Social Interaction and Political Preferences

An Agent-Based Approach to Estimate Social Interaction Effects on Government Satisfaction in Germany

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Abstract

Existing research is inconclusive about if and how social interactions affect individuals' political preferences. This study formulates and tests an agent-based model of opinion dynamics which claims to explain the evolution of political preferences by means of social interaction effects. The approach incorporates a majority and a momentum mechanism claiming that individuals are affected by perceived opinion levels as well as by opinion changes. This theoretical model is empirically tested by estimating its parameters on government satisfaction in Germany. The results support the empirical validity of the approach: A significant momentum mechanism can be identified while other significant parameters display meaningful estimates. Additionally, almost every week's level of government satisfaction is a likely realization of the process given the data of the previous week. Beyond that, the findings suggest that individuals are rather affected by opinion changes than by opinion levels and that nonconformity plays a more important role in the evolution of the considered preference than conformity.

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1 Introduction

Distinct and sudden shifts in the temporal development of political preferences are not rare. The 2016 United States presidential election or the 2015 Brexit referendum are just two instances. In this context, public but also scientific debates often addressed a doubtful accuracy of opinion polls (cf. Lusinchi, 2017). By contrast, the work at hand argues that it are mechanisms of social interaction that are crucially responsible for these volatile temporal evolutions of political preferences. Especially in times of intense communication via different media channels and loosening party affiliations, it stands to reason that social interaction plays a fundamental role for the formation of political preferences.

While there is consensus that social interaction influences voting intentions via strategic considerations (e.g. Abramson et al., 1995), there is still ambiguity about if and how the dynamics of aggregate political preferences are significantly affected by this interaction. There are psychologically-based explanations which presume conformity towards the majority opinion ('bandwagon effect', e.g. Gimpel and Harvey, 1997), others conjecture nonconformist tendencies ('underdog effect', e.g. Lavrakas and Holley, 1991) and others again assume that social interaction effects are neglectable (e.g. Feldman, 1988). The comprehensive empirical research was inconclusive about if both effects exist and which effect dominates in view of aggregate preferences (e.g. Agranov et al., 2017). However, it is vitally important to understand the nexus between social interaction and political preferences: For reasons of voter coordination, voters are dependent on exact information about other's voting intention; if the release of social information (e.g. via polls) triggers mechanisms of social interactions which impact on political preferences and hence on voting intentions, an inefficient coordination could entail (Lehtinen, 2007).

While the bulk of empirical investigations tested non-formal theories or implicit models with vague theoretical considerations, the aim of the present work is to formulate and test a formal model which claims to explain the dynamics of political preferences especially by means of social interaction effects. In this context, the parameters of the model are estimated to investigate if significant social interaction effects can be identified but also to deepen the understanding of the dynamics. It will be drawn on the comprehensive research area of opinion dynamics by employing an agent-based model that considers a population of interacting individuals which is suitable to explain the dynamical process of opinion evolution. In particular, the prominent agent-based model of Weidlich and Haag

(1983) and Lux (1995) is used. I seek to contribute to the literature on political preferences and social interaction in two respects. Firstly, I discriminate between two mechanisms of social interaction: a majority and a momentum mechanism. While the first assumes that individuals are affected by the prevalent and publicly visible majority situations, the latter proceeds on the assumption that individuals are also influenced by perceived changes of the majority situations. The introduction of this widely neglected momentum mechanism (for an exception see Fichnová and Wojciechowski, 2015) is theoretically justified with regard to the propagation of a horse race journalism which rather reports changes than levels of opinion (e.g. Faas, 2017). The model's mechanisms are not predetermined in the direction of conformity or nonconformity which is convenient since the empirical evidence was ambiguous in this regard. Second, opinion dynamics models provide significant qualitative insights into the evolution of political opinions; however they were rarely tested by use of real word data on political preferences (cf. e.g. Sobkowicz, 2016).

The model is tested by means of unpublished and weekly aggregate survey data on German government satisfaction of the German Federal Press Office (FPO) and data of exogenous factors of influence which I collected using webscraping. I obtain evidence which suggests that the model of social interaction can explain the changes in aggregate government satisfaction: A significant momentum mechanism can be identified and also other parameter estimates are meaningful; the effects of social interaction seem to be more important for the model fit than exogenous factors of influence. Computations of 95 percent bounds show that almost every week's value of government satisfaction is a likely realization of the process given the data of the previous week. Interestingly, the parameters indicate rather a tendency of nonconformity than a propensity of conformity. In addition, no significant majority mechanism can be identified which indicates that respondents rather respond to changes than levels of public opinion. Contrary to my expectations, I do not find that social interaction effects appear to be more pronounced under the presence of opinion polls.

The structure of the present paper is constitutes as follows: In Section 2, the relevant literature and its limits are discussed. Ensuing, the agent-based model of Weidlich and Haag (1983) and Lux (1995) is expounded and respecified for the present context in Section 3. At the and of this chapter, I formulate expectations about the parameter estimates. In Section 4, the data, operationalizations and the estimation framework are stated respectively

justified. In the same section, the results are presented and discussed. Terminatory, I draw conclusions in Section 5.

2 Political Preferences and Social Interaction Effects

This chapter attends to the literature, which addresses the effects of social interaction on individual political preferences and, subsequently, on aggregate political opinion. It comprises a discussion of existing formal and non-formal theories as well as a consideration of their empirical assessment. In the course of this review, former approaches are appreciated; in addition, existing limitations are identified which the work at hand strives to tackle.

Although general determinants of individual preference changes were extensively and effectively studied by authors from the political sciences and neighboring disciplines, the understanding of political opinion mutations is limited (cf. Jin et al., 2017). This also applies to the influence of social interaction on changes of political preferences. The question of whether and how these social interaction effects are at work is subject to a controversial scientific debate. One line of literature takes the view that political preferences and values are largely stable and thus unaffected by social interaction. The related research typically assumes that individuals possess core believes which do not alter over time (cf. Feldman, 1988). According to this reasoning, these stable convictions are essentially associated with political positions and policy preferences (cf. Heath et al., 1994). Mostly non-varying political moods observed in aggregate (Page and Shapiro, 1982) or panel data (Ansolabehere et al., 2008) on political opinion and voting preferences were taken as empirical evidence for this line of argument. Specifically regarding social interaction, empirical work indicating that early media coverage of US election results on the East does not significantly affect the behavior of later balloting voters in the West, might point out the irrelevance of interaction effects on preferences (Adams, 1985; Fuchs, 1966; Mendelsohn, 1966; Tuchman and Coffin, 1971).[2][3] Following the literature assuming stable beliefs, social interaction effects can not find expression in the evolution of political opinion, however in voting behavior via strategic considerations. The existence of these strategic voting effects is un-

[2]The empirical analysis of survey data by Daschmann (2000) and Giammo (2004) yield similar results.
[3]To be precise, these studies consider voting intentions rather than political preferences.

controversial in both the theoretical and empirical literature (cf. Cain, 1978; Abramson et al., 1992, 1995).[4]

In contrast to this conjecture of stable political preferences, the present work takes side for the (partially more recent) literature assuming that individual political opinions are not immutable but subject to social forces. As I argue later on, social interaction effects are of concern in times of increased communication between individuals mediated by the media while natural affiliations with political parties as well as their positions recede and political options are increasingly difficult to localize in the political landscape. The respective literature essentially differentiates between two types of response subsequent to social interaction: conformity and nonconformity.[5] This assumes that individuals experience their peer's prevalent mood in the course of indirect or direct communication. Then, conformity to the majority opinion is typically labeled as *bandwagon effect* while the converse nonconformist behavior is denoted by the *underdog effect* (precise definitions follow in Section 2.1. However, not just the majority situation relating to a political issue may influence individual political preferences but also perceived changes of the peer's opinion (see Table 1). I designate movements in direction of the opinion change caused by social interaction as *momentum effect* while the rather nonconformist switching to a political option which lost support is indicated by *anti-momentum effect*. Predominantly, no distinction is made between these *majority* and *momentum mechanisms*. Therefore, one contribution of the paper at hand is their conceptual distinction. The literature is categorized along these mechanisms. To begin with, non-formal and formal theories considering bandwagon and underdog effects as well as their empirical evidence are discussed. Thereupon, the theoretical and empirical foundations of the momentum mechanism are studied. Conclusively, existing limitations are summarized.

[4]For instance, in the case of Germany, the *guillotine effect* could prevent a individual from voting for a party which might fail to enter the parliament. The reverse *coalition insurance effect* could a citizen vote for a small party in order to make a preferred coalition possible (see e.g. Faas, 2017).

[5]Withal, also other social reactions are focused at times. For instance, some studies consider the effects of social interaction on the intensity of opinion expressions. For example, studies find evidence for a significant impact of social interaction on electoral turnout (DuBois, 1983; Jackson, 1983; Sudman, 1986) which was challenged by other investigations (Epstein and Strom, 1984; Fuchs, 1966; Mendelsohn, 1966; Mendelsohn and Crespi, 1970; Tuchman and Coffin, 1971). However, in the sequel, these effects on electoral voting behavior are not considered since social influences on political preferences are the primary object of interest.

Table 1: Overview over responses subsequent to social interaction.

	Majority Mechanism	**Momentum Mechanism**
Conformity	Bandwagon Effect	Momentum Effect
Nonconformity	Underdog Effect	Anti-Momentum Effect

Source: Own representation.

2.1 Majority Mechanism: Bandwagon and Underdog Effects

This section discusses non-formal and formal theories concerned with bandwagon and underdog effects on political preferences. When regarding formal theories, special focus will be given to models originating from the interdisciplinary field of opinion dynamics. Following Simon (1954, p. 246), a *bandwagon effect* occurs if an individual changes his or her preference towards a candidate, party or policy position which is favored by the majority. A preference shift towards a inferior political alternative is labeled as *underdog effect* (Simon, 1954, p. 246). These concepts are also applicable to shifts of aggregate preferences (cf. Rothschild and Malhotra, 2014, p. 1). No notional distinction will be made between social interaction effects on individual and those on aggregate political preferences.

2.1.1 Non-Formal Theories: How the Exposure to Other's Opinions Influences Political Preferences

The considered non-formal theories essentially rest upon psychological approaches and are subsequently subdivided into contributions espousing either bandwagon or underdog arguments. Thereafter, findings of the empirical literature are discussed.

2.1.1.1 Bandwagon Theories

Arguments for the existence of bandwagon effects are principally based on three different theoretical approaches. Firstly, socio-psychological reasoning refers to a assumed propensity to conform to the majority opinion in order to avoid social punishments and sanctions (cf. Asch, 1955; McAllister and Studlar, 1991; Dahlem, 2001; Aronson et al., 2010). Especially the influential spiral of silence theory of Noelle-Neumann (1980) has to be mentioned in this regard. According to this viewpoint, individuals' attitudes are exposed to

group pressure which initiates an self-enhancing process. This would finally eventuate in a "silent majority" (Noelle-Neumann, 1989, p. 42). Secondly, another line of socio-psychological theories explains bandwagon effects not with reference to social punishments but rather by means of psychological rewards. Accordingly, these gratifications are triggered by being member of a (visible) majority such as preferring a party, candidate or policy position which is commonly favored (Ashworth et al., 2006; Lazarsfeld et al., 1968). Thirdly, the cognitive psychological theory of impersonal influence developed by Mutz (1998) provides two theoretical mechanisms which explain bandwagon behavior. On the one hand, information about other's opinion may abbreviate the process of forming an own opinion by trusting in the quality of the majority's judgment. Thus, social information could be used for a heuristic short cut; especially if no pertinent stable beliefs are present (cf. Axsom et al., 1987). On the other hand, this social information would activate a cognitive process during which an individual brings possible reasons for the majority's opinion to his or her mind (cf. Raab et al., 2010). Although all three theoretical approaches differ in their psychological reasoning, they coincide in their corollary: the existence of a tendency of conformity in the evolution of (political) preferences.

