sum_{i=1}^{n} resources_n \cdot S_n \tag{A.27}$$
Note that this weighted average might be difference for each agent as it is based on partial knowledge and not full knowledge. The belonging parameter will be affected by the perception of other agent's beliefs.
2. The belonging level is then calculated using the following equation:
$$Belonging = 1 - \left|S_{pol,agent} - S_{pol,weighted}\right| \tag{A.28}$$

For the policy formulation, the same process is performed but at the secondary issue level.

A.5.6. Three streams actions related algorithms - Team belief actions

Once the teams have been constituted, these teams must perform actions. These are the belief actions. There are two types of actions that the team can conduct. They can first perform intra-team actions to help the team get more consistent beliefs. They can also perform inter-team actions. In this case the aim is to convince other agents outside of the team that the belief of the team are more important. Each type of actions uses 50% of the resources reserved for the team. These actions are performed in intervals of 10% of the total amount of resources reserved. The resources available to team are equal to the sum of the belonging attributes for each of the members of the team.

Intra-team actions There are four main intra-team actions: blanket framing on causal relations, blanket framing on policy impact, direct influence on aim and direct influence on state beliefs. The aim for these actions is to have the entire team as a more coherent entity with agents having similar beliefs regarding the issues they advocate for. As each of the team is based on trust between the different agents, each agent has a say on which action should be chosen. Therefore each agent assesses all of the possible actions based on the partial knowledge he has of the other agents in the team. Because the agents are in a team, they all know fairly well the beliefs of the others in the team.

Within the context of a team, these actions are performed by the team leader. Considering that the agents are all in the same team, they all know each other's almost exact beliefs and it therefore does not matter who decides on which action to take as the results will be the same.

The blanket framing action on causal relation is used in the case where the team has selected a problem as the issue it is advocating for. This action is calculated using the following equation for each agent and for each causal relation:

$$\begin{aligned} \Delta CW_{agent} &= \left(CW_{avg} - CW_{agent}\right) \cdot affiCoef_n \cdot resources \cdot \frac{1}{nagents} \\ G_{n,framing} &= \sum^{nagents} \Delta CW_{agent} \end{aligned} \tag{A.29}$$

The blanket framing action on the policy impact is used in the case where the team has selected a policy as the issue it is advocating for. This action is calculated using the following equation for each agent and for each impact:

$$\begin{aligned} \Delta I_{agent} &= \left(I_{avg} - I_{agent}\right) \cdot affiCoef_n \cdot resources \cdot \frac{1}{nagents} \\ G_{n,framing} &= \sum^{nagents} \Delta I_{agent} \end{aligned} \tag{A.30}$$

The state influence action is calculated using the following equation for each agent and for each issue:

$$\begin{aligned} \Delta S_n &= (S_1 - S_n) \cdot resources \cdot affiCoef \cdot \frac{1}{nagents} \\ G_{n,state} &= \sum^{nagents} \Delta S_n \end{aligned} \tag{A.31}$$

where agent 1 is the agent performing the action and n is the agent being influenced.

The aim influence action is calculated using the following equation:

$$\begin{aligned}\Delta A_n &= (A_1 - A_n) \cdot resources \cdot affiCoef \cdot \frac{1}{nagents} \\ G_{n,aim} &= \sum^{nagents} \Delta A_n\end{aligned} \tag{A.32}$$

where agent 1 is the agent performing the action and n is the agent being influenced.

For each of these actions, the grade is the sum for all agents of the action as these are intra-team actions. The total grades for each are compared and the one with the highest impact is selected to be implemented.

The actual change in the agents impacted is then given by the following equations:

$$\begin{aligned}CW_{agent} &:= CW_{agent} + \left(CW_{avg} - CW_{agent}\right) \cdot affiCoef_n \cdot resources \cdot \frac{1}{nagents} \\ I_{agent} &:= I_{agent} + \left(I_{avg} - I_{agent}\right) \cdot affiCoef_n \cdot resources \cdot \frac{1}{nagents} \\ S_n &:= S_n + (S_1 - S_n) \cdot resources \cdot affiCoef \cdot \frac{1}{nagents} \\ A_n &:= A_n + (A_1 - A_n) \cdot resources \cdot affiCoef \cdot \frac{1}{nagents}\end{aligned} \tag{A.33}$$

Inter-team actions There are also four inter-team actions: framing on causal relations, framing on policy impact, direct influence on aim and direct influence on state beliefs. The aim for these action is to influence the belief of individual agents present outside of the team. These actions are graded by each of the agents present in the team and the action that has the most merit from all actions of all the agents is the one selected by the team as a whole. To benefit better from the team, the agents can count on the overall team network and the team resources. The framing on causal relation is performed if the team has chosen a problem as its issue while the framing on policy impact is for when the team has chosen a policy as its issue.

To better benefit from the team network, a shadow network is established between the team and all agents outside of the team. The trust for the established links is equal to the highest found between one of the agents in the team and the outsider agent. Furthermore, the conflict level between the team and this agent is calculated for the issue of the team based on the average beliefs of the team and the outsider agent's beliefs. The links behave similarly to the normal links between the agents.

Each of the actions are performed using 10% of the resources of the team and using the partial knowledge of the agents within the team. As mentioned before, the trust and conflict levels are obtained through the team-outside agent links.

The framing on causal relation grade is obtained using:

$$CW_n := CW_n + \left(CW_n - CW_{n_m}\right) \cdot resources \cdot trust_{team,m} \cdot actionWeight \tag{A.34}$$

where m is the outsider agent and n is the agent within the team.

The framing on policy impact grade is obtained using:

$$I_n := I_n + \left(I_n - I_{n_m}\right) \cdot resources \cdot trust_{team,m} \cdot actionWeight \tag{A.35}$$

The state and aim influence action grades are obtained using:

$$S_n := S_n + \left(S_n - S_{n_m}\right) \cdot resources \cdot trust_{team,m} \cdot conflictLevel \cdot actionWeight \tag{A.36}$$

$$A_n := A_n + \left(A_n - A_{n_m}\right) \cdot resources \cdot trust_{team,m} \cdot conflictLevel \cdot actionWeight \tag{A.37}$$

where m is the outsider agent and n is the agent within the team.

All of the actions are performed and then the agents update what they believe will be the new beliefs after the actions. The actions that results in the smallest difference between the preference of the team and the preference of the agent influenced for the policy or problem advocated by the team will be chosen to be implemented.

When the actions are performed, the following equations are used to obtain the final values of the beliefs:

$$\begin{aligned} CW_m &:= CW_m + (CW_n - CW_m) \cdot resources \cdot trust_{team,m} \\ I_m &:= I_m + (I_n - I_m) \cdot resources \cdot trust_{team,m} \\ S_{m,state} &:= S_{m,state} + (S_n - S_m) \cdot resources \cdot trust_{team,m} \\ A_{m,aim} &:= A_{m,aim} + (A_n - A_m) \cdot resources \cdot trust_{team,m} \end{aligned} \tag{A.38}$$

A.5.7. Three streams actions related algorithms - Individual actions

The agent can also perform actions as a simple individual regardless of being in a team or not similarly to the actions performed in the backbone+ model. The resources used to this effect are the resources left depending on the belonging parameter if the agent is in a team. If the agent is team-less, then all his resources left after the agent-team actions are the resources can be used.

The actions that the agent can perform are dependent on whether he has first chosen a policy or a problem similarly to the inter-team actions. In both cases, the agent can perform a state and aim influence action on other agents. Furthermore, if the agent has first chosen a problem, he will be able to perform a framing on causal relation action while if the agent had first chosen a policy, he will be able to perform a framing on impact action. The process and equations used are the same as the ones presented in the inter-team actions section.

A.6. Backbone model with advocacy coalition framework

This section presents the model of the backbone and the backbone+ model combined to the advocacy coalition framework but excluding the three streams theory. The items that are similar to what is presented in the previous section are not re-explained. Note that several key elements from introduced in the three streams theory are also used for the advocacy coalition framework. They are not re-explained.

The ACF model is very similar to thebackbone+ model. The main difference relates to the addition of coalition to which agents are assigned. These coalitions are formed based on a deep core belief that was selected by the modeller as the deep core around which the coalitions should be assembled. Coalitions are formed fundamentally differently than the teams within the three streams theory. However, they still have a leader and are still advocating for an issue. The difference relates in the fact that agents are assigned to them depending on their deep core beliefs and regardless of their policy core or secondary beliefs. Note that the coalitions used for the agenda setting process are different than the coalitions that are used at the policy formulation level. These are considered as two different arenas due to the different levels of aggregation.

A.6.1. The ACF policy cycle

The policy cycle that is used for the ACF is detailed below. The main difference with the backbone+ policy cycle is the addition of coalitions-related steps.