2.1.1.2 Underdog Theories

In contrast to the above-mentioned arguments, there are competing theories which are taking sides for the existence of an underdog effect. Compared with bandwagon theories, the psychological mechanisms leading to nonconformist behavior while being exposed to the majority's opinion are at times less concisely enunciated (cf. Sanders, 2003, p. 8). Explanations are usually based on compassion and sympathy for an unpopular party, candidate or policy position (Donsbach, 1984; Brettschneider, 2000; Schoen, 2002). More explicitly, Vandello et al. (2007) argue for two different psychological mechanisms: Firstly, an aversion to inequalities is theoretically identified as driving force for an attitude shift towards an inferior alternative. Secondly, the outgunned entity might face a competitive disadvantage e.g in financial or political terms. In this case, individuals will assess the performance of the underdog better than comparable achievements displayed by the preponderantly preferred alternative (Vandello et al., 2007, p. 1604). The latter mechanism theoretically ties on deservingness theories which states that the performance of positively valued entities is itself evaluated in an beneficial way (Feather, 1999). Without

regarding opposing bandwagon forces, these underdog theories conjecture a tendency of nonconformity in the development of (political) opinions.

2.1.1.3 Empirical Evidence

The empirical literature frequently attempted to investigate the validity of these general psychological mechanisms for the process of political opinion formation by testing hypothesis essentially derived from these theories. Since bandwagon and underdog mechanisms work in different directions, especially the question of which effect dominates comes to the fore. This section provides a systematic overview over this large body of literature. Especially studies which focus the effect of social information on political preferences are discussed. In years past, two types of data were employed for related (purely) statistical analyses: (1) experimental and (2) polling data. Some experimental data originates from natural experiments: In several countries several time zones exist wherefore election results for parts of the country become public before the last polling station closes (e.g. USA, see the aforementioned *west coast effect*). Thus, it is possible to test if social information from early voters' behavior has an effect on later electors (e.g. Fuchs, 1966; Sudman, 1986; Behnke, 2008). However, since voting behavior rather than bare political preferences are investigated, these studies usually do not isolate bandwagon and underdog effects from strategic voting effects. Laboratory experiments are able to overcome these problems: Several contributions tested the implications of bandwagon and underdog theories under controlled environment conditions. In the course of these investigations, participants are asked to state their attitude towards a political candidate, party or general issue; some randomly selected attendees are confronted with a distribution of other's opinions. The respective evidence is inconclusive: Some studies find significant bandwagon effects (cf. Marsh, 1985; Nadeau et al., 1993; Ansolabehere and Iyengar, 1994; Morwitz and Pluzinski, 1996; Mehrabian, 1998; Bischoff and Egbert, 2013) while others detect underdog effects (cf. Laponce, 1966; Fleitas, 1971; Ceci and Kain, 1982; Vandello et al., 2007). Analyses of polling data were mainly conducted with reference to the limited external validity of those examinations.[6] Those studies seek to investigate the relationship between the exposure to opinion polls and voter's preferences.[7] Again, evidence of those

[6] In turn, investigations based on polling data have difficulties, among others, to disentangle the observed effects from exogenous factors like incisive occurrences (cf. Kiss and Simonovits, 2014).

[7] There are also studies which attempt to identify bandwagon or underdog effects in actual electoral behavior (Skalaban, 1988, e.g.). However, those studies do not distinguish bandwagon effects and strategic voting effects.

examinations is split: Both bandwagon (cf. Teer and Spence, 1973; Bartels, 1985; McAllister and Studlar, 1991; Gimpel and Harvey, 1997) and underdog effects (cf. Lavrakas and Holley, 1991; Sanders, 2003; Goot, 2010) were found.[8] Those investigations almost exclusively focused electoral preferences regarding candidates or parties in different countries such as the US (e.g. Bartels, 1985; Gimpel and Harvey, 1997), Great Britain (e.g. Sanders, 2003) or Germany (e.g. Wuttke, 2014). To summarize, "the empirical literature has been inconclusive regarding which of these two effects is expected to dominate in different settings" (Agranov et al., 2017, p. 4) which can be interpreted as call for further theoretical and empirical attempts. The paper at hand complies with this request - by empirically testing a formal model of social interaction which is not predetermined in the direction of social response to interaction (either conformity or nonconformity).

2.1.2 Formal Theories of Opinion Dynamics: Models of Political Opinion Formation incorporating Bandwagon and Underdog Effects

Repeatedly, formal or at least explicit models were formulated which (1) incorporate bandwagon or underdog effects and (2) are applicable to the formation of political preferences. The popularity of formal theories (not just) in political science arises from their argumentative stringency, coherence and persuasiveness (Martin, 2009, p. 37). Formal theories make their assumptions explicit and provide precise statements about what to observe given the validity of the formal theory (Coppedge, 2012, Chapter 6). Naturally, modeling human behavior is a difficult endeavor since, especially in the present case, psychological processes are largely unknown. However, those models do not claim to represent an extremely accurate image of reality but rather an appropriate simplification in order to approach the corresponding research question. The model of Simon (1954) incorporates both bandwagon and underdog effects for the first time. This model of voting behavior in a two-party system was designed in order to tackle the question weather opinion forecasting is possible even if social interaction effects would cause a change in opinion after publication of those polls. Simon concludes that the voter reaction function has to be known in order to deliver accurate, self-confirming predictions. Also the model of Baumol (1957) considers bandwagon and underdog effects[9] which affect the

[8] Other applications could identify neither bandwagon nor underdog effects (e.g. Blais et al., 2006; Giammo, 2004).

[9] Actually, Baumol (1957) introduces a definition which differs from the one of Simon (1954). Baumol's definitions would rather correspond to the abovementioned momentum and anti-momentum effects.

preference distribution of the public. In contrast to the theory of Simon (1954), it focuses multiple opinion poll publications during one campaigns and their impact on the actual public opinion. Baumol concludes that underdog effects would result in oscillatory behavior of the public opinion; bandwagon effects would lead to a rising popularity of one political alternative. Aldrich (1980) considers a dynamic model of presidential nomination campaigns based on difference equations. He disregards underdog motivations but incorporates bandwagon effects. This effect is justified in a non-psychological way: Leading candidates would be able to gather more recourses for campaigning than followers. As a result, frontrunners could increase their lead and weed out their competitors.

These theoretical investigations may be thought of as predecessors of the interdisciplinary field of *opinion dynamics* (cf. Xia et al., 2011). Instead of employing individualistic attempts which consider choices and interests of (representative) individuals, this approach focuses social relations between a population of interacting individuals. Thus, examinations associated with opinion dynamics study complex structural properties of social groups such as dynamical processes of diffusion and evolution of opinions. For this endeavor, mathematical and physical models are employed and coupled with computational tools. *Agent-based modeling* is a prominent class of computational models often utilized in this context since it is able to simulate the interactions between several (and possibly heterogeneous) agents. The interplay of these individual units allows to study *emergent properties* at the level of the whole system - properties which are not immediately evident via analyzing single agents (cf. e.g. Xia et al., 2011).

Most models are formulated general enough to be applicable to the evolution of political preferences. The amount of different models is vast and steadily growing. Early and fruitful attempts originate from statistical physics: Of outstanding importance is the *sociodynamic* model developed and studied by Weidlich and Haag (1983) and Lux (1995) which is also utilized in the paper at hand (the model is explicitly expounded in Section 3). Other prominent models of opinion dynamics used to describe political opinion formation are the *voter model* (with the *majority rule model* as special case), the *q-voter model* (with the *Sznajd model* as special case) and the *bounded confidence model* (see Castellano et al., 2009a; Xia et al., 2011; Siedlecki et al., 2016, for an overview). In the voter model individuals have direct neighbors (often on a regular lattice) and binary opinions; randomly chosen individuals then adopt the opinion of a neighbor (e.g. Holley and Liggett, 1975). In the majority rule model groups of individuals with binary opinions are successively

selected; all individuals in one group then adopt the constellation's majority opinion (e.g. Galam, 1999). In the q-voter model, q neighbors of an agent are randomly picked; if all q individuals share the same binary opinion the respective neighboring agent adopts this opinion (e.g. Castellano et al., 2009b). In case of the Sznajd model, an agent adopts the binary opinion of an agreeing neighbor pair (usually on a regular lattice) (e.g. Slanina and Lavicka, 2003). In the bounded confidence model, opinions are continuous values; in the course of interaction, the opinions of interacting agents are e.g. averaged (e.g. Deffuant et al., 2002). Numerous variants of these and other models were intensively studied. Especially out of an qualitative perspective, these models made an enormous contribution to the understanding of several mechanisms of (political) opinion change (cf. Sobkowicz, 2016).

With regard to the present issue, bandwagon and underdog effects and the evolution of political opinion, two structural limitations can be recognized. First, the predominant role of conformity in plenty models is noteworthy (also cf. Siedlecki et al., 2016): "While conformity underlies many models of opinion dynamics, [...] anticonformity is a much less considered type of social response." (Apriasz et al., 2016, p. 2).[10] This also becomes apparent in the comprehensive review of Castellano et al. (2009a) in which it is emphasized that "the key factor is that agents interact and this generally tends to make people more similar" (Castellano et al., 2009a, p. 2). Since the theoretical and empirical results of the foregoing chapter also suggest nonconformist behavior subsequent to social interaction in form of the underdog effect, a model which is able to implement this type of social response has to be considered when describing the evolution of political opinion. Secondly, a general limitation is the lack of connecting these models to real world data of political opinion evolution (cf. Sobkowicz, 2009, 2016). In order to validate models that claim to explain changes of political preferences, an empirical assessment is essential. Among the few models connected to data, the work of Fortunato and Castellano (2007) revealed phenomenological universalities of vote distributions in election data. These do not depend on countries, years, political and economically contexts. The authors show that a simple model of opinion dynamics based on opinion conformity is able to reproduce this pattern (in earlier investigations Costa Filho et al., 2003, and Filho et al., 1999, show universal feature of the vote distribution in Brazilian elections). Burghardt et al. (2016) also designed a model based on conformity respectively contagion which is able to display empirical

[10] Nonconformity was however considered by Galam (2004). Also the sociodynamic model of Weidlich and Haag (1983) as well as Lux (1995) is able to express a tendency of nonconformity as mentioned by Lux (2009).

observed universalities of Polish elections in 2005. Palombi and Toti (2015) shows that the voter model is able to reproduce empirical vote distributions of Brazilian elections. Caruso and Castorina (2005) employ a model of local interaction and binary opinions which was able to describe and predict elections in Italy and Germany. Gonzalez et al. (2004) use the abovementioned Sznajd model to reproduce the distribution of votes in Brazilian and Indian elections. However, instead of focusing actual electoral behavior or voting intentions, I want to make statements about the evolution of political preferences which might exhibit other patterns of interaction (as argued above). Furthermore, the addressed models which were empirically tested do not take nonconformity as a possible response to social interaction into account which was identified as potentially relevant for describing the evolution of political opinion.