1. Tick initialisation:
   (a) *World simulation*
   (b) *Trigger of external events*
   (c) *Update of the truth agent*
   (d) *Electorate actions*
   (e) *External parties belief update*
   (f) *All agents belief update*
2. Agenda setting:
   (a) *Agent issue classification and selection*
   (b) *Deliberations:*
      i. *Resources receival*
      ii. *Creation of the coalitions:* Agents are assigned to specific coalitions depending on the deep core belief of interest selected by the modeller.
      iii. *Coalition belief actions:* Each of the coalitions can perform their belief actions. These are once again split between the intra- and inter-coalition actions.
      iv. *Policy network upkeep or maintenance*
      v. *Individual belief actions*
   (c) *The policy makers rank the issues*
   (d) *Agenda setting*
3. Policy formulation:
   (a) *Policy pool selection*
   (b) *Policy instrument selection*
   (c) *Deliberations:*
      i. *Resources receival*
      ii. *Creation of the coalitions*
      iii. *Coalition belief actions*
      iv. *Policy network upkeep or maintenance*
      v. *Individual belief actions*
   (d) *The policy makers rank the instruments*
   (e) *The system decides if a policy instrument should be implemented*
4. *The model advances to the next time step*

A.6.2. ACF actions related algorithms

The following sections present the different algorithms that are used to model the advocacy coalition framework.

Coalition creation There are several algorithms that can be used to create coalitions. One is proposed here. First the leader of any potential coalition is selected. This is done by selecting the agent with the most amount of trust throughout his links. This agent is assigned as the head of a coalition and must then constitute his coalition. In the agent setting step, the coalitions are formed around a common deep core belief. This deep core belief is originally selected by the modeller. For the policy formulation, the agents will be gathered around their belief in the policy core issue that is selected for the agenda. The leading agent will look throughout his network of agents and will select all agents that are within a certain threshold value of his own state belief for the concerned issue. All these agents will be added to his coalition by default. This decision by the leading agent is based on the perceived knowledge he has of the other agents. Note that differently from the teams creation, during the creation of the coalition part, there is no exchange of knowledge between the agents. This is because it is assumed that the leading agent looks through his network mentally and does not have to contact the different agents. This also means that the creation of a coalition is not a resource consuming process.

With the remaining agents present in the model which are coalition-less, the same steps are reproduced. The agent with the largest amount of trust is selected and a coalition is created around him. These steps are repeated until less than 10% of the agents present in the model are left coalition-less.

The issue that will be advocated by the team is the one that the agent is supporting upon the creation of the coalition. Furthermore, the belonging level of the agents is calculated based on the issue being advocated by the team. This belonging value is calculated as the difference between the leader agent and their own belief values. This also means that the leader of the coalition will have a belonging value of 1.

Alternative algorithms can be used to create a coalition. Such algorithm could consider, for example, the selection of agents on the extreme of the spectrum of beliefs for the given deep core or policy core of interest and constituting coalitions aroun them. Such method would however consider that there is full knowledge of other agent's beliefs throughout the model which is not the case.

Intra-coalition actions There are three main intra-coalition actions. These are the blanket framing of causal relations of the issue the coalition is advocating for, and aim and state influence actions on individual agents. These actions are performed in the same was as was presented in the three streams theory. These actions are the same in the agenda setting and the policy formulation processes. The difference relates to the issue that are being influenced only.

Inter-coalition actions The actions that can be performed by the coalition on agents are also limited to the three actions. These are framing on causal relation actions, and aim and state influence actions. These are once again similar to the actions presented in the three streams theory for the teams. The main difference in on how the actions are selected. WIthin the coalition framework, the actions are decided by the leader. Not all agents present in the team are consulted and only the leader looks at the possible actions and implements the actions. It is therefore important that the leader have a robust policy network.

Do we need coalition on coalition actions? Right now this is limited to coalition on agent actions - Furthermore, is this leader only action approach the right one? Wouldnt that limit the policy learning that will happen within the system?

A.7. Backbone model with feedback theory

The feedback theory is related to the `feedback` attribute within the policy instruments. This attribute is written as a 3-tuple given by `feedback = (citizenship, groups, agenda)`. When the feedback theory is not engaged by the modeller, each of these take the value `None` and they are not considered within the model. When the feedback theory is used, they can each take a value or only a set of these attributes can be considered. They are then defined as follows:

1. The *citizenship* attribute relates to the representation attribute of the electorate. This attribute is therefore given as a list of 2-tuples written as `(electorate, representation)` which is as long as the number of affiliation present in the model. The values used within the *citizenship* attribute will replace the representation.
2. The *groups* attribute relates to the resources provided to the different groups of policy entrepeneurs and policy makers receive each round. This attribute is also given as a 2-tuple written as `(affiliation, change)` where the change is a positive or negative percentage. This feedback effect will change the resources by a certain percentage when the instrument is implemented. This can be done for one affiliation or more than one at a time depending on what the modeller requires. This cannot however be done at an agent level. All agents sharing that affiliation will be affected.
3. The *agenda* attribute relates to the issues that the *awareness* attribute of the agents within their belief trees. This attribute can change the awareness of specific agents to the issues in their belief tree. They can have a list of 2-tuples written as `(issue, awareness)` which is as long as the number of issues in the belief tree (all layers included). Implementing a policy instrument with this attribute will change the awareness value.

It is important that the feedback theory does not work like the three streams or ACF models with respect to the backbone. The feedback theory will work better when combined with the three streams theory or the ACF. On its own, the effects will be limited as no actions are performed within the model due to the agents limitations when the backbone is simulated on its own.

A.8. Backbone model with diffusion (optional)

The use of the diffusion theory is similar to the use of the feedback theory. Although it can be used without any other policy making theories, it is advised to consider either the three streams or the ACF theories with the babckone when using the diffusion theory. The main reason is related to the fact that diffusion theory only adds an linking and interaction effect between different systems. To use the diffusion theory, the modeller needs to simulate several systems in parallel with their own agents and networks. The diffusion theory defines how these systems are linked and what effect each system has on the other. All actions performed through the diffusion theory are performed after each of the system has gone through its cycle chronologically as shown previously for the other theories.

The systems network is used to link the different systems. Each of the directed link can take one of four types as shown earlier on. Depending on the type of link, the actions that the agents will perform from one system to the other will be different. The agents from the different systems are connected together through the super-policy network. The actions that the agent will perform are shown below.

A.8.1. Friendly link

When an agent from system 1 interacts with an agent from system 2 and the link from system 1 to system 2 is friendly, the action performed will be very similar to the actions performed within the policy network

A.8.2. Dominant link

A.8.3. Competitive link

A.8.4. Coercive link

There will be a need to explain how the super-policy network works here.

This is how far I got.

1. *Resources receival*
2. *Selection of an issue*
3. *Policy network upkeep or maintenance*
4. *Introduction of an issue:* Some of the issues are not known by all the agents. There is therefore a need for them to be introduced to the different agents. Agents with knowledge of these problems can do that. 10% of their resources are allocated for such tasks. Upon dissemination of this knowledge, the agents will be aware of the issue and will also be able to disseminate information about it. This action will only happen with issues that were newly introduced to the simulation (within the last 5 ticks). If the issue is older than that, agents can disseminate the knowledge if there is less than 50% of their network that has knowledge of the issue. They first choose agents with similar affiliation as them and then choose randomly other agents. If both thresholds are not met, the action is skipped altogether by the agent. This interaction between two agents will stop the trust decay in the link between the two agents for 3 ticks.
5. *Individual belief actions*

A.8.5. Diffusion actions related algorithms

Transfer of an issue from another system [This is not even mentioned in the cycle at this point, it should be added. Note that diffusion should also be able to introduce new causal relation that agents didnt think were of interest?]

Issue introduction The introduction of the issue is explained previously. The algorithm that is used to simulate this behaviour is given here. It is important to note that agents do not have full knowledge on the `knowledge.status` parameter of other agents. It is therefore important to initially not set all these parameters to 0 but to distribute the knowledge of this parameter depending on the affiliation weight used for the affiliation network. Therefore, agents sharing the same affiliation should have full knowledge of the `knowledge.status` parameter. While for agents not sharing the same affiliation, the probability of knowing another agent's `knowledge.status` parameter should be related to the affiliation weight between their two respective affiliations.

A.9. Policy brokers (optional)

[Incomplete and/or incorrect]

Connect agents: This action is only performed by policy brokers. It consists of placing in contact different agents in the model that do not know they exist or to boost their trust level temporarily such that they can better influence each other.

A.10. Additional required algorithms

A.10.1. End of tick algorithms

1. Trust decay - Influencing another agent will stop the trust decay in the link between the two interacting agents for five ticks.

A.11. Notes/Questions

1. Is the affiliation in the literature?
2. What happened to the technical parameters? Are they used to define the initial aim and/or perceived states of the different agents?

B

Technical Model Formalisation

When rewriting this part of the report, check carefully what was written in the code, there are several important small numbers in there that affect the assumptions that were made.

B.1. Calculation of the states

1. DC1 - Economy: A value of 1 would mean that the map is filled with empty and camp site cells and there was no fire. A value of -1 would mean that the whole map is filled with burnt cells.
$$Economy = \frac{Tourism + Safety}{2} \tag{B.1}$$
2. DC2 - Environment: A value of 1 would mean that the mao is covered in forest. A value of -1 would mean that the map is fully burnt.
$$Enviornment = \frac{Forest\ size + Safety}{2} \tag{B.2}$$
3. PC1 - Forest size: A value of 1 would mean the map is full of thick forest. A value of -1 would mean it is empty of all forests.
$$Forest\ size = \frac{0.75 Thick + 0.25 Thin}{Total} \tag{B.3}$$
4. PC2 - Tourism: A value of 1 would mean that the map is full of camps. A value of -1 would mean it is full of thick forest.
$$Tourism = \frac{0.75 Camp + 0.25 Thick}{Total} \tag{B.4}$$
5. PC3 - Safety: A value of 1 would mean that there is no burnt land. A value of -1 would mean that everything has burnt.
$$Safety = \frac{Monitoring + Firefighters + Prevention - Camp - Thick}{5} \tag{B.5}$$
6. S1 - Camp sites: A value of 1 would mean the map is covered with camps. A value of -1 would mean the map has no camps.
$$Camp = \frac{Camp}{Total} \tag{B.6}$$

Table B.1: Initial for the issues in the belief tree of three affiliations.

Issues	Affiliation 1	Affiliation 2	Affiliation 3
DC1	0	1	1
DC2	1	0	1
PC1	1	0.5	1
PC2	-0.6	1	-0.7
PC3	0.2	-0.5	1
S1	-0.5	0.9	-0.9
S2	0.9	0.1	-0.2
S3	0.3	0.8	-1
S4	-0.4	1	-1
S5	-0.5	0.3	0.75

7. S2 - Planting: A value of 1 would mean that there area lot of thin forests. A value of -1 would mean there is a no thin forests.

$$Planting = \frac{Thin}{Total} \tag{B.7}$$

8. S3 - Monitoring: A value of 1 would mean that the burning probability is of 10% for thin forest and 100% for thick forests. A value of -1 would mean the porbability is of 0% for both.

$$Monitoring = 0.1 - burning\ probability \tag{B.8}$$

9. S4 - Firefighters: A value of -1 would mean that there is the maximum 50% of firefighters extinguishing the fire. A value of 1 would mean there is no change of extinguishing the fire.

$$Firefighters = 0.5 - firefighter\ probability \tag{B.9}$$

10. S5 - Prevention: A value of 1 would mean the map is filled with empty cells. A value of -1 would mean the map has no empty cells.

$$Prevention = \frac{Empty}{Total} \tag{B.10}$$

Calculation of the states of the beliefs Check in the code that the burning and firefighter probabilities are limited. The agents should not be able to increase these values above a certain threshold no matter what they want. This maximum value should then be the 1 value. This remark might apply to other parts of the belief tree.

Selection of the initial values for the actors For the electorate, the following lines are using to qualify their beliefs:

1. Affiliation 1: For the environment, with a lack of care for fire prevention.
2. Affiliation 2: For the economy overwhelmingly.
3. Affiliation 3: Against fires.

For the external parties, we will use similar values for affiliations but also add the causal relations:

Table B.2: Initial values for the causal relations in the belief tree of three affiliations.

Causal relations	**Affiliation 1**	**Affiliation 2**	**Affiliation 3**
DC1 - PC1	0.5	0.2	-0.2
DC1 - PC2	0.9	0.9	-0.3
DC1 - PC3	-0.8	-0.7	0.9
DC2 - PC1	0.9	0.4	0.5
DC2 - PC2	-0.9	0.7	-0.9
DC2 - PC3	0	-0.6	0.8
PC1 - S1	-0.6	0.8	-0.8
PC1 - S2	0.9	0.5	0.7
PC1 - S3	0.6	-0.4	0.4
PC1 - S4	0.8	0.8	0.2
PC1 - S5	0.3	-0.5	0.2
PC2 - S1	1	0.8	-0.3
PC2 - S2	-0.4	0	-0.5
PC2 - S3	-0.7	0	-0.5
PC2 - S4	-0.1	0	-0.8
PC2 - S5	-0.8	-0.9	-0.4
PC3 - S1	-0.6	0.9	0
PC3- S2	0	-0.7	0
PC3 - S3	0.1	0.7	0.9
PC3 - S4	0.2	0.8	0.9
PC3 - S5	-0.4	0	0.9

Table B.3: Values for five different instruments.

Related issue	**Instrument 1**	**Instrument 2**	**Instrument 3**	**Instrument 4**	**Instrument 5**
S1	0.5	0	0	0	0
S2	0	0.5	0	0	0
S3	0	0	0.5	0	0
S4	0	0	0	0.5	0
S5	0	0	0	0	0.5

B.2. The backbone - this whole part is probably not needed

The backbone model requires policy makers with their affiliation and beliefs. Fifteen policy makers are introduced in three different affiliations. One belief tree is specified per affiliation. The policy maker's tree are based on this with some randomness added to their aims so that they do not all match the same value.

Notes:

1. The implementation of the causal relations within the belief tree matrix is given as follows for 2 DC, 2PC and 4S:
   (a) DC1 - PC1
   (b) DC1 - PC2
   (c) DC2 - PC1
   (d) DC2 - PC2
   (e) PC1 - S1
   (f) PC1 - S2
   (g) PC1 - S3
   (h) PC1 - S4
   (i) PC2 - S1
   (j) PC2 - S2
   (k) PC2 - S3
   (l) PC2 - S4
2. For the calculation of the preference of the policy instruments, the following was done. First the preference of the secondary issues is updated to only contain links related to the policy core that has been selected. Then the grade of the policy instrument preference is calculated with the updated preference of the secondary issue.

B.3. The intermediate model

This is probably about the general infrastructures for the theories.

Some notes:

1. Specify how the initial trust values are specified.
2. Should the resources distribution be a subject of study? Its variation and its impact? For now, all resources are set the same way for the three types of agents: $0.5 + representation/2$.
3. For the network upkeep, the definition of similar belief is defined as such: if one of the agent has an aim belief within 0.2 of the other agent on one of the agent's problem selection (level 2).
4. For the electorate influence of the external parties, it is now assumed that the external parties have full knowledge of the electorate's beliefs.

B.3.1. The initialisation

1. The initialisation of the trust in the policy network is done as follows: 10% of the links are -1 (unknown) but these cannot be with one policy maker in the link. 40% of the links have trust level at 0 and 50% of the links have a certain random amount of trust between 0 and 1.
2. The conflict level in the policy network is calculated based on what was presented during the formalisation.

3. The trust decay is set by default at 0.05.

The policies implemented are cited below as a function of the secondary beliefs to which they are associated.

1. Camp sites - Actions related to the camp sites will either increase or reduce the addition of new camp sites. The action is to turn a certain percentage of empty cells and thin forests into camp sites every round.
2. Planting - Actions related to planting will either increase of reduce the addition of new trees. The action is to turn a certain percentage of empty cells into thin forests.
3. Monitoring - Action related to the probability for forest to catch on fire. The action is to change the probability that forest will catch fire depending on the maximum and minimum probabilities if it is increase or reduced respectively.
4. Firefighters - Action related to the probability that the fire will be extinguished by firefighters. The action is to change the probability that forest fires will be extinguished depending on the maximum and minimum probabilities if it is increased or reduced respectively.
5. Prevention - Action related to the increase or reduction of the addition of empty cells. The action is to turn a certain percentage of thick forests into empty cells every round.

Based on these tiles, the policy makers can perform a certain number of actions related to their belief tree as shown in Figure A.2. The different outcomes from these actions are mentioned below:

1. Camp sites - Additional camp sites increase fire potential. It also has a positive impact on tourism and economy.
2. Planting new trees - Turns empty cells into a thin forest patch.
3. Monitoring - This decreases the likelihood of a fire for both thin and thick forest.
4. Firefighters - This is the total number of firefighters present in the model (the sum of all present on the tiles at any point). If there are 10 firefighters and 20 fires, 10 fires will not be extinguished in time. (The ratios can be adjusted)
5. Prevention - Prevention returns a number of thick forest to the state of thin forest.

C
Verification

1. The effect of the burning probability instrument is applied appropriately.
2. The effect of the firefighter force instrument is applied appropriately.
3. Preference calculation for instruments is applied appropriately - the initial values of the beliefs are crucial here.
4. Related to the network upkeep:
   (a) Increase trust in links of less than 30% is applied appropriately.
   (b) Set new links is applied appropriately.

C.1. Problems fixed

1. Issues with the creation of teams being infinite.
2. Fixed the indexing problem for the arrays and/or lists with the issue of the team and the looking in the agent's beliefs.