2.2 Momentum Mechanism: Momentum and Anti-Momentum Effects

The non-formal and formal theories discussed above make statements about how the majority situation in an individual's peer may influence individual political preferences (majority mechanism). However, also the perceived changes of the peer's opinion may be influential (momentum mechanism). Following my above definition, a momentum effect is observable when an individual follows the opinion change of his or her peers while an anti-momentum effect would describe a converse opinion change. Rarely, theoretical or empirical investigations of social interaction effects in political contexts differentiate between these two interaction mechanisms (see Fichnová and Wojciechowski, 2015, for an exception). Most investigations make no conceptual difference between majority and momentum mechanism. Like addressed above, the definitions of underdog and bandwagon effects proposed by Baumol (1957) rather correspond to my definition of momentum and anti-momentum effects while I coincide in Simon's (1954) use of underdog and bandwagon terms. Another example is the study Nadeau et al. (1993) in which both the adoption of the majority opinion and of a opinion that is increasing in popularity is designated by 'bandwagon effect'. Thus, often no terminological distinction is made between bandwagon and momentum effects: "The terms 'bandwagon' and 'momentum' are used interchangeably by most political scholars and journalists" (Kenney and Rice, 1994, p. 924). Analogously, Denter and Sisak (2015) do not discriminate between underdog and anti-momentum effects. Most often, however, the momentum mechanism is, to the best of my knowledge, not at all considered. Also the empirically tested models

of opinion dynamics mentioned above are frameworks in which agents are affected by the state of the majority of their interaction partners and not by the opinion changes of their peers. As I argue in Section 3.2.2.1.2, it is of importance to consider the momentum mechanism since individuals are intensely exposed to political opinion changes due to the widespread "horse race media coverage" (Mutz, 1995, p. 1024) which especially focuses on changes in public support of candidates, parties or political issues. As I contend furthermore, it can be assumed that the psychological mechanisms expounded in Section 2.1.1 may also be triggered by perceived opinion changes and not only by opinion levels.

2.3 Conclusion

One line of literature emphasizes that social interaction significantly influences political values and preferences. Formal agent-based models of opinion dynamics which claim to describe the evolution of political preferences based on social interactions are not often (but increasingly) empirically tested or estimated employing real-life data. To the best of my knowledge, models which were empirically validated do not consider both majority and momentum mechanisms (or respectively do not differentiate between them). Furthermore, those studies usually rest upon conformity as typical response to social interaction - not on nonconformity. However, the theoretical and empirical evidence of non-formal theories pointed out that also the underdog effect may play a relevant role in the evolution of political preferences which implicates nonconformist behavior. Thus, the aim of the next chapters is to formulate (Section 3) and test (Section 4) an agent-based model which (1) incorporates both majority as well as momentum mechanisms and (2) is not predetermined in the direction of these social interaction effects (either conformity or nonconformity).

3 Agent-Based Model for the Dynamics of Political Preferences

In the present work, I contend that fluctuations and general macroscopic dynamics of political preferences are in particular explainable by social interaction among political subjects. As I argue later on, (1) the intense and increasing communication between voters (especially indirect interaction via the mass media), (2) plummeting affiliations with political positions as well as parties and (3) political alternatives which are hard to local-

ize in the political landscape give rise to the importance of social interaction effects in the evolution of political preferences.

To explain the ongoing dynamics of political preferences, this chapter aims for the set up of an agent-based model that allows for social interaction between multiple individuals. Identifying political preferences as a special manifestation of political opinion and following the extensive literature of opinion dynamics, an agent-based model of dynamic opinion formation is decidedly suitable for this endeavor: The interaction between several (heterogeneous) voters results in a system behavior (average political preference) that might not be deduced by studying the voters on the micro level. In contrast, one representative or aggregated agent is not able to interact and thus unsuitable to explain the emergent phenomenon of opinion formation. The agent-based model, that will be stated subsequently, is a model of opinion dynamics from statistical physics that can be tracked back to the groundbreaking work of Weidlich and Haag (1983) and Lux (1995). This model is especially appropriate for my requirements. Firstly and most importantly, it is able to incorporate both majority and momentum mechanisms. Secondly, it is not predetermined in the direction of these social interaction effects (either conformity or nonconformity). Thirdly, it particularly allows for indirect interaction via a social field (cf. Lux, 2009, p. 639; Saam, 1999, p. 50; Weidlich, 2002, p. 11; Gilbert and Troitzsch, 2005, p. 101; Helbing, 2010, p. 187). This is plausible since electorates or political communities are usually large and a bulk of communication between individuals is mediated via the media. Fourthly, the model allows to implement external effects which is convenient since social interaction may not be the only influential force in the evolution of political preferences. Fifthly, its properties as well as respective estimation approaches are well studied (Lux, 1995, 1997, 1998, 2009, 2012; Ghonghadze and Lux, 2012).

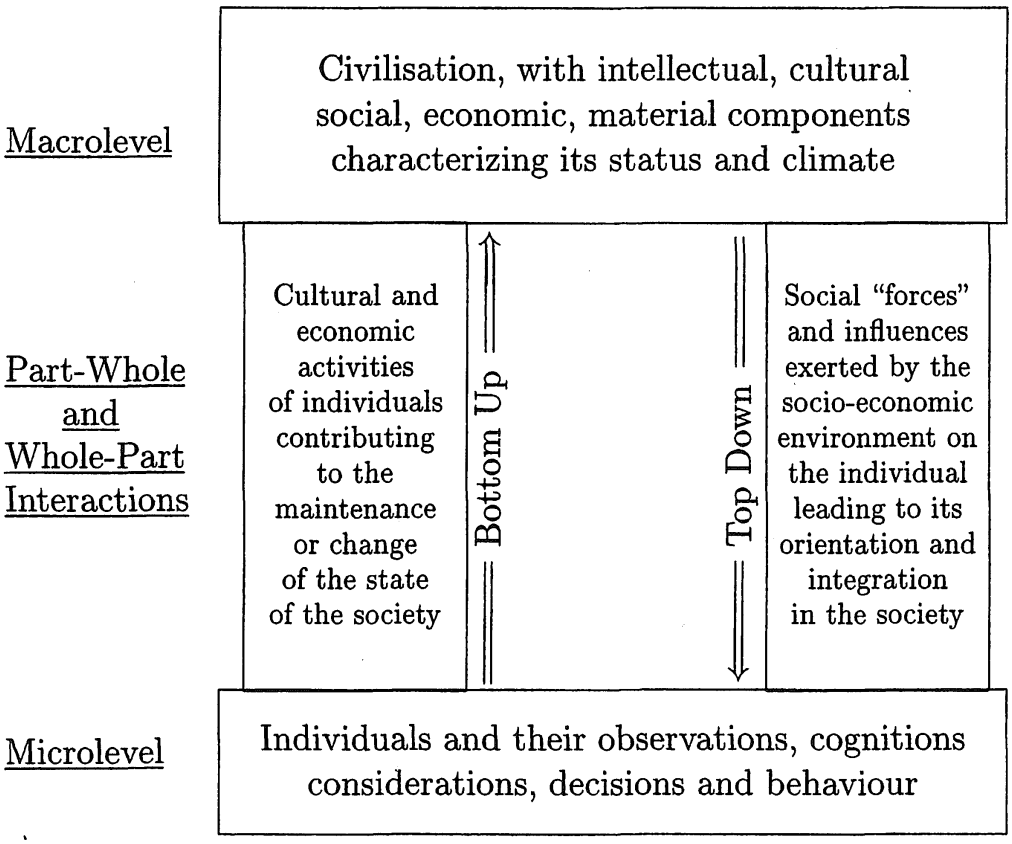
During the further procedure, I elucidate the general theoretical backgrounds of this social modeling approach from statistical physics (*sociodynamics*) to apprehend the conceptual backgrounds of the model of Weidlich and Haag (1983) and Lux (1995). Subsequently, I tie on a specific sociodynamic model of opinion formation and adjust it for the needs of studying the evolution of political preferences since the model is not specified at the outset for every social application. Finally, I state and justify behavioral assumptions, outline the model properties, expound my expectations and compare the model with other formal and non-formal theories.

3.1 Theory of Sociodynamics - An Approach to Mathematical Modelling in the Social Sciences

The science of *synergetics* can be considered as origin of the subsequently employed model framework. While synergetics was originally introduced to study the formation of self-organizing physical structures (cf. Haken, 1983), Weidlich and Haag (1983) used this concept to examine phenomena in social sciences by identifying a structural affiliation, even a "formal isomorphism" (Weidlich and Haag, 1983, p. 11) between natural and social sciences. Accordingly, both sciences would investigate large numbers of individual 'units'. Furthermore, these units would adopt and change between different 'states'. The global behavior of both systems would be analogously describable by introducing collective macro variables. This application of synergetics to systems of social interactions is designated as *sociodynamics*. In contrast to the dated transfer of complete models from physics to social sciences, this framework uses a methodological approach from the natural sciences which has to be adequately adjusted for applications in social sciences. Especially the complexity of social systems as well as the stochasticity of individual decision have to be considered (cf. Weidlich, 2002, p. 37).

Sociodynamics describes social systems as especially shaped by interaction between micro (composed of individual observations, considerations and decisions) and macro level (general societal atmosphere) (cf. Helbing, 2010, p. 187). This especially constitutes an indirect interaction between individuals due to their coupling to the whole system (e.g. Gilbert and Troitzsch, 2005, p. 101). The multilevel framework of Weidlich and Haag (1983) is grounded on this indirect interaction in consequence of its presumed pivotal significance for the "system character of the system" (Weidlich, 2002, p. 11). Accordingly, micro and macro level are connected via a *cyclical relation* (see Figure 1): Over the course of *bottom-up interactions*, members of society are contributing to the general macroscopic *social field* due to their individual opinions and actions (Weidlich, 2002, p. 43). This socio-political field can be understood as a general environment of trends, public opinion, etc., and thus characterizes the macro level. The converse *top-down interactions* are then characterized by social forces which ensue from this collective field with its societal structures and functions and affect individual thinking and behavior (Weidlich and Haag, 1983, p. 13). This fundamental interdependence of the whole social system and its parts implies that social individuals "are no more independent, because of the top-down influence restricting or even determining their dynamic behavior" (Weidlich, 2002, p. 13).

Figure 1: Bottom-up and top-down interaction between macro and micro level of a social system.



Source: Weidlich (2002, p. 13).

Hence, individual thoughts and actions are part-way free and part-way conducted (Weidlich, 2002, p. 44). However, the actual microscopic behavior of social agents is, in contrast to the natural sciences, unknown due to a complex tangle of individual motivations, strategies and emotions. Thus, the motion on the micro level can not be described via equations (Weidlich, 2002, p. 31). Therefore, sociodynamics uses a probabilistic description for the motion of individual agents taking the social driving forces into account without restricting individual "freedom of decision and action" (Weidlich, 2002, p. 51). Due to this, probabilistic *transition rates* are introduced on the micro level which are then constitutive for the motion on the macro level of the social system. Consequently, the movement of the macroscopic variables (the temporal evolution of the state distribution) is characterized by stochastic dynamics which are expressed by the so called *master equation* or by the *Fokker-Planck equation*, a Taylor approximation of the master equation. Thus, this

framework is a *phenomenological model* to the effect that it doesn't particularly describe the movements on the micro level.

Instead of linear cause-effect relationships, sociodynamics generally assumes non-linear interactions between individuals (cf. Helbing, 2010, p. 12). This characteristic induces complex dynamics: Contingent upon the initial state, the system may head to one of several time-independent (stationary) solutions; even small changes of the parameters governing the dynamics may cause an approach of the system to another stationary solution, oscillations or chaos (cf. Helbing, 2010, p. 13). Thus, if a certain parameter exceeds a critical value, the system dynamics may change dramatically and exhibit a *social phase transition* which implies the emergence of new properties on the macro level (cf. Weidlich and Haag, 1983, p. 2). According to the literature of sociodynamics, this phenomenon is also designated as *self-organizing process* indicating that altered behavior of the system is primarily based on the interaction of individuals rather than on changes in environmental conditions.