C.1.1. Agent behaviour for the backbone model

1. Because of a lack of communications between the actors, if the electorate belief and the policy makers belief are similar initially, the system should tend to a state where no instrument is agree on. This is considering that the three affiliations are sufficiently separate.
2. If the electorate belief is different from the policy makers beliefs, then we should see a constant shift towards the electorate for the aims of the policy makers over time.

C.2. The belief tree

The belief tree is one of the most complex part of the model. The belief tree structure contains the beliefs of the agent plus the belief of all other agents. This is built into a multi-dimensional array.

The belief tree is present throughout the model in most functions. The fact that it is such a complex array means that verification is required throughout to make sure that every time a part of this belief tree is selected, the right indexes are chosen. If the right indexes are not chosen, the code will still run but the results will be completely wrong. This is particularly important for the causal relations which are saved in the array in a certain sequence mentioned within the code comments. Without following this sequence, the code would run but the results would be flawed.

C.2.1. Preference calculation

For the preference calculation, several checks were performed to make sure the right indexes are selected. The preference calculation is performed for the agent's own beliefs but also for all the partial belief trees in the belief tree parameter. For the principle belief calculation, the selection of the right issue was checked, and it was made sure that the preferences of the two preferences added up to one. Note that this preference calculation works regardless of the tree structure. Nothing has been hardcoded.

For the policy core belief preference calculations, the selection of the right issue was checked. The selection of only the causal relations with matching sign to the gap in the principle beliefs are also checked. Finally, it was checked that all the preferences on that level add up to 1.

For the secondary belief preference calculation, a check was performed that only the issues related to the issue on the agenda are selected. Then the same checks were performed as the checks performed for the policy core beliefs.

C.2.2. Instrument selection

C.2.3. Preference calculation

C.3. The actions selection and grading

C.4. The technical model

C.5. The trust decay

C.6. The data saving functions

C.7. The team behaviours

C.8. The coalition behaviours

C.9. The Network maintenance

D

The Model Parameters

Do not forget to investigate probabilitic versus deterministic. This relates to the restart of the random generator for every simulation to have similar results.

Mention endogenous and exogenous parameters here

D.1. For the technical model

These are all the parameters that are related to the forest-fire model.

1. The initial thin forest burning probability
2. The initial firefigther force
3. The mulitplier coefficient between the thin forest burning probability and the thick forest burning probability
4. Time for the growth from thin to thick forests
5. Time between burnt cell and thin forest/empty cell
6. The percentage between empty cell and thin forest when a cell is past burnt

D.2. For the technical-emergence bridge

The parameters mentionned here are the ones that are related to the calculation of the states and how the technical model is coupled to the emergence model. Changes in these parameters will affect the sensitivity of the emergence model to the initial conditions of the agent's belief trees. It also has an effect on the ultimate control that the agents will have on the overall technical model.

1. Maximum percentage of camp sites allowed [calculation of the states of S1]
2. Maximum percentage of thin forests allowed [calculation of the states of S2]
3. Maximum thin forest burning proabibility allowed [calculation of the states of S3]
4. Maximum firefighter force allowed [calculation of the states of S4]
5. Maximum percentage of empty cells allowed [calculation of the states of S5]
6. Maximum percentage of thick forests allows [calculation of the states of PC3]

D.3. For the policy emergence model

These are only parameters related to the policy emergence model:

1. The choice of theories for each part (bacbkone v. 3 streams v. ACF for the AS and PF) [all]

2. The backbone model:
   (a) The belief tree aims [backbone]
   (b) Number of policy makers [backbone]
   (c) Number of affiliations [backbone]
   (d) The affiliation weights [backbone]
   (e) The number/type/weights for each of the instruments [backbone]
   (f) The way the state parameters are initialised for the policy makers [backbone]
   (g) The distribution of affiliation, how many agents of which type take what affiliation [backbone]
   (h) The coefficient used for electorate influence on policy makers [backbone]
3. The intermediate model:
   (a) Ratio of policy entrepreneurs per policy makers [intermediate]
   (b) The strategy that is used to assign the partial knowledge of other agent's beliefs [intermediate]
   (c) The way the state parameters are initialised for the policy entrepreneurs [intermediate]
   (d) The 30% parameter cut-off used for the strategy 1 of network maintenance [intermediate]
   (e) The 4% resources amount used for the network maintenance actions [intermediate]
   (f) The speed at which trust in links is increased [intermediate]
   (g) Change the definition of smiliar beliefs in the network maintenance actions [intermediate]
   (h) The different strategies for the maintenance of the agents networks [intermediate]
   (i) Change the equation that is used to calculate the addition of trust for the trust upkeep equations [intermediate]
   (j) The times for which the conflict level is implemented [intermediate]
   (k) The values determining the different levels of conflict [intermediate]
   (l) The amount of share knowledge that happens after an action (randomness) [intermediate]
   (m) The default value for the conflict level [intermediate]
   (n) A coefficient for the resources to make each action more potent (this can be important for the good progression of policy learning [intermediate]
   (o) The decay level coefficient chosen for each of the actions can be changed from 5 to something else [intermediate]
   (p) The resources potency coefficient [intermediate]
   (q) The conflict level coefficients [intermediate]
4. The three streams theory:
   (a) Belonging level required to leave a team [3S]
   (b) The number of ticks required for each check of team disbanding - Agent policy issue matching [3S]
   (c) The number of ticks required for each check of team disbanding - Member agent matching requirements [3S]
   (d) The number of agents required to start a team for strategy 1 [3S]
   (e) The amount resources allocated to intra- and inter-team actions [3S]

   (f) Choice of strategy 0 or 1 for the creation of team for each type of agent and for each agent [3S]
   (g) The gap requirement for the creation of teams in normal times [3S]
   (h) The gap requirement for the creation of teams in event times [3S]
   (i) The state requirement for the creation of teams [3S]
   (j) Randomness during the partial knowledge exhange of the creation of teams [3S]
   (k) Amount of resources spend when looking to join a team [3S]
   (l) Amount of resources allowed to be spent for joining a team [3S]
   (m) The order in which intra and inter-team actions [3S]
   (n) Change the 10% interval of spending resources for the intra-team actions [3S]
   (o) Change the 10% interval of spending resources for the inter-team actions [3S]
5. The ACF:
   (a) The choice of deep core policy used to create coalitions [ACF]
   (b) The choice of threshold for the constitution of the coalitions [ACF]
6. The feedback theory:
   (a)
7. The diffusion theory:
   (a)

E

Further Work

This appendix presents the list of items that has been thought of for further work.

1. The implementation of the diffusion theory
2. The implementation of the feedback theory
3. The implementation of a tested partial belief tree initialisation
4. The introduction of the media influence through the selective choice of certain states by the external parties.
5. The introduction in the code of a system to allow for the use of more than the current three affiliations.
6. To enhance the model, it could be possible to introduced the three types of subsystem behaviour mentioned in the literature (Nohrstedt and Weible, 2010; Weible, 2008). These are the unitary subsystem, the collaborative subsystem and the adversarial subsystem. The introduction of such differences could affect the behaviour algorithms of the different actors or change specific weights of specific actions within the actors' algorithms.
7. Policy are currently not differentiated between technical and non-technical. According to the literature (Nohrstedt and Weible, 2010), this can be important. Actors are more likely to agree on technical issues and disagree on non-technical issues. This could be implemented in a later version where technical issues have a different weight than non-technical issue to quicken the pace of policy learning within the policy emergence context.
8. The introduction of an advanced media model.
9. The introduction of a policy package tool.
10. The feedback theory is currently passive. Actors cannot take into account the effect from the instruments which are specified as part of the feedback theory. This means that they cannot consider them in their calculation of the grades for the policies. This is sometimes good and sometimes important to know.
11. A way of honinh in for tha partial knowledge such that the partial knowledge always gets closer to the actual value and not further apart (if not for all actions, at least for some of the actions).
12. Add over time instruments. Right now, all instrument are instantantaneous. This does not allow for instruments where the implementation might happen over several ticks in the technical model. The main issue to solve for such an implementation is the grading of such measure against a measure that would happen only over one tick.

F

Policy Making Theories Concepts

This appendix is a summary of all of the concepts that are mentioned within the theories. It includes their corresponding concepts within the model created in this thesis. When there is no relation, then the concept has not yet been addressed and is therefore not mentioned in the table. Note that a third column is added to signify the policy making theories concepts that have been addressed in the conceptualisation and formalisation but are not yet present within the code.

The concepts with an asterisks are detailed further after the table.