3.2 Sociodynamic Model for the Evolution of Political Preferences

This general conception of sociodynamics was designed general enough to be adaptable to a variety of different social systems. Weidlich and Haag (1983, p. 18 et seqq.) explicitly state and illustrate opinion formation as fruitful example. They do this in modeling a binary choice problem and describing the ongoing transition process between these two opinions.

Especially Lux (1995, 1997, 1998) developed, devised and studied these and closely related[11] models of opinion formation and used them to explain stylized facts in financial markets. In particular, he developed a systematic approach to estimate these models and applied this framework very successfully to identify social interaction as substantial driving force in sentiments about the business climate (Lux, 2009, and Franke, 2008, for a similar approach) in sentiments of financial investors (Lux, 2012) and in European business and consumer sentiments (Ghonghadze and Lux, 2012). Consequently, these models were used to formalize the concepts of *animal spirits* (Akerlof and Shiller, 2010) and *herding* (Keynes, 1930) in the evolution of macroeconomic variables (cf. Lux, 2009, p. 639).

[11] See e.g. Lux and Marchesi (1999) for an extended model in with agents which are able to switch between, in contrast, three groups or Alfarano and Lux (2007), Alfarano et al. (2008) and Ghonghadze and Lux (2016) for variants of a herding model based on Kirman (1993).

This comes very close to the endeavor of this paper since social interaction effects in the evolution of political preferences may be thought of as a form of herding.[12]

Models of this type were also repeatedly applied political opinion formation. As mentioned above, Weidlich and Haag (1983) themselves use the framework to describe the opinion formation e.g. in a revolutionary situation with two competing political ideologies. In another applications, Weidlich (1994; 2002, p. 149 et seqq.) investigates the political phase transition from liberal to totalitarian systems in a similar manner arguing that unpredictable fluctuations rather than continuously evolving trends are causing these transformations. Weidlich presumes and analyzed universal features of these revolutionary transformations. Roth (2012) utilizes the model to study dynamics in early political campaigning considering the influx and efflux of supporters in the context of primary elections. He suggested that the intensity of this herding behavior as well as the speed of the process increases in the forefront of the primaries. Thus, the impact of resulting feedback loops would increase (Roth, 2012, p. 13). Therefore, Roth concludes that incriminating evidence about competitors should be released in the late pre-primary period to achieve the maximum effect. Müller-Benedict (2001) uses the respective opinion formation model to formalize theoretical considerations concerning the "spiral of silence" (Noelle-Neumann, 1980) and showes how the dynamics of this model can produce a silent majority. Moreover, Saam (1999) explains military coups by means of this framework showing that the model is able to emulate the trends of political opinion in Thailand between 1932 and 1992.

Models of this type describing the dynamics of political preferences were however not estimated in a systematic way (Müller-Benedict, 2001, estimated the conformity parameter by means of original tables of Noelle-Neumann), especially not so as to identify majority and momentum mechanisms in the dynamics of political preferences.

3.2.1 The Model

In the following, the aforementioned model framework in keeping with Weidlich and Haag (1983) and Lux (1995) is presented and adjusted for describing the general dynamics of political preferences.

[12] Especially bandwagon and momentum effects may be associated with some kind of herding since they imply a tendency of conformity.

3.2.1.1 The Population: Political Individuals

A population of a political system is considered that consists out of a constant number of *political individuals*, $2N$. Note that N is defined as half of the population to simplify calculations later on and to ensure an even number of individuals which makes a perfectly balanced majority situation possible (Lux, 1995, p. 883). The political individuals are not only voters in the political system: Also relevant non-voters might possess political preferences or even voting intentions. Thus, the dynamics of political preferences might also be influenced by these individuals without suffrage. However, the opinions of these non-voters are typically less or not visible than those of voters especially due to their exclusion from participation in political opinion polls.

As mentioned above, the interactions between these political individuals are particularly indirect and mediated by the socio-political climate (in particular by the media and public information). It is now supposed that the population is homogeneous[13] insofar as each individual displays "the same individual behavior probabilities of reactions and interactions in the opinion formation process (Weidlich and Haag, 1983, p. 18). This homogeneity assumption also implies that we neglect structural individual differences in how the majority opinion affects the individuals: It could be conceivable some agents exhibit underdog and yet others bandwagon motives. In the following these individual differences are neglected. This strong simplification could in part be vindicated by a reference to all-encompassing mass media that exert comparable influence on the political individuals in modern societies: The media are progressively penetrating all social areas ("mediatisation", Donges and Jarren, 2017, p. 28) and receive large societal attention as well as utilization (within the meaning of "Mediengesellschaft", Donges and Jarren, 2017, p. 1).

3.2.1.2 The Opinions: Political Preferences

The political system features only two relevant *political opinions*. More precisely, the special manifestations of political opinion that is focused in the present work are *political preferences*. The two political preferences in the political system might be designated by "$+$" and "$-$". Alternatively these groups could be labeled, more neutrally, as group "1" and "2". However, I adopt the notation of Lux (1995) to obtain an intuitive interpreta-

[13] Differences between individuals are later on ensured by the stochasticity of the model framework.

tion of the opinion index later on. Note that these two political preferences could express support for two different political parties or political candidates. Also preferences for the government or for the opposition (as investigated in Section 4) are within the scope of this concept. However, these preferences could also enunciate dichotomous political attitudes (e.g. if classifications of "left-wing" and "right-wing" are meaningful) concerning a publicly debated topic or a ballot question.

In contrast to Weidlich (2002, p. 162 et seqq.), I suppose that the political preference which is openly exhibited by a political individual coincides with that agent's internal or hidden opinion. Weidlich (2002) considers political opinion formation in a totalitarian setting in which the individuals' hidden attitudes are not visible in (and thus do not contribute to) the social field. I however, presume a free and democratic society in which both preferences are locatable within the constitutional framework and are, thus, publicly tolerated.

Due to the existence of just two openly exhibited political preferences, the political system decomposes into two opposing political groups. Each individual is member of one of these two groups at any point in time; accordingly, a neutral position not allowed. The number of members in the "+"-group ("−"-group) is denoted by n_+ (n_-). Therefore, one has

$$2N = n_+ + n_-. \tag{1}$$

Two measures for the general opinion observed on the macro level are defined. The difference between the number of individuals in the two political opinion groups is denoted by the *socio-configuration*, n:

$$2n := n_+ - n_- \Leftrightarrow n = \frac{1}{2}(n_+ - n_-) \tag{2}$$

with $n \in [-N, N]$. A measure of the average opinion, other than the scalar attained by the socio-configuration, is obtained introducing the *opinion index*, x:

$$x := \frac{n_+ - n_-}{2N} = \frac{n}{N} \tag{3}$$

with $x \in [-1, 1]$. Because we assumed a homogeneous population with same individual weights, the two political opinions feature the same number of supporters for $x = 0$. In

contrast, $x > 0$ ($x < 0$) indicates a majority for the "$+$"-opinion ("$-$"-opinion).[14] For $x \in \{-1, 1\}$, all individuals adopt the same political opinion. When speaking of the *state of the political system* in the following, I am referring to the opinion observed on the macro level, expressed by the opinion index, x, or the socio-configuration, n.

In the course of the reasoning later on, it is important to introduce the *visibility* as a characteristic of the general political opinion. I assume that the general opinion on the macro level is equally visible for all individuals (similar to the assumptions of Müller-Benedict, 2001, p. 106). In an extreme and unrealistic scenario, the societal opinion could be unobservable and, thus, invisible for political individuals due to no media coverage in specific or due to an absence of publicly addressing political issues in general. To be sure, elections regularly reveal the general political opinion within the democratic system at all events. However, in elections, strictly speaking, voting intentions rather than political preferences are unveiled. Even if we ignore the (potentially minor) differences between both concepts, elections remain comparatively rare events. Thus, the top-down interactions from the social field towards the micro level would not be influenced by the general political opinion. In another extreme (but less unrealistic) scenario, the general political opinion could be exactly known and, thus, perfectly visible for all political individuals such as through abundantly published opinion polls. I understand visibility of the general political opinion as continuum between these two extremes. This concept can be transfered to all other relevant macro variables that influence the probability that individuals change their opinions.

3.2.1.3 The Dynamics of Interacting Individuals

The dynamics of ongoing opinion formation are now described as stochastic process implying that changes in the macroscopic state of the political system happen with a certain probability. This uncertainty is caused since micro level agents change their political opinions in a probabilistic manner (see Section 3.1).

[14] As will be seen below, many political survey report their results in this format.

At the macro level, the probability that the political system exhibits socio-configuration n at time t is defined as

$$p(n;t) \quad \text{with} \quad \sum_{-N}^{N} p(n;t) = 1. \tag{4}$$

The aim is to solve for $p(n;t)$, the probability density function over all possible socio-configurations, n, at time t, and to study the change of this function over time to capture the stochastic process of political opinion formation.

Since changes in opinion may happen all of a sudden, transitions between states are assumed to occur in continuous time (cf. Lux, 2009). The switches are described via Poisson processes as special Markov jump processes with *configurational transition rates* per unit of time $w(n \to n^*)$ (see e.g. Helbing, 2010, p. 101).[15] With $n \to n^*$ we denote the change from socio-configuration n to n^*. We have $w(n \to n^*) = 0$ for $n^* \neq n \pm 1$ because it is assumed that in an infinitesimal interval of time only one agent a time changes its opinion and, thus, only neighboring states are reached (see e.g. Ghonghadze and Lux, 2012).

At the micro level, the switching rate per individual from "$-$" to "$+$" is denoted by the *individual transition rate* per unit of time, $p_{+-}(x)$ (see e.g Weidlich, 2002, p. 52; Ghonghadze and Lux, 2012, p. 3070 for designation). The switching rate per individual for changes in the other direction is analogously designated as $p_{-+}(x)$. Note that all agents in one group hold identical individual transition rates due to the above assumption that all individuals are exposed to the forces of the socio-political field in the same way.

Further note that these individual transition rates will be chosen in a way such that they depend (among others) on the prevailing average opinion, x: Political views of individuals are influenced by others' opinions. Thus, an implementation of social interaction effects (of any size and direction) is ensured. The individual transition rates are further supposed to depend on the opinion index, x, rather than on the socio-configuration, n, because opinion intensities should matter rather than a raw number that depends on the size of the overall population. The specific assumptions for the individual transition rates are explicitly stated in Section 3.2.2.

[15] If $p(n^*; t + \Delta t|n; t)$ is the conditional probability to sight state n^* in time $t + \Delta t$ given that state n is observable in time t, the configurational transition rate, $w(n \to n^*)$, can be written as (cf. Helbing, 2010, p. 50):

$$w(n \to n^*) = w(n^*|n;t) := \lim_{\Delta t \to 0} \frac{p(n^*; t + \Delta t|n;t)}{\Delta t}. \tag{5}$$

The linkage between individual and configurational transition rates is established via the multiplicative form (see e.g. Ghonghadze and Lux, 2012)

$$w_{\uparrow}(n) := w(n \to n+1) = n_{-}p_{+-}(x) \tag{6}$$

$$w_{\downarrow}(n) := w(n \to n-1) = n_{+}p_{-+}(x) \tag{7}$$

since all individuals are assumed to change their opinion independently from each other and individual transition rates for one group into the other are identical. Hence, the configurational transition rate from state n to $n+1$ is proportional to the number of agents who are able to change from the "$-$" to the"$+$"-opinion (this analogously applies for transitions in the other direction).

Since the individual transition rates were identified as influenced by the opinion index, x, rather than by the raw number of group occupations, n, the transition rates of the population process are rewritten for convenience in terms of the opinion index, x, and get:

$$w_{\uparrow}(x) := w(x \to x + \frac{1}{N}) = n_{-}p_{+-}(x) \tag{8}$$

$$w_{\downarrow}(x) := w(x \to x - \frac{1}{N}) = n_{+}p_{-+}(x) \tag{9}$$

as the opinion index changes in increments of $\Delta x = \frac{1}{N}$ (see Weidlich and Haag, 1983, p. 22-25, for a detailed conversion of the transition rates from a description in terms of the socio-configuration, n, to a description with regard to the opinion index, x).[16]

The temporal evolution of the state distribution, that we are ultimately interested in, is then described via the *Master equation*:

$$\frac{dP(x;t)}{dt} = \sum_{x^*}[w(x^* \to x)P(x^*;t) - w(x \to x^*)P(x;t)] \tag{10}$$

where $w(x^* \to x)P(x^*;t)$ denotes the *flow* from state x^* to x, a measure for the transitions from state x^* to x.[17] Thus, the master equation is defined as difference between the num-

[16] For reasons of simplicity, the notation of the transition rate, w, remains unchanged after the transition from the socio-configuration, n, to the opinion index, x. Moreover, transition rates may be dependent on time t which is not explicitly shown in the denotation, again for the sake of simplification.

[17] Note that the probability distribution function for the opinion index is denoted by $P(x;t)$ in comparison to $p(n;t)$ which was defined for the socio-configuration.

ber of all flows into state x and the number of all flows out of state x. Because we assumed $w(x \to x^*) = 0$ for $x^* \neq x \pm \frac{1}{N}$, a simplified expression can be obtained:

$$\begin{aligned}\frac{dP(x;t)}{dt} =& w_{\downarrow}\left(x + \frac{1}{N}\right) P\left(x + \frac{1}{N}; t\right) + w_{\uparrow}\left(x - \frac{1}{N}\right) P\left(x - \frac{1}{N}; t\right) \\ & - (w_{\uparrow}(x) + w_{\downarrow}(x)) P(x;t)\end{aligned} \tag{11}$$

Because this exact evolution of the state distribution is, especially for large N, cumbersome to simulate, it is subsequently approximated via a Taylor approximation of second-order (see Appendix A for the derivation). For that, we assume that the Master equation is a continuous function of x implying that the transition rates are continuous functions of x and N is large. This approximation yields the *Fokker-Planck equation* (see Weidlich and Haag, 1983; Lux, 1997, 2009)[18]:

$$\frac{\partial P(x;t)}{\partial t} = -\frac{\partial}{\partial x}[A(x)P(x;t)] + \frac{1}{2}\frac{\partial^2}{\partial x^2}[B(x)P(x;t)] \tag{12}$$

with drift $A(x)$ and diffusion $B(x)$ terms:

$$A(x) = \frac{1}{N}(w_{\uparrow}(x) - w_{\downarrow}(x)) \tag{13}$$

$$B(x) = \frac{1}{N^2}(w_{\uparrow}(x) + w_{\downarrow}(x)). \tag{14}$$

While the drift term is governing the systematic tendency of the opinion evolution, the diffusion term is determining the volatility of the system (see e.g. Ghonghadze and Lux, 2012).

3.2.2 Behavioral Assumptions about the Individual Transition Rates of the Model

For specific results of the model, it is necessary to theoretically hypothesize which factors could influence the agents to switch their opinion. The behavioral assumptions about these driving forces are implemented in the individual transition rates p_{+-} and p_{-+}. Following Lux (1995, 1997, 2009, 2012), Ghonghadze and Lux (2012) as well as Weidlich and

[18]The Fokker-Planck equation can be thought of as a special partial difference equation and also known as *Kolmogorov forward equation*.

Haag (1983) and motivated by the discrete-choice literature the succeeding form is assumed:

$$p_{+-} = v \exp(U) \tag{15}$$

$$p_{-+} = v \exp(-U) \tag{16}$$

The exponential representation is convenient since non-negativity for the transition rates and symmetry of changes between the opinion groups are ensured (cf. Lux, 1997). Considering Equations 15 and 16, the individual transition rates are not constant but dependent on a *forcing function*, U, comprising the forces of the social field. Accordingly, an increase in U is leading to an increase of the individual transition rate from the "$-$"- to the "$+$"-opinion, p_{+-}, and an decrease of the opposite individual transition rate, p_{-+}. Parameter v is the *flexibility parameter* (Weidlich and Haag, 1983, p. 41) that regulates the time scale in which changes between opinions occur (cf. Lux, 2009, p. 641). The higher v is, the more often individuals switch their opinion (cf. Gilbert and Troitzsch, 2005, p. 104). Note that, for $v > 0$, $U = 0$ does not imply that the individual transition rates are zero, i.e., that no changes between the two opinions happen. Although no feedback forces are present, individuals may decide to switch their opinion due to personal reasons (cf. Lux, 1998, p. 151). The following form is assumed to express these influences on individuals to switch the political opinion:

$$U = \alpha_0 + \alpha_1 x + \alpha_2 \dot{x} + \beta y. \tag{17}$$

Accordingly, the opinion index (general opinion), x, the change of this index, $\dot{x}$, and other exogenous factors of influence, y, are assumed to influence the individual transition rates. The evolution of the opinion distribution over time is then dependent on the vector of parameters $\theta = (v, \alpha_0, \alpha_1, \alpha_2, \beta)'$. Also recall that the configurational transition rates are also dependent on the total number of political individuals in the population, $2N$ (see equations 6 and 7).

Drift (Equation 13) and diffusion (Equation 14) terms which govern the dynamics of the opinion formation, hence, appear as[19]:

$$A(x;\theta) = v(1-x)e^{\alpha_0+\alpha_1 x+\alpha_2 \dot{x}+\beta y} - v(1+x)e^{-\alpha_0-\alpha_1 x-\alpha_2 \dot{x}-\beta y} \tag{18}$$

$$B(x;\theta) = [v(1-x)e^{\alpha_0+\alpha_1 x+\alpha_2 \dot{x}+\beta y} + v(1+x)e^{-\alpha_0-\alpha_1 x-\alpha_2 \dot{x}-\beta y}]/N. \tag{19}$$

α_0 can be considered as *predisposition parameter* (Weidlich and Haag, 1983, p. 41).[20] Positive (negative) values of α_0 indicate a bias in favor of the "+"-opinion ("−"-opinion) increasing the rate of individual changes to the "+"-group ("−"-group).

β indicates the feedback of the *exogenous factor of influence*. Weidlich (2002) assumes in his totalitarian setting that "all macrovariables are dominated [...] by the ruling ideology" (Weidlich, 2002, p. 163) implying that these variables on the macro level are functions of the opinion index. Because I, in contrast, assume a liberal and democratic setting, it stands to reason that exogenous forces (e.g. political or economic variables), besides intrinsic social feedback, play a role in the dynamic process of political preference formation. These exogenous variables are context dependent and especially contingent on the specific type of political preference. In the course of the validation of this model in Section 4, specific preferences (satisfaction with government) with meaningful exogenous factors of influence are considered.

3.2.2.1 Social Interaction Effects

Besides a natural preference and exogenous factors, also social interaction effects have to be incorporated. Political individuals are supposed to communicate. In the course of this interaction and the resulting encounter with the others' opinions, individuals might change their opinions due to the psychological mechanisms (of conformity or nonconformity) discussed in Section 2. To incorporate these social interaction effects, a measure for the others' opinions, the opinion index, x, and its change, $\dot{x}$, is incorporated into the forcing function, U. This implementation of the average opinion can be understood as implementation of indirect interaction via a social field (cf. Lux, 2009, p. 639; Saam, 1999, p. 50; Weidlich, 2002, p. 11; Gilbert and Troitzsch, 2005, p. 101; Helbing, 2010, p. 187) like expounded in Section 3.1. Although personal contact is an important mechanism

[19] For a representation using hyperbolic trigonometric functions see (Ghonghadze and Lux, 2012, p. 3070).
[20] This parameter may also be considered as *bias parameter* (Lux, 2009, p. 641).

to exchange opinions, social interactions between political individuals may be described especially as indirect due to (1) the typical large size of the political system and (2) the comprehensive mass media coverage of elections and other political issues which can be conceived as mediators of communication between agents. Particularly because of the dominance of medial influences for the imparting of political contents, processes and institutions (cf. Donges and Jarren, 2017, for the example of Germany), it can be reasonably assumed that the bulk of social interactions in political contexts is mediated via newspapers, broadcasting and digital media. In addition to this supposed outstanding significance of the mass media, note that the social field can also be experienced via other means of communication (e.g. via the average atmosphere within agent's peers, cf. Lux, 2009, p. 639).

The consideration of social interaction effects are not only plausible but of vital importance. It can be reasonably assumed that they play a crucial role in the dynamics of political preferences. First, the observable increase in the mediating media coverage of political opinions, contents and processes (cf. Donges and Jarren, 2017, p. 30, for the example of Germany) can be interpreted as increase of indirect interaction between individuals. These mediating mass media comprise broadcasting, print media as well as digital contents (cf. e.g. Chadwick, 2013, p. 52). Due to this step up of communication, social interaction effects on political preferences may grow stronger. Second, it can be widely observed that natural and stable affiliations with parties (cf. e.g. 2012, van Biezen et al.; Houghton, 2015, p. 196; Wessels, 2007) and their positions (e.g. Hoffmann, 2017, p. 98) decline. When predispositions get weaker, political preferences might exhibit a higher volatility. In this setting, social interaction effects can be assumed to be especially influential. Thirdly, political constellations, such as the landscape of political parties and positions, get increasingly complex and convoluted (cf. e.g. Ballensiefen, 2009 studying the example of Germany). Thus, when individuals have straits to localize and classify different political alternatives (even if there are just two like in the present model), the effects of social interaction on the adoption of political opinions are or particular significance.[21]

3.2.2.1.1 Majority Mechanism

[21] The second and third argument could also imply a increasing importance of exogenous factors. If exogenous factors or social interaction effects are more meaningful can be empirically analyzed in Section 4.

The social interaction parameter α_1 is labeled as *majority parameter* (in the style of Franke, 2008, p. 41) and formalizes a tendency of (non)conformity.[22] The direction of this feedback is not predetermined: A positive parameter α_1 increases the rate for switches in direction of the current majority opinion and decreases the rate for changes in direction of the minority group. Therefore, $\alpha_1 > 0$ indicates a tendency of conformity (Lux, 2009, p. 641). Following the literature on social interdependence and political preferences, this tendency towards conformity would indicate an *bandwagon effect* (cf. e.g. Bischoff and Egbert, 2013). Conversely, a negative parameter α_1 enlarges the rate that individuals change from the majority to the minority opinion while it reduces the rate for switches in the other direction. Therefore, $\alpha_1 < 0$ suggests a tendency of nonconformity (cf. Lux, 2009, p. 641; Ghonghadze and Lux, 2012, p. 3070). Analogous to the above designation, this tendency towards nonconformity would portend an *underdog effect* (cf. e.g. Goot, 2010). If $\alpha_1 = 0$, the individual rates would not depend on the general opinion meaning that no tendency for conformity or nonconformity is incorporated (in accordance with the no-effect-hypothesis, cf. e.g. Giammo, 2004). Note that both effects increase for a rising absolute value of the opinion index, $|x|$, which indicates a enlargement of the majority group (Weidlich and Haag, 1983, p. 41).