Policy making theories concept	Model	Concep.
The three streams theory		
Fluid participation		
Problem preferences		
Unclear technology		
Policy stream		
Value acceptability		
Technical feasibility		
Integration of the instrument		
Problem stream		
Indicators		
Focusing event		
Feedback		
Load		
Politics stream		
Policy makers	✓	✓
Policy entrepreneurs	✓	✓
Policy entrepreneurs time constraints	✓	✓
Policy window		
Team creation criteria	✓	✓
Leading by example	✗	✗
Independent streams		
The advocacy framework coalition		

Subsystem	✓	✓
Coalitions	✓	✓
Coalitons influence policy makers		
Devil shift		
Limited amount of information		
Deep core beliefs		
Policy core beliefs		
Secondary beliefs		
Stable coalitions		
Actors show substantial consensus		
Secondary before policy core		
Bounded rationality*	✓	✓
Belief system	✓	✓
Coalitions creation criteria	✓	✓
External event		
Internal subsystem event		
Negotiated agreement		
Policy-oriented learning		
Policy learning is more likely with moderate level of conflicts	✓	✓
Learning is more likely in a prestigious forum		
Quantitative problems are more conducive to policy learning	✗	✗
Problems involving natural systems are more conducive to policy learning	✗	✗
Accumulation of technical information does not change the view of opposing coalitions	✗	✗
Administrative agencies advocate for more moderate measures		
Actors within purposive groups are more constrained in their expression beliefs and policy positions than actors from material groups		
The diffusion theory		
Leaning mechanism		
Imitation		
Normative pressure		
Competition		
Coercion		
The feedback theory		
Meaning of citizenship		
Form of governance		
Power of groups		
Definition of policy problems		

The resource effect		
The interpretive effect		
The policy entrepreneurhsip model		
Social acuity	✓	✓
Definition of problems		
Policy entrepreneurs should be ready to build teams	✓	✓
Definition of policy problems		
The resource effect		
The interpretive effect		

Notes concerning the concepts in the advocacy framework coalition:

- The bounded rationality concepts: The agents are not introduced within the model with bounded rationality for say. However, because the agents are included within a large set of agents and each of these agents perfom actions, the overall resulting model can be considered to have agents with boudned rationality.

G

Reference index

Papers groups with their typical general topic:

- Policy reviews papers (Bovaird, 2008; Cairney, 2012; 2016; Geyer and Cairney, 2015; Heclo, 1972; Jordan, 1981; Klijn, 2008; Lindblom, 1959; Little, 2015; McCool, 1998; Richardson, 2000; Room, 2015; Skocpol et al., 1999; Walker, 2000)
- Complex systems papers (Ehrenfeld, 2000)
- LSSTS papers (Castells, 2000; Herder et al., 2008; Luhmann, 1995; Watts and Strogatz, 1998)
- ABM papers (Axelrod, 2006; Bak et al., 1988; Bednar and Page, 2007; Castelfranchi, 1998; Cohen et al., 2001; Epstein, 2006; Epstein and Axtell, 1996; Holland, 1995; Mika, 2004; Miller and Page, 2009; Naveh and Sun, 2006)
- Policy entrepeneur papers (Brouwer et al., 2011; Mintrom and Norman, 2009; Mintrom and Vergari, 1996; 1998)
- Media impact papers (Birkland, 2004; Cook et al., 1983; Kosicki, 1993; McCombs and Shaw, 1972; Van Belle, 1993; 2000; Waldherr, 2014)
- Policy brokers papers (Ingold, 2011; Ingold and Varone, 2011)
- Learning papers (individual and for organisations) (Borgatti and Cross, 2003; Contu and Willmott, 2003; Crossan et al., 1995; 1999; Dunlop and Radaelli, 2013; Dyck et al., 2005; Fazey et al., 2005; Fiol and Lyles, 1985; Freeman, 2006; Grin and van De Graaf, 1996; Grin and Van de Graaf, 1996; Hajer, 2003; Hall, 1993; Hoberg, 1996; Holcomb et al., 2009; Howlett and Ramesh, 2002; Kim, 1998; Levinthal and March, 1993; Levitt and March, 1988; Liao et al., 2008; Mantzavinos et al., 2004; Meijerink, 2008; Moran et al., 2008; Nicholson-Crotty, 2009; Nonaka, 1994; Ohlsson, 2011; Radaelli, 1999; Williams, 2009)
- Learning and structures papers (Cashore and Howlett, 2007; Huber, 1991; May, 1992; Newig et al., 2010; Schneider and Ingram, 1988)
- Learning and collective change of behaviour papers (Argyris, 2003; Henry, 2009; Knight, 2002)
- Conceptualisation of the learning process papers (Heikkila and Gerlak, 2013)
- Crisis papers (Alink et al., 2001; Boin and Hart, 2003; Dekker and Hansén, 2004; Dudley, 2007)
- Belief papers (Henry and Dietz, 2012;?; Henry et al., 2011; Lord et al., 1979; McPherson et al., 2001; Munro et al., 2002; Stern, 2000)

- ACF papers (Howlett and Cashore, 2009; Nohrstedt, 2005; Nohrstedt and Weible, 2010; Zohlnhöfer, 2009)
- Rules papers (ADICO) Crawford and Ostrom (1995)
- Policy papers Grin and Loeber (2006)
- Diffusion papers (Boehmke, 2009; Braun and Gilardi, 2006; Gray, 1973; Rapaport et al., 2009; Walker, 1969)
- Election papers (Fowler and Smirnov, 2005)
- Model papers (Barreteau et al., 2010)
- Conceptualisation media papers (Djerf-Pierre, 2013; Elmelund-Præstekær and Wien, 2008; Krassa, 1988; Neuman, 1990; Nisbet and Huge, 2006; Vasterman, 2005)
- Causal maps and everything related to the belief system (Axelrod, 2015; Chaib-Draa and Desharnais, 1998; Huff, 1990)
- DANA stuff: (Bots, 2007; 2008; Bots and Hulshof, 2000; Bots et al., 2000; Rahmatian and Hiatt, 1989)
- Cairney Skype: (Bendor, 1995; Howlett et al., 2015)

Bibliography

Robert Ackrill and Adrian Kay. Multiple streams in eu policy-making: the case of the 2005 sugar reform. *Journal of European Public Policy*, 18(1):72–89, 2011.

Fleur Alink, Arjen Boin, and Paul t'Hart. Institutional crises and reforms in policy sectors: the case of asylum policy in europe. *Journal of European Public Policy*, 8(2):286–306, 2001.

Graham Tillett Allison, Graham T Allison, Maria Oslaida Aguero Martinez, Obdulia Maria Aguado Barrena, Ricardo Vargas Pallares, Lucas Cordov de Armas, Gerardo Luis Garcia Garcia, Nunez Alonso, Javier Espinaco Valdes, Javier Espinaco Valdes, et al. *Essence of decision: Explaining the Cuban missile crisis.* Number 327.5 (729.1). e-libro, Corp., 1971.

Chris Argyris. A life full of learning. *Organization Studies*, 24(7):1178–1193, 2003.

Robert Axelrod. *Structure of decision: The cognitive maps of political elites.* Princeton university press, 2015.

Robert M Axelrod. *The evolution of cooperation.* Basic books, 2006.

Per Bak, Chao Tang, and Kurt Wiesenfeld. Self-organized criticality. *Physical review A*, 38 (1):364, 1988.

Eugene Bardach. *Getting agencies to work together: The practice and theory of managerial craftsmanship.* Brookings Institution Press, 1998.

Olivier Barreteau, P Bots, and Katherine Daniell. A framework for clarifying participation in participatory research to prevent its rejection for the wrong reasons. *Ecology and Society*, 15(2):22–p, 2010.

Jenna Bednar and Scott Page. Can game (s) theory explain culture? the emergence of cultural behavior within multiple games. *Rationality and Society*, 19(1):65–97, 2007.

Jonathan Bendor. A model of muddling through. *American Political Science Review*, 89(04): 819–840, 1995.

Jonathan Bendor. Recycling the garbage can: An assessment of the research program. In *American Political Science Association*, volume 95, pages 169–190. Cambridge Univ Press, 2001.

William D Berry and Brady Baybeck. Using geographic information systems to study interstate competition. *American Political Science Review*, 99(04):505–519, 2005.

Thomas A Birkland. "the world changed today": Agenda-setting and policy change in the wake of the september 11 terrorist attacks. *Review of Policy Research*, 21(2):179–200, 2004.

Irene Bloemraad, Anna Korteweg, and Gökçe Yurdakul. Citizenship and immigration: Multiculturalism, assimilation, and challenges to the nation-state. *Annu. Rev. Sociol*, 34:153–179, 2008.

Frederick J Boehmke. Approaches to modeling the adoption and diffusion of policies with multiple components. *State Politics & Policy Quarterly*, 9(2):229–252, 2009.

Arjen Boin and Paul't Hart. Public leadership in times of crisis: mission impossible? *Public Administration Review*, 63(5):544–553, 2003.

Eric Bonabeau. Agent-based modeling: Methods and techniques for simulating human systems. *Proceedings of the National Academy of Sciences*, 99(suppl 3):7280–7287, 2002.

Stephen P Borgatti and Rob Cross. A relational view of information seeking and learning in social networks. *Management science*, 49(4):432–445, 2003.