3.2.2.1.2 Momentum Mechanism

Besides this majority mechanism, I implement a second social interaction mechanism:[23] Agents might not only respond to the current general mind of others individuals, x, but also to the change of the opinion index, $\dot{x}$. It is reasonable, that the agents' exposure to the general opinion as well as its change might cause similar psychological mechanisms of social interaction discussed in Section 2.1: The political individuals might consider the motion of agents as "early warning system of future changes" (Franke, 2008, p. 310) and, thus, react to opinion changes in a similar manner. This behavior is especially possible due to the practice of the mediating mass media to intensively discuss rather the changes of political opinion (often supported by opinion polls) than the momentarily general opinion (cf. Faas, 2017, p. 18, for an elucidation of corresponding horse race journalism in

[22] α_1 might also, among other, be labeled as *degree of group pressure* (Lux, 2009, p. 641) or *coupling parameter* (Gilbert and Troitzsch, 2005, p. 104).

[23] Also Lux (2009) and Franke (2008) consider momentum mechanisms.

Germany). This media coverage phenomenon depicts the political competition as race between different ideas, parties or contestants.

The parameter of this second social interaction effect α_2 is labeled as *momentum parameter* and formalizes a second variant of (non)conformity (Lux, 2009, p. 648, also incorporated such a momentum effect)[24]. Again, the feedback direction is not predefined: $\alpha_2 > 0$ implies that a majority opinion which is recently increasing (decreasing) in size leads to a higher (lower) transition rate that agents switch to the majority opinion. Following my definition in the literature discussion, this tendency of conformity is called *momentum effect*. Inversely, $\alpha_2 < 0$ portends a tendency of nonconformity and is designated by *anti-momentum effect*.

3.2.2.1.3 Remarks on the Interpretation of the Social Interaction Effects Recall that the phenomenological model at hand is not suitable to describe underlying psychological incentives or mechanisms on the micro level of political individuals but rather the general tendency of (non)conformity observed in the macroscopic opinion dynamics (cf. Lux, 2009, p. 641). Thus, it cannot be concluded how and which psychological mechanisms respectively individual motivations outlined in Section 2.1 contribute to this tendency. The same tendency of (non)conformity could come into being with very differing motivations of individuals (cf. Weidlich, 2002, p. 38). Also other motivations not considered in the mentioned chapter could play a role.

While the behavioral model stated above was adjusted to explain political preferences, it could also be employed to describe the evolution of voting intentions. Political preferences can be assigned to corresponding *voting intentions* if the preferences can be expressed in an election or a ballot. A political preference and intention are only congruent if the political individual strives to vote for the party, candidate or option he or she prefers the most. In this case the voter aims for *sincere voting* (cf. Farquharson, 1969). Although voters want to influence the outcome of an election or ballot in accordance with their interests, they might decide not to give their votes to the preferred party, candidate or opinion due to the design of the voting system. In this instance voters intend to cast a *strategic vote* (cf. Heath and Evans, 1994).[25]

[24] Franke (2008) is designating this effect by *moving-flock-effect*.

[25] One could argue that political preferences and intentions are identical in the present case due to the assumption that only two political opinions exist. According to Downs (1957), the necessary condition for the occurrence of strategic voting is the presence of more than two choices. However, this is only true if both op-

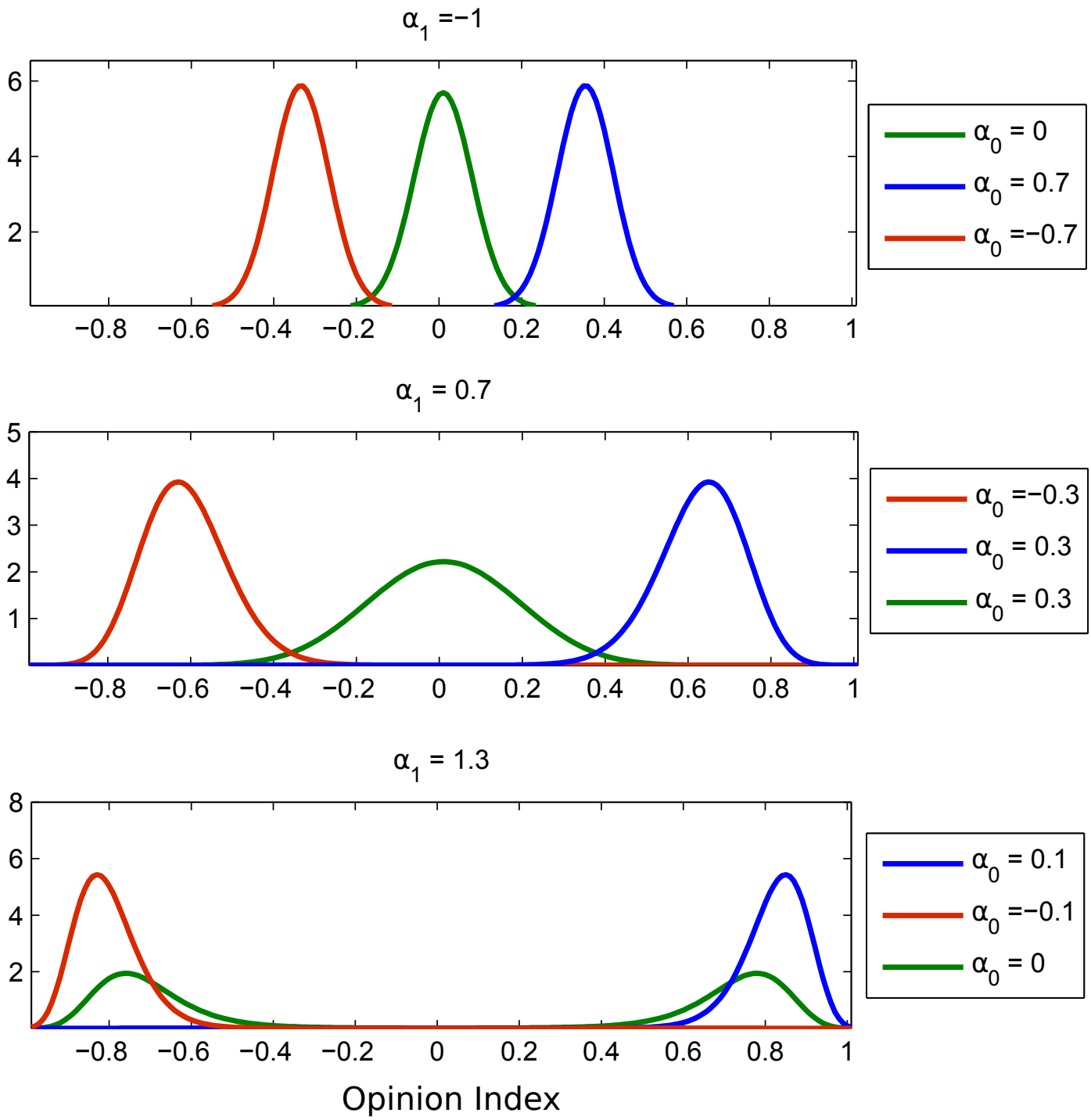
Due to the divergent concepts of political preferences and corresponding voting intentions, their evolution could in principle be characterized by different social interaction pattens: While the recognition of a bandwagon or momentum effect ($\alpha_1 > 0$ or $\alpha_2 > 0$) and of an underdog or anti-momentum effect ($\alpha_1 < 0$ or $\alpha_2 < 0$) may be conclusive if considering the evolution of political preferences, it is not unconditionally valid for voting intentions. Although one has no knowledge about which motivations bring about a certain tendency of (non)conformity, it can be concluded that, in the case of political preferences, no strategic motivations are among them due to the absence of elections or ballots. Other, rather psychological reasons justified the designation of bandwagon/momentum and underdog/anti-momentum effects. Tendencies of (non)conformity in voting intentions might be observable due to the same kind of motivations like in the case of political preferences. However, these (non)conformity effects in the evolution of voting intentions could also be noticeable if political preferences don't exhibit tendencies of (non)conformity. In this case, (non-)conformance would indicate strategic voting (see e.g. Blais et al., 2006). This connotes that voters stick to their political preferences but may change their behavior due to strategic considerations with respect to the outcome of an election or ballot. Thus, in the case of voting intentions, it can not be differentiated if tendencies of (non)conformity indicate bandwagon/momentum/underdog/anti-momentum effects, strategic voting effects or to both.

3.2.3 Properties of the Model

The properties of similar models like the one above were extensively studied especially by Weidlich and Haag (1983) and Lux (1995). The stationary distribution of the opinion evolution which is describing the limiting behavior of the system might be obtained by setting the expression for the Fokker-Planck equation (which can be easier studied than the Master equation) to zero (cf. Ghonghadze and Lux, 2012). However, a solution of this equation can be just obtained for drift and diffusion terms of simple forms.

tions are not composed of several minor choices. If, however, the ranking of those minor choices determine the decision for one of the two major alternatives, strategic voting is possible.

Figure 2: Stationary distributions of the model process.



Note: Stationary distribution for $\alpha_1 \in \{-1, 0.7, 1.3\}$ and different values of α_0 (inspired by Ghonghadze and Lux, 2012, p. 3071).

For the sake of simplicity and in light of yet no specific exogenous factors at hand, the properties of a model version with the forcing function (henceforth called *baseline form*)

$$U_b = \alpha_0 + \alpha_1 x \tag{20}$$

is considered. It is of vital importance to include α_1 when studying the model properties because the limiting behavior of the process was found to crucially depend on this parameter. Lux (2009, p. 641 et seqq.) and Ghonghadze and Lux (2012, p. 3070 et seqq.) provide a summary of the main properties of the stationary distibution (see also Lux, 1995; Weidlich and Haag, 1983): For $\alpha_0 = 0$, $\alpha_1 > 1$ implies a bimodal stationary distribution with one mode at a positive value of the opinion index and the other one at a negative value of the index such that symmetry around 0 is ensured. This means that a high positive value of α_1 implies that rather extreme majority situations are likely. $\alpha_1 \leq 1$ connotes that the limiting behavior of the process can be described by the presence of one single mode at 0. For $\alpha_0 \neq 0$, the location of the modes is shifted to the left (for $\alpha_0 < 0$) or to the right (for $\alpha_0 > 0$). If the absolute value of α_0 exceeds the bifurcation value $\overline{\alpha_0}$ an unique mode might be observable although $\alpha_1 > 0$.[26] Although the above properties are not derived within the present paper, the derivation of macroscopic laws of motion (such as mean and variance) via *first* and *second jump moments* is shortly sketched in Appendix D. These macroscopic values already give a profound insight in the dynamics of the system. For clearness purposes and inspired by Ghonghadze and Lux (2012, p. 3071), different stationary distributions for various values of α_1 ($\gtrless 0$) and α_0 ($\gtrless 0$) were simulated which are presented in Figure 2. Note that, for $0 < \alpha_1 < 1$, the distribution is flatter that for $\alpha_1 < 0$; in both cases, in accordance to the summary above, unimodality can be observed.[27]

3.2.4 Expectations

In light of the upcoming empirical validation of the model and its hypothesized transition rates, I possess expectations about the data-based parameter estimates.