P. W. G. Bots. Designing the policy analysis process. In W. A. H. Thissen and W. E. Walker, editors, *Public Policy Analysis*, volume 179, pages 103–132. Springer, 2013.

Pieter WG Bots. Analysis of multi-actor policy contexts using perception graphs. In *Intelligent Agent Technology, 2007. IAT'07. IEEE/WIC/ACM International Conference on*, pages 160–167. IEEE, 2007.

Pieter WG Bots. Benchmarking in dutch urban water management: an assessment. In *Adaptive and Integrated Water Management*, pages 277–300. Springer, 2008.

Pieter WG Bots and Josée AM Hulshof. Designing multi-criteria decision analysis processes for priority setting in health policy. *Journal of Multi-Criteria Decision Analysis*, 9(1-3):56–75, 2000.

Pieter WG Bots, Mark JW Van Twist, and JH Ron Van Duin. Automatic pattern detection in stakeholder networks. In *System Sciences, 2000. Proceedings of the 33rd Annual Hawaii International Conference on*, pages 10–pp. IEEE, 2000.

Tony Bovaird. Emergent strategic management and planning mechanisms in complex adaptive systems: the case of the uk best value initiative. *Public Management Review*, 10(3):319–340, 2008.

Sally Brailsford. Discrete-event simulation is alive and kicking! *Journal of Simulation*, 8(1): 1–8, 2014.

Dietmar Braun and Fabrizio Gilardi. Taking 'galton's problem' seriously towards a theory of policy diffusion. *Journal of theoretical politics*, 18(3):298–322, 2006.

Peter Bridgman and Glyn Davis. *The Australian policy handbook*. Allen & Unwin, 2004.

Stijn Brouwer, Frank Biermann, et al. Towards adaptive management: examining the strategies of policy entrepreneurs in dutch water management. *Ecology and Society*, 16(4):5, 2011.

Steffen Brunner. Understanding policy change: Multiple streams and emissions trading in germany. *Global Environmental Change*, 18(3):501–507, 2008.

Jennifer L Bussell. Why get technical? corruption and the politics of public service reform in the indian states. *Comparative Political Studies*, 2010.

Paul Cairney. The role of ideas in policy transfer: the case of uk smoking bans since devolution. *Journal of European public policy*, 16(3):471–488, 2009.

Paul Cairney. Complexity theory in political science and public policy. *Political Studies Review*, 10(3):346–358, 2012.

Paul Cairney. *The Politics of Evidence-Based Policy Making*. Springer, 2016.

Benjamin Cashore and Michael Howlett. Punctuating which equilibrium? understanding thermostatic policy dynamics in pacific northwest forestry. *American Journal of Political Science*, 51(3):532–551, 2007.

Cristiano Castelfranchi. Simulating with cognitive agents: The importance of cognitive emergence. In *International Workshop on Multi-Agent Systems and Agent-Based Simulation*, pages 26–44. Springer, 1998.

Manuel Castells. The rise of the network society, revised edition, 2000.

Steven B Caudill, Jon M Ford, Franklin G Mixon Jr, and Ter Choa Peng. A discrete-time hazard model of lottery adoption. *Applied Economics*, 27(6):555–561, 1995.

Brahim Chaib-Draa and Jules Desharnais. A relational model of cognitive maps. *International Journal of Human-Computer Studies*, 49(2):181–200, 1998.

Michael D Cohen, James G March, and Johan P Olsen. A garbage can model of organizational choice. *Administrative science quarterly*, pages 1–25, 1972.

Michael D Cohen, Rick L Riolo, and Robert Axelrod. The role of social structure in the maintenance of cooperative regimes. *Rationality and Society*, 13(1):5–32, 2001.

Alessia Contu and Hugh Willmott. Re-embedding situatedness: The importance of power relations in learning theory. *Organization science*, 14(3):283–296, 2003.

Fay Lomax Cook, Tom R Tyler, Edward G Goetz, Margaret T Gordon, David Protess, Donna R Leff, and Harvey L Molotch. Media and agenda setting: Effects on the public, interest group leaders, policy makers, and policy. *Public Opinion Quarterly*, 47(1):16–35, 1983.

Sue ES Crawford and Elinor Ostrom. A grammar of institutions. *American Political Science Review*, 89(03):582–600, 1995.

Mary M Crossan, Henry W Lane, Roderick E White, and Lisa Djurfeldt. Organizational learning: Dimensions for a theory. *The International Journal of Organizational Analysis*, 3(4):337–360, 1995.

Mary M Crossan, Henry W Lane, and Roderick E White. An organizational learning framework: From intuition to institution. 1999.

Sander Dekker and Dan Hansén. Learning under pressure: The effects of politicization on organizational learning in public bureaucracies. *Journal of public administration research and theory*, 14(2):211–230, 2004.

Martha Derthick. *Policymaking for social security*. Brookings Institution Press, 1979.

Monika Djerf-Pierre. Green metacycles of attention: Reassessing the attention cycles of environmental news reporting 1961–2010. *Public Understanding of Science*, 22(4):495–512, 2013.

Nives Dolšak and Karen Sampson. The diffusion of market-based instruments: The case of air pollution. *Administration & Society*, 44(3):310–342, 2012.

Geoffrey Dudley. Individuals and the dynamics of policy learning: the case of the third battle of newbury. *Public Administration*, 85(2):405–428, 2007.

Claire A Dunlop and Claudio M Radaelli. Systematising policy learning: From monolith to dimensions. *Political Studies*, 61(3):599–619, 2013.

Bruno Dyck, Frederick A Starke, Gary A Mischke, and Michael Mauws. Learning to build a car: an empirical investigation of organizational learning. *Journal of Management Studies*, 42(2):387–416, 2005.

John R Ehrenfeld. Industrial ecology paradigm shift or normal science? *American Behavioral Scientist*, 44(2):229–244, 2000.

Christian Elmelund-Præstekær and Charlotte Wien. What's the fuss about? the interplay of media hypes and politics. *The International Journal of Press/Politics*, 13(3):247–266, 2008.

B Enserink, J. F. M. Koppenjan, and I. S. Mayer. A policy sciences view on policy analysis. In W. A. H. Thissen and W. E. Walker, editors, *Public Policy Analysis*, volume 179, pages 11–40. Springer, 2013.

Joshua M Epstein. *Generative social science: Studies in agent-based computational modeling*. Princeton University Press, 2006.

Joshua M Epstein and Robert Axtell. *Growing artificial societies: social science from the bottom up*. Brookings Institution Press, 1996.

Ioan Raymond Albert Fazey, John A Fazey, and Della MA Fazey. Learning more effectively from experience. *Ecology and Society*, 2005.

C Marlene Fiol and Marjorie A Lyles. Organizational learning. *Academy of management review*, 10(4):803–813, 1985.

Frank Fischer. Beyond the rationality project: Policy analysis and the postpositive challenge. *Policy Studies Journal*, 17(4):941–951, 1989.

James H Fowler and Oleg Smirnov. Dynamic parties and social turnout: An agent-based model1. *American Journal of Sociology*, 110(4):1070–1094, 2005.

Richard Freeman. Learning in public policy. *The Oxford handbook of public policy*, pages 367–388, 2006.

Carl Joachim Friedrich. *Man and his government: An empirical theory of politics*. McGraw-Hill, 1963.

Robert Geyer and Paul Cairney. *Handbook on complexity and public policy*. Edward Elgar Publishing, 2015.

Amineh Ghorbani, Pieter Bots, Virginia Dignum, and Gerard Dijkema. Maia: a framework for developing agent-based social simulations. *Journal of Artificial Societies and Social Simulation*, 16(2):9, 2013.

Virginia Gray. Innovation in the states: A diffusion study. *American political science review*, 67(04):1174–1185, 1973.

Mick Green and Barrie Houlihan. Advocacy coalitions and elite sport policy change in canada and the united kingdom. *International review for the sociology of sport*, 39(4): 387–403, 2004.

John Grin and Anne Loeber. 15 theories of policy learning: Agency, structure, and change. *Handbook of public policy analysis*, page 201, 2006.

John Grin and Henk van De Graaf. Implementation as communicative action. *Policy Sciences*, 29(4):291–319, 1996.

John Grin and Henk Van de Graaf. Technology assessment as learning. *Science, technology & human values*, 21(1):72–99, 1996.

Kuhika Gupta. Comparative public policy: Using the comparative method to advance our understanding of the policy process. *Policy Studies Journal*, 40(s1):11–26, 2012.

Misrad Hadzikadic, Joseph Whitmeyer, and Ted Carmichael. Using agent-based modelling to inform policy for complex domains. In Robert Greyer and Paul Cairney, editors, *Handbook on Complexity and Public Policy*, chapter 14, pages 221–241. Edward Elgar Publishing, 2015.

Maarten Hajer. Policy without polity? policy analysis and the institutional void. *Policy sciences*, 36(2):175–195, 2003.

Peter A Hall. Policy paradigms, social learning, and the state: the case of economic policymaking in britain. *Comparative politics*, pages 275–296, 1993.

H Hugh Heclo. Policy analysis. *British journal of political science*, 2(01):83–108, 1972.

Tanya Heikkila and Andrea K Gerlak. Building a conceptual approach to collective learning: Lessons for public policy scholars. *Policy Studies Journal*, 41(3):484–512, 2013.

Dirk Helbing. Agent-based modeling. In *Social self-organization*, pages 25–70. Springer, 2012.

Adam Douglas Henry. The challenge of learning for sustainability: A prolegomenon to theory. *Human Ecology Review*, 16(2):131–140, 2009.

Adam Douglas Henry and Thomas Dietz. Understanding environmental cognition. *Organization & Environment*, 25(3):238–258, 2012.

Adam Douglas Henry, Mark Lubell, and Michael McCoy. Belief systems and social capital as drivers of policy network structure: The case of california regional planning. *Journal of Public Administration Research and Theory*, 21(3):419–444, 2011.

Paulien M Herder, Ivo Bouwmans, Gerard PJ Dijkema, Rob M Stikkelman, and Margot PC Weijnen. Designing infrastructures using a complex systems perspective. *Journal of design research*, 7(1):17–34, 2008.

Nicole Herweg, Christian Huß, and Reimut Zohlnhöfer. Straightening the three streams: Theorising extensions of the multiple streams framework. *European Journal of Political Research*, 54(3):435–449, 2015.

Michael Hill and Frederic Varone. *The public policy process*. Routledge, 2016.

George Hoberg. Putting ideas in their place: a response to "learning and change in the british columbia forest policy sector". *Canadian journal of political science*, 29(01):135–144, 1996.

Jennifer Hochschild and Vesla Mae Weaver. "there's no one as irish as barack o'bama": the policy and politics of american multiracialism. *Perspectives on Politics*, 8(03):737–759, 2010.

Brian W Hogwood, Lewis A Gunn, et al. *Policy analysis for the real world*, volume 69. Oxford University Press Oxford, 1984.

Tim R Holcomb, R Duane Ireland, R Michael Holmes Jr, and Michael A Hitt. Architecture of entrepreneurial learning: Exploring the link among heuristics, knowledge, and action. *Entrepreneurship Theory and Practice*, 33(1):167–192, 2009.

John Henry Holland. *Hidden order: How adaptation builds complexity*. Basic Books, 1995.

Michael Howlett and Benjamin Cashore. The dependent variable problem in the study of policy change: Understanding policy change as a methodological problem. *Journal of Comparative Policy Analysis*, 11(1):33–46, 2009.

Michael Howlett and M Ramesh. The policy effects of internationalization: A subsystem adjustment analysis of policy change. *Journal of Comparative Policy Analysis*, 4(1):31–50, 2002.

Michael Howlett, Allan McConnell, and Anthony Perl. Streams and stages: Reconciling kingdon and policy process theory. *European Journal of Political Research*, 54(3):419–434, 2015.

George P Huber. Organizational learning: The contributing processes and the literatures. *Organization science*, 2(1):88–115, 1991.

Anne Sigismund Huff. *Mapping strategic thought.* John Wiley & Sons, 1990.

Karin Ingold. Network structures within policy processes: Coalitions, power, and brokerage in swiss climate policy. *Policy Studies Journal*, 39(3):435–459, 2011.

Karin Ingold and Frédéric Varone. Treating policy brokers seriously: evidence from the climate policy. *Journal of Public Administration Research and Theory*, page mur035, 2011.

Werner Jann and Kai Wegrich. Theories of the policy cycle. *Handbook of public policy analysis: Theory, politics and methods*, pages 43–62, 2007.

Hank C Jenkins-Smith, Daniel Nohrstedt, Christopher M Weible, and Paul A Sabatier. The advocacy coalition framework: Foundations, evolution, and ongoing research. *Theories of the policy process*, 3, 2014.

A Grant Jordan. Iron triangles, woolly corporatism and elastic nets: Images of the policy process. *Journal of public policy*, 1(01):95–123, 1981.

Jason Jordan. Policy feedback and support for the welfare state. *Journal of European Social Policy*, 23(2):134–148, 2013.

Daniel H Kim. The link between individual and organizational learning. *The strategic management of intellectual capital*, pages 41–62, 1998.

Seoyong Kim. Irresolvable cultural conflicts and conservation/development arguments: Analysis of korea's saemangeum project. *Policy Sciences*, 36(2):125–149, 2003.

John W Kingdon. *Agendas, alternatives, and public policies.* Longman Pub Group, 2003.

Erik-Hans Klijn. Complexity theory and public administration: What's new? key concepts in complexity theory compared to their counterparts in public administration research. *Public Management Review*, 10(3):299–317, 2008.

Louise Knight. Network learning: Exploring learning by interorganizational networks. *Human relations*, 55(4):427–454, 2002.

Gerald M Kosicki. Problems and opportunities in agenda-setting research. *Journal of communication*, 43(2):100–127, 1993.

Michael A Krassa. Social groups, selective perception, and behavioral contagion in public opinion. *Social Networks*, 10(2):109–136, 1988.

Philip Leifeld. Reconceptualizing major policy change in the advocacy coalition framework: a discourse network analysis of german pension politics. *Policy Studies Journal*, 41 (1):169–198, 2013.

James Lester and Joseph Stewart. Public policy. *Belmont, CA: Wadsworth*, 2000.

Daniel A Levinthal and James G March. The myopia of learning. *Strategic management journal*, 14(S2):95–112, 1993.

Barbara Levitt and James G March. Organizational learning. *Annual review of sociology*, pages 319–340, 1988.

Shu-hsien Liao, Wu-Chen Fei, and Chih-Tang Liu. Relationships between knowledge inertia, organizational learning and organization innovation. *Technovation*, 28(4):183–195, 2008.

Charles E Lindblom. The science of "muddling through". *Public administration review*, pages 79–88, 1959.

Charles Edward Lindblom. *The intelligence of democracy: Decision making through mutual adjustment*. Free Pr, 1965.

Adrian Little. Complexity and real politics. In Robert Greyer and Paul Cairney, editors, *Handbook on Complexity and Public Policy*, pages 32–47. Edward Elgar Publishing, 2015.

Charles G Lord, Lee Ross, and Mark R Lepper. Biased assimilation and attitude polarization: The effects of prior theories on subsequently considered evidence. *Journal of personality and social psychology*, 37(11):2098, 1979.

Niklas Luhmann. *Social systems*. Stanford University Press, 1995.

Michael W Macy and Robert Willer. From factors to actors: Computational sociology and agent-based modeling. *Annual review of sociology*, pages 143–166, 2002.

Chrysostomos Mantzavinos, Douglass C North, and Syed Shariq. Learning, institutions, and economic performance. *Perspectives on politics*, 2(01):75–84, 2004.

Peter J May. Policy learning and failure. *Journal of public policy*, pages 331–354, 1992.

Igor S. Mayer, C. Els van Daalen, and Pieter W. G. Bots. *Perspectives on Policy Analysis: A Framework for Understanding and Design*, pages 41–64. Springer US, Boston, MA, 2013. ISBN 978-1-4614-4602-6. doi: 10.1007/978-1-4614-4602-6_3. URL `http://dx.doi.org/10.1007/978-1-4614-4602-6_3`.

Michael J Mazarr. The iraq war and agenda setting. *Foreign Policy Analysis*, 3(1):1–23, 2007.

Maxwell E McCombs and Donald L Shaw. The agenda-setting function of mass media. *Public opinion quarterly*, 36(2):176–187, 1972.

Daniel McCool. The subsystem family of concepts: a critique and a proposal. *Political Research Quarterly*, 51(2):551–570, 1998.

Miller McPherson, Lynn Smith-Lovin, and James M Cook. Birds of a feather: Homophily in social networks. *Annual review of sociology*, pages 415–444, 2001.

Sander Meijerink. Explaining continuity and change in international policies: Issue linkage, venue change, and learning on policies for the river scheldt estuary 1967–2005. *Environment and Planning A*, 40(4):848–866, 2008.

Suzanne Mettler. Bringing the state back in to civic engagement: Policy feedback effects of the gi bill for world war ii veterans. *American Political Science Review*, 96(02):351–365, 2002.

Suzanne Mettler and Mallory SoRelle. Policy feedback theory. *Theories of the policy process*, pages 151–181, 2014.

Suzanne Mettler and Joe Soss. The consequences of public policy for democratic citizenship: Bridging policy studies and mass politics. *Perspectives on politics*, 2(01):55–73, 2004.

Peter Mika. Social networks and the semantic web. In *Proceedings of the 2004 IEEE/WIC/ACM International Conference on Web Intelligence*, pages 285–291. IEEE Computer Society, 2004.

John H Miller and Scott E Page. *Complex adaptive systems: An introduction to computational models of social life*. Princeton university press, 2009.