3.2.4.1 Social Interaction Parameters

First and foremost, I expect to identify social interaction effects due to its assumed relevance and significance in the evolution of political preferences. As stated in Section 3.2.2.1, this significance is supposed to result from the extensive and increasing communication between individuals (mediated via the mass media), abating natural affiliations with parties and positions as well as the increasingly intricate localization of political op-

[26] This value is characterized by $\cosh^2(\overline{\alpha_0} - \sqrt{\alpha_1(\alpha_1 - 1)}) = \alpha_1$ (cf. Lux, 2009, p. 641).
[27] For the computations the Crank?Nicolson method was employed which is stated in Section 4.2.

tions. Accordingly, I hypothesize that majority and momentum parameters turn out significant. It is noteworthy that I do not expect a specific direction of those effects. Because the psychological effects (see the arguments for bandwagon and underdog theories in Section 2.1) on micro level work in different directions, a tendency of conformity as well as of nonconformity on the macro level could be plausible. The determination of the sign of these parameters contributes to the open research problem of the bandwagon/underdog-literature. If the majority parameter, α_1, is found to be positive, it is, furthermore, of interest if α_1 exceeds unity. As shown in Section 3.2.3, the limiting behavior of the process changes towards bimodality in this case: Thus, $\alpha_1 > 1$ can be conceived as *strong bandwagon effect* which can lead to the formation of a strong majority at the "$+$"- or the "$-$"-opinion. Another contribution to the bandwagon/underdog-literature constitutes the joint consideration of majority and momentum parameters especially due to the missing consideration of both effects or their lacking differentiation (see Section 2.2) in earlier studies. It is not excluded that both parameters do not coincide in their signs.

Note that it is not possible to ascertain if nonsignificant majority and momentum parameters indicate impertinent motivations to (not) conform or a perfect and stable compensation of conformist and nonconformist motives: In both cases, social interaction effects do not, contrary to my expectations, play a relevant role in the evolution of political preferences.

3.2.4.2 Social Interaction Parameters under the Presence of Opinion Polls

In addition to this general expectation of the social interaction effect, I expect that social interaction patterns change under the influence of political opinion polls. In the context of media reporting, political opinion polls are one, albeit strongly perceived, type of publicly accessible social information which reveals the social field in respect of one specific political issue or circumstance. I suppose that these polls are relevant for the dynamics of political preferences because they are strongly and increasingly perceived by individuals (cf. Faas, 2017, p. 19, using the example of Germany). This is accompanied with a rise in the frequency in which opinion polls are published (Schroth, 2017, p. 68).

Recalling the concept of visibility introduced in Section 3.2.1.2, I argue that the visibility of the macro variable measured by a published opinion polls increases so that these polls provide an anchor for communication processes via the social field. Because the presence

of polls adds to other social information, I expect that the intensity of social interactions, $|\alpha_1|$ and $|\alpha_2|$, rises while the direction of these parameters should remain unchanged since the individual psychological response to social interaction is not supposed to change its directions (just its intensity).

3.3 Comparison of the Model with Non-Formal and Formal Theories

A model based on social interaction was presented which claims to explain the evolution of political preferences. Both majority and momentum effects are included while the directions of these social interaction effects are not predetermined (either conformity or nonconformity). This chapter strives to compare this model with non-formal and formal theories outlined in Section 2.

The expounded model is able to formalize earlier addressed non-formal theories. As expounded by Müller-Benedict (2001), the model at hand is able to describe the spiral of silence theory of Noelle-Neumann (1980). He considers two groups: The first group consists out of individuals who publicly support a (political) issue whereas the second group is composed of individuals who are silent about this issue. Parameter α_1 is then indicating the fear of isolation (except of α_0 and α_1 no other parameters were considered). As Müller-Benedict (2001) states, a "silent majority" (Noelle-Neumann, 1989, p. 42) might occur if the fear of isolation is sufficiently large ($\alpha_1 > 1$). Besides the formalization of this bandwagon theory, the sociodynamic model is also able to illustrate processes in which social interaction is accompanied by nonconformist behavior (see underdog theories). This can be expressed by negative values for α_1 (or α_2).

In contrast to many of the formal opinion dynamics models stated in Section 2.1.2, I presumed an all-to-all interaction (indirect interaction) rather than local rules of interaction with specific environmental structures (the voter model for instance incorporates direct interaction between neighbors with a regular lattice as structure of the interaction network). While a model which is built on indirect interaction may be considered a huge simplification, I argue that this form of interaction is plausible when considering political communication: The political community is large and a greater part of the communication is mediated via the mass media. This partly justifies why the majority situation of political issues as well as changes of these aggregate opinions influence the model's individual transition rates. Considering the opinion representation from the sociodynamic

model at hand, it could be argued that binary opinions are less realistic than continuous opinions (which are e.g. implemented in the bounded confidence model). It is very reasonable to allow gradations of political opinions rather that restricting political opinions to extremes and in this regard I distinctly simplify the process of opinion formation. However, the concept of a 'majority opinion' does not exist anymore (in the sense in which it is used above) if considering continuous opinions. Also, media coverage often treats political opinions as being binary, since opinion polls tend to present dichotomous preferences (e.g. satisfaction or dissatisfaction with government).

Despite these potential limitations, and in contrast to other opinion dynamics models, this approach is able to incorporate both momentum and majority mechanisms where the direction of these interaction effects is not predetermined. Thus, bandwagon, underdog, momentum and anti-momentum effects as well as external influences can be incorporated using this approach. In the next step, this model is validated employing real-life data.

4 Model Estimation: Analyzing Data on Satisfaction with the German Government

The objective of this chapter is to apply the agent-based model laid out above to specific data on political preferences, to wit data on the satisfaction with the German Government. I seek empirically validate the model. Therefore I estimate the parameters of the model and examine if I can detect significant social interaction effects (as expected). Also, I study if the social interaction effects behave as expected under the presence of opinion polls. Additionally, I examine if the parameter estimates of exogenous factors appear with sensible signs. Further, it is investigated whether the data points are verisimilar results of the opinion process given the data one period before (following Lux, 2009, p. 649 et. seqq.). Apart from this general validation of the model, an aim is to gain further insights into the dynamics of the selected political preference.

Hereafter, I proceed as follows: First, the decision for choosing data on the satisfaction with the German Government is justified (Section 4.1.1) which is followed by theoretical considerations about relevant exogenous factors of influence (Section 4.1.2). It is stated how these factors are operationalized (partially using Web scraping) (Section 4.1.2.2). Thereupon, the estimation framework for the univariate model at hand developed by

Lux (2009) is propounded (Section 4.2). After that, the estimation results are presented and discussed in Section 4.3.

4.1 Data and Methods

In this section the selection of a particular political preference and respective exogenous factors of influence is justified. The used data, operationalizations and methods are expounded.

4.1.1 Selecting and Operationalizing German Government Satisfaction as Specific Political Preferences

In this section, the decision to select government satisfaction as the specific political preference to be studied is justified. Ensuing, the employed operationalization of this concept is stated. This includes the indication of the data used, alternative operationalization and a description of the operationalizations.

Due to the claim of the above model to explain the evolution of unspecific political preferences, various fields of applications are available. However, especially two requirements have to be fulfilled to ensure a fruitful application. First, suitable preferences should be of dichotomous nature according to the binarity of opinions in the agent-based model. Second, these preferences are optimally associated with a politically relevant and publicly debated issue in order to assure that individuals, in point of fact, hold an opinion concerning that topic. In addition, a certain visibility of the average opinion on the macro level may serve as anchor for interaction processes (as discussed in Section 3.2.1.2).

I contend that the concept of the *satisfaction with the government* meets these demands. First, it can be associated with a binary set of preferences (satisfied with the government/ dissatisfied with the government). This is particularly favorable due to the possibility to obtain these preferences in different countries independent of the prevalent party system. Thus, not just two party systems can be considered. Second, the satisfaction with the current government is a issue of particular relevance in political systems. It was repeatedly empirically shown that the appraisal of the government performance especially decides about the success of the incumbent parties employing the political system of the United States (Key, 1961; Miller and Wattenberg, 1985). Wessels (2002) analogously shows for Germany that governments tend to be voted out of office if their performance is evalu-

ated as rather poor. Thus, the significance of this specific manifestation of public opinion for the public and policy makers finds expression in comprehensive media coverage: In Germany, which is in the following considered to study the evolution of government satisfaction, two different opinion polls, 'Deutschlandtrend' and 'Politbarometer', are regularly collecting data on government satisfaction, as stated in Table 2. These polls are using telephone surveying (Computer Assisted Telephone Interview, CATI) and usually exhibit around 1000 respondents (cf. Forschungsgruppe Wahlen, 2017c; Infratest dimap, 2017b, for overviews of the respective methodologies). Typically, these surveys are conducted once a month and presented in television (ZDF in the case of 'Politbarometer' and ARD as regards 'Deutschlandtrend') and daily newspapers. In so doing, the data on satisfaction and dissatisfaction with the German Government are explicitly commentated and brought into line as well as compared with past values of this survey question (Forschungsgruppe Wahlen, 2017c; Infratest dimap, 2017b). Due to this encompassing reporting, a certain visibility of government satisfaction, which could act as anchor for social interaction processes, could be assumed. Altogether, it can be presumed that government satisfaction is a relevant political issue and that individuals actually hold an opinion concerning this topic.

Table 2: Conspectus of opinion polls regularly reporting government satisfaction.

Name of Opinion Poll	**Principals**	**Polling Agency**	**Respondents**	**First Year of Publication**	**Interval of Data Collection**
Published Opinion Polls					
'Politbarometer'	ZDF	Forschungsgruppe Wahlen	circa 1.250	1977	once a month
'Deutschlandtrend'	ARD, Die Welt	infratest dimap	circa 1000	1997	once a month
Unpublished Opinion Polls					
unnamed	Federal Press Office	Forsa	circa 1.500	2008-2015	every week

Remarks: Overviews of methods and survey procedures of both opinion polls can be found in Forschungsgruppe Wahlen (2017c) and Infratest dimap (2017b). For a sample survey summary of the Federal Press Office see Appendix B. Note that at times other daily newspapers act as principals of 'Deutschlandtrend' e.g. Frankfurter Rundschau, Kölner-Stadt-Anzeiger, Sächsische Zeitung, Stuttgarter Zeitung, Thüringer Allgemeine, Die Rheinpfalz (cf. Infratest dimap, 2007).

4.1.1.1 Operationalizing German Government Satisfaction

The operationalization for the concept of government satisfaction follows from the questions, polling agencies ask to evaluate the work of the German Federal Government. The

respective questions proposed by Forschungsgruppe Wahlen and Infratest dimap read as follows:

- Politbarometer: *'Ganz allgemein: Macht die Bundesregierung aus* [Regierungsparteien hinzufügen] *ihre Arbeit alles in allem gesehen eher gut oder eher schlecht?'* ['gut'/ 'neutral'/ 'schlecht'] (Question 5)[28]
- Deutschlandtrend: *'Wie zufrieden sind Sie mit der Arbeit der Bundesregierung?'* ['sehr zufrieden'/ 'zufrieden'/ 'neutral'/ 'weniger zufrieden'/ 'gar nicht zufrieden'] (Question 12)[29]

Subsequently, the data on these preferences associated with government satisfaction are usually presented in a very suitable way for the present analysis: The above opinion polls report the percentages of respondents who are rather in favor of and rather against the government (see e.g. Infratest dimap 2017c, p. 10, and Forschungsgruppe Wahlen 2017b). It is not distinguished between respondents who state that they are *very* satisfied (*very* unsatisfied) and those who are *rather* satisfied (*rather* unsatisfied) with the federal cabinet (for a divergent index construction for options with gradations see e.g. Ghonghadze and Lux, 2012, p. 3067, footnote 9). Neutral responses (neither satisfied nor unsatisfied with the federal government) are usually not revealed. Looking at Equation 3, it becomes clear that the opinion index can be easily constructed by means of the difference between both percentages (many polls, e.g. business and consumer surveys, direcly report this opinion index as shown by Ghonghadze and Lux, 2012, p. 3067). This makes an application of the above model all the more easier.

For the ensuing analysis, however, the data of these polls isn't being used. Instead, similar data of the German Federal Press Office (FPO) are applied. The respective question reads:

- FPO: *'Wie zufrieden sind Sie mit der Arbeit der Bundesregierung* aus [Regierungsparteien hinzufügen] *?'* ['sehr zufrieden'/ 'zufrieden'/ 'weniger zufrieden'/ 'gar nicht zufrieden']

Like 'Politbarometer' and 'Deutschladtrend' these data are collected within the scope of a survey of elective citizens of Germany. The fact that these data are collected by a German federal agency was commonly unknown until a member of the German parliament

[28]This issue and all other questions can be found in Forschungsgruppe Wahlen (2017a).
[29]These questions can be found in Infratest dimap (2017c).

requested complete access to all opinion surveys commissioned by the German Federal Government in 2014 (Becker and Hornig, 2014, p. 20). Among other data e.g. on specific members of the government and their popularity ("Regierungsmonitor", Becker and Hornig, 2014, p. 23) or on the currently most important topics ("Themenmonitor", Becker and Hornig, 2014, p. 23), data on government satisfaction (as well as on chancellor satisfaction) are collected in order to provide feedback for government work (see Appendix C for a sample feedback report). Altogether, the German Government commissioned approximately 600 unpublished opinion polls between 2008 and 2013 (Becker and Hornig, 2014, p. 23). Also due to criticism pointing out that the incumbent parties would use these data for campaign purposes, this procedure was most widely stopped in 2015. During a visit at the FPO, I could obtain the complete FPO data on government satisfaction from January 2008 to April 2015.[30]

I use these data of government satisfaction because, first, they were collected every week instead of once a month. This allows to study the development of government satisfaction in greater detail. Second, the interval of producing this poll is characterized by a high regularity; usually only in the weeks around Christmas no polls are commissioned. In contrast, 'Politbarometer' and 'Deutschlandtrend' are often not published in a periodic manner (see Figure 5). Thirdly, this data would allow to study if interaction patterns change after the publication of opinion polls. The corresponding investigation is conducted in Section 4.3.3. Fourthly, the number of respondents every week is greatly constant at 1500 (see Appendix B). This allows a tentative fixation of the number of voters in the model at $N = 750$ (recall that $2N$ was the number of individuals in the population). Fifthly, the relatively high number of agents (in comparison with the two public opinion polls) leads to a more precise second-oder approximation of the master equation. Sixthly, to the best of my knowledge, these data have not been subject to empirical analysis so far, especially not as to test an agent-based model of political preference formation.

The reported percentages of individuals who are in favor of or against the government are used to construct the opinion index.[31] Note that I associate the "$+$"-opinion with the preference *for* and the "$-$"-opinions with a attitude rather *against* the government. Thus,

[30] I obtained sample summary reports of these weekly surveys, see Appendix B, as well as a complete data sheet with aggregated percentages of government popularity.

[31] More precisely, the respective opinion index, x_1, is calculated by $x_1 = \frac{n_+ - n_-}{n_+ + n_-}$, where n_+ (n_-) is the number of respondents who are rather satisfied (rather dissatisfied) with the government. The FPO data do not consider the possibility of neutral responses.

a positive opinion index indicates a majority for the group of individuals that is in favor of the administration.

4.1.1.2 Alternative Operationalization of German Government Satisfaction

In the literature, an alternative operationalization of government popularity can be found. Paldam (1991, p. 9) argues that the intention to vote for the government is an equivalent measure of government satisfaction (also cf. Paldam, 2008). The intention to vote for the government could be operationalized by adding measurements of voting intentions for the incumbent parties. In the case of Germany, these party measures can be obtained by polls which inquire voting intentions with regard to the federal election and are regularly conducted.

However, as Enkelmann (2014, p. 1009) expounds, this operationalizations can distinctly differ from the measure stated before (also cf. Nannestad and Paldam, 1994). If all political individuals who are satisfied (dissatisfied) with the government intend to vote for a governing (opposition) party, both measurements are identical. Individuals may, however, vote in a deviating manner; among others, strategic voting may play a role[32] among other motivations (cf. Enkelmann, 2014, p. 1009). Therefore, the opinion index introduced in this section can be understood not so much as a measure of government satisfaction as political preference but rather of the corresponding voting intentions. Therefore, this alternative operationalization is rather not suitable for studying the dynamics of political preferences and therefore not considered in the empirical analysis.

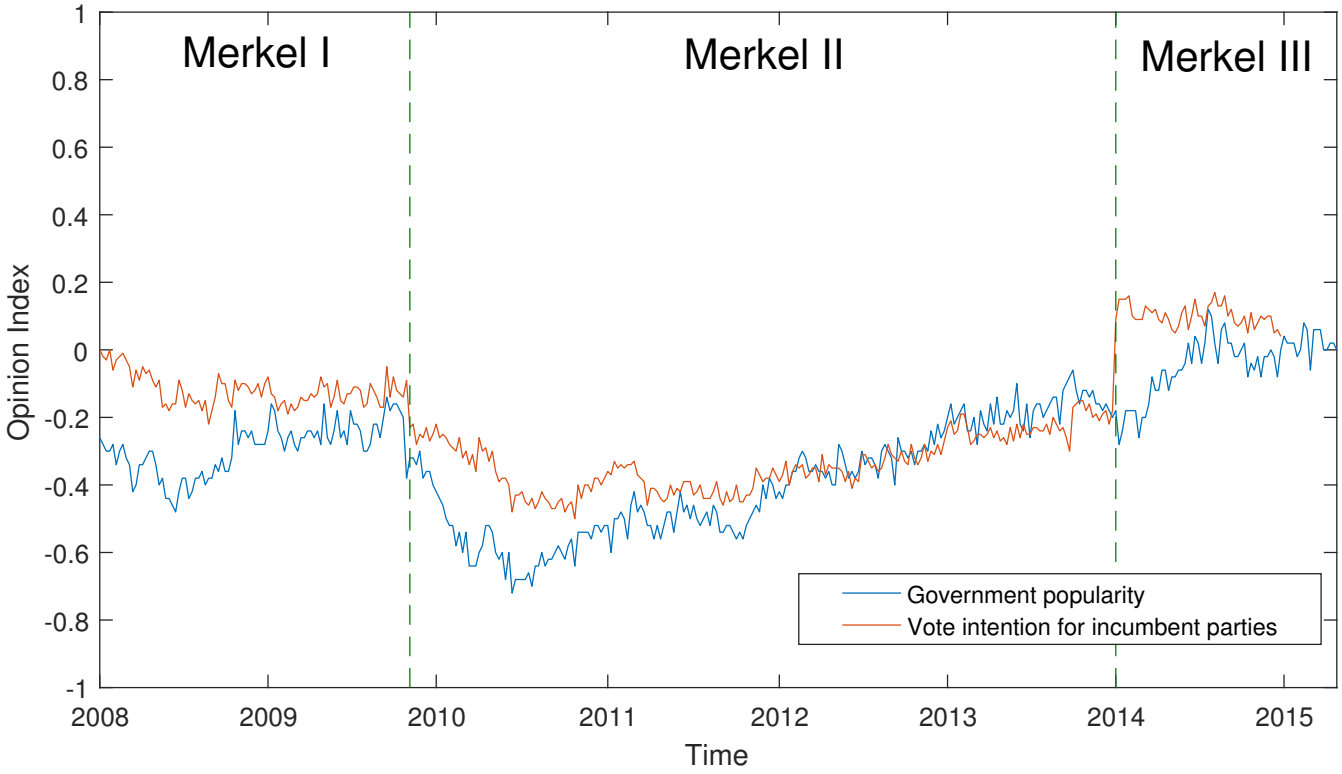
4.1.1.3 Description and Comparison of the Time Series

The time series plots of both opinion indices constructed in Section 4.1.1.1 (government popularity) and 4.1.1.2 (vote intention for incumbent parties) are presented in Figure 3. In addition, the three different cabinets between January 2008 to April 2015 are sketched in. Overall, the movements of both indices seem rather similar. However, it is striking that the level of both measures distinctly differs after the formation of new governments (e.g. end of 2010 and beginning of 2014). In the mid and end of a term of office (e.g.

[32] E.g. a voter who is contented with the work of a grand coalition (CDU/CSU-SPD) and prefers to ballot for CDU/CSU may decide to vote for FDP to hit the 5-percent hurdle in order to make a more preferred CDU/CSU-FDP coalition possible.

end of 2009, 2012-2014), on the contrary, both indices seem to converge to a similar level although their short-term fluctuations are not synchronous. A possible explanation for these observations could be that (especially new) incumbent parties are not yet associated with the government and its performance at the beginning of a term of office. Later on, the incumbent parties are judged by the accomplishments of the government. It can be further observed that the voting intentions tend to remain rather constant within a period of office (like indicated by Enkelmann, 2014, p. 1003). However, an absence of fluctuations as observed in other data on voting intention (e.g. by Hoffmann, 2017, p. 109) cannot be noticed.

Figure 3: Popularity of the German government and vote intention for the incumbent parties 2008-2015.



In the light of the upcoming parameter estimation, a negative predisposition parameter, α_0, for both indices can be expected since both measure mostly exhibit negative values (this is in line with other surveys, see e.g. Infratest dimap, 2017a). Considering the different terms of office, the levels for both measurements indicate that the α_0 could show

negative values for the first as well as the second Merkel cabinet and a slightly positive account for the grand coalition since 2013. Further, it can be expected that α_0 has the lowest value for the CDU/CSU-FDP coalition from 2009-2013. Comparatively stronger predispositions towards government contentment with German grand coalitions (Merkel I/II) are widely observed and could be explained with reference to a larger partisan foundation (cf. e.g. Bytzek, 2011). Further, in part large and abrupt differences between two consecutive weeks which often run in the other direction than previous changes can be observed. This could (in absence of exogenous factors) indicate the significance of an anti-momentum effect. This, however, has to be systematically investigated by the empirical estimations in Section 4.3.

4.1.2 Selecting and Operationalizing Relevant Exogenous Factors of Influence

As a matter of course, the evaluation of the government could not just be influenced by the others' opinions but also by exogenous factors. The assumption that exogenous factors are "functions of the majority variable" (Weidlich, 2002, p. 163) is reasonable in an totalitarian setting but not in the liberal and democratic system of Germany. As stated in Section 3.2.2, the present agent-based model is able to incorporate these exogenous effects. To avoid arbitrariness in the selection of variables, the literature on government satisfaction is considered in order to identify relevant factors of influence. Subsequently, the employed operationalization of these factors is stated.

4.1.2.1 Government Satisfaction and Relevant Influential Factors

As a first step, relevant concepts of explaining government support (as specific form of institutional trust) are identified in the theoretical literature. In a second step, concrete macroscopic factors and conditions within these concepts are detected which were found to be significant in empirical analyses. As seen from a systemic-constitutional perspective, institutional trust could refer to the support for *the political system* as such (also labeled as "diffuse government support" Aydın and Cenker, 2012, p. 231). Considering the "democratic reality" (Rohrschneider and Schmitt-Beck, 2002, p. 37), also support for *the government* can be identified as one category of institutional trust (also designated by "specific government support", Aydın and Cenker, 2012, p. 231). Since the polls stated in Section 4.1.1 explicitly refer to the evaluation of the administration, the latter concept is regarded