Michael Mintrom and Phillipa Norman. Policy entrepreneurship and policy change. *Policy Studies Journal*, 37(4):649–667, 2009.

Michael Mintrom and Sandra Vergari. Advocacy coalitions, policy entrepreneurs, and policy change. *Policy studies journal*, 24(3):420–434, 1996.

Michael Mintrom and Sandra Vergari. Policy networks and innovation diffusion: The case of state education reforms. *The Journal of Politics*, 60(01):126–148, 1998.

Michael Moran, Martin Rein, and Robert E Goodin. *The Oxford handbook of public policy*. Oxford University Press, 2008.

Göktuğ Morçöl. *A complexity theory for public policy*. Routledge, 2013.

Stéphane Moyson et al. The individuals in policy change: Policy learning in the liberalization of network industries in belgium. *Louvain–la–Neuve: Université catholique de Louvain–la–Neuve*, 2014.

Gary Mucciaroni. The garbage can model & the study of policy making: A critique. *Polity*, pages 459–482, 1992.

Geoffrey D Munro, Peter H Ditto, Lisa K Lockhart, Angela Fagerlin, Mitchell Gready, and Elizabeth Peterson. Biased assimilation of sociopolitical arguments: Evaluating the 1996 us presidential debate. *Basic and Applied Social Psychology*, 24(1):15–26, 2002.

Isaac Naveh and Ron Sun. A cognitively based simulation of academic science. *Computational & Mathematical Organization Theory*, 12(4):313–337, 2006.

W Russell Neuman. The threshold of public attention. *Public Opinion Quarterly*, 54(2): 159–176, 1990.

Jens Newig, Dirk Günther, Claudia Pahl-Wostl, et al. Synapses in the network: learning in governance networks in the context of environmental management. *Ecology and Society*, 15(4):24, 2010.

Sean Nicholson-Crotty. The politics of diffusion: Public policy in the american states. *The Journal of Politics*, 71(01):192–205, 2009.

Matthew C Nisbet and Mike Huge. Attention cycles and frames in the plant biotechnology debate managing power and participation through the press/policy connection. *The Harvard International Journal of Press/Politics*, 11(2):3–40, 2006.

Daniel Nohrstedt. External shocks and policy change: Three mile island and swedish nuclear energy policy. *Journal of European Public Policy*, 12(6):1041–1059, 2005.

Daniel Nohrstedt and Christopher M Weible. The logic of policy change after crisis: Proximity and subsystem interaction. *Risk, Hazards & Crisis in Public Policy*, 1(2):1–32, 2010.

Ikujiro Nonaka. A dynamic theory of organizational knowledge creation. *Organization science*, 5(1):14–37, 1994.

Stellan Ohlsson. *Deep learning: How the mind overrides experience*. Cambridge University Press, 2011.

Laurence J O'Toole Jr. Strategies for intergovernmental management: Implementing programs in interorganizational networks. *International Journal of Public Administration*, 11(4):417–441, 1988.

Dennis James Palumbo and Donald J Calista. *Symposium: Implementation: What we have learned and still need to know*, volume 7. Policy Studies Organization, 1987.

Jonathan J Pierce. Coalition stability and belief change: Advocacy coalitions in us foreign policy and the creation of israel, 1922–44. *Policy Studies Journal*, 39(3):411–434, 2011.

Paul Pierson. When effect becomes cause: Policy feedback and political change. *World politics*, 45(04):595–628, 1993.

Claudio M Radaelli. Harmful tax competition in the eu: policy narratives and advocacy coalitions. *JCMS: Journal of Common Market Studies*, 37(4):661–682, 1999.

Sasan Rahmatian and Charlotte Hiatt. Toward an information-based theory of irrational systems behavior. *Systems Research*, 6(1):7–16, 1989.

Orit Rapaport, David Levi-Faur, and Dan Miodownik. The puzzle of the diffusion of central-bank independence reforms: Insights from an agent-based simulation. *Policy Studies Journal*, 37(4):695–716, 2009.

Jeremy Richardson. Government, interest groups and policy change. *Political studies*, 48 (5):1006–1025, 2000.

Graham Room. Complexity, power and policy. In Robert Greyer and Paul Cairney, editors, *Handbook on Complexity and Public Policy*, chapter 2, pages 19–31. Edward Elgar Publishing, 2015.

Paul A Sabatier and Hank C Jenkins-Smith. *Policy change and learning: An advocacy coalition approach*. Westview Pr, 1993.

Paul A Sabatier and Christopher Weible. *Theories of the policy process.* Westview Press, 2014.

Susan M Sanchez and Thomas W Lucas. Exploring the world of agent-based simulations: simple models, complex analyses: exploring the world of agent-based simulations: simple models, complex analyses. In *Proceedings of the 34th conference on Winter simulation: exploring new frontiers*, pages 116–126. Winter Simulation Conference, 2002.

Anne Schneider and Helen Ingram. Systematically pinching ideas: A comparative approach to policy design. *Journal of public policy*, 8(01):61–80, 1988.

Peer-Olaf Siebers, Charles M Macal, Jeremy Garnett, D Buxton, and Michael Pidd. Discrete-event simulation is dead, long live agent-based simulation! *Journal of Simulation*, 4(3): 204–210, 2010.

Theda Skocpol, Peter Evans, and Dietrich Rueschemeyer. Bringing the state back in. *Cambridge*, 1999.

Metodi Sotirov and Michael Memmler. The advocacy coalition framework in natural resource policy studies - recent experiences and further prospects. *Forest policy and economics*, 16:51–64, 2012.

Paul C Stern. New environmental theories: toward a coherent theory of environmentally significant behavior. *Journal of social issues*, 56(3):407–424, 2000.

Joseph Stewart Jr, David Hedge, and James P Lester. *Public policy: An evolutionary approach.* Nelson Education, 2007.

Frances Stokes Berry and William D Berry. Innovation and diffusion models in policy research. *Theories of the policy process*, 169, 1999.

Araz Taeihagh, René Bañares-Alcántara, and Claire Millican. Development of a novel framework for the design of transport policies to achieve environmental targets. *Computers & Chemical Engineering*, 33(10):1531–1545, 2009.

Rick Travis and Nikolaos Zahariadis. A multiple streams model of us foreign aid policy. *Policy Studies Journal*, 30(4):495–514, 2002.

Douglas Van Belle. Domestic imperatives and rational models of foreign policy decision making. *The limits of state autonomy: Societal groups and foreign policy formulation*, pages 151–183, 1993.

Douglas A Van Belle. New york times and network tv news coverage of foreign disasters: The significance of the insignificant variables. *Journalism & Mass Communication Quarterly*, 77(1):50–70, 2000.

Koen H van Dam, Igor Nikolic, and Zofia Lukszo. *Agent-based modelling of socio-technical systems*, volume 9. Springer Science & Business Media, 2012.

Peter LM Vasterman. Media-hype self-reinforcing news waves, journalistic standards and the construction of social problems. *European Journal of Communication*, 20(4):508–530, 2005.

Annie Waldherr. Emergence of news waves: A social simulation approach. *Journal of Communication*, 64(5):852–873, 2014.

Jack L Walker. The diffusion of innovations among the american states. *American political science review*, 63(03):880–899, 1969.

Warren E Walker. Policy analysis: a systematic approach to supporting policymaking in the public sector. *Journal of Multicriteria Decision Analysis*, 9(1-3):11, 2000.

Duncan J Watts and Steven H Strogatz. Collective dynamics of 'small-world' networks. *nature*, 393(6684):440–442, 1998.

Christopher M Weible. Expert-based information and policy subsystems: a review and synthesis. *Policy Studies Journal*, 36(4):615–635, 2008.

Christopher M Weible, Paul A Sabatier, and Kelly McQueen. Themes and variations: Taking stock of the advocacy coalition framework. *Policy Studies Journal*, 37(1):121–140, 2009.

Russell Alan Williams. Exogenous shocks in subsystem adjustment and policy change: the credit crunch and canadian banking regulation. *Journal of Public Policy*, 29(01):29–53, 2009.

Oliver E Williamson. *The mechanisms of governance*. Oxford University Press, 1996.

Antje Witting. The role of expertise in policy development: Towards a de-carbonized british road transport infrastructure. 2012.

Adam Wyner and Neil Benn. Modelling policy-making (mpm 2011). 2011.

Nikolaos Zahariadis. *Ambiguity and choice in public policy: Political decision making in modern democracies*. Georgetown university press, 2003.

Nikolaos Zahariadis. The multiple streams framework: Structure, limitations, prospects. *Theories of the policy process*, 2:65–92, 2007.

Nikolaos Zahariadis. Ambiguity and multiple streams. *Theories of the policy process*, pages 25–58, 2014.

Reimut Zohlnhöfer. How politics matter when policies change: Understanding policy change as a political problem. *Journal of Comparative Policy Analysis*, 11(1):97–115, 2009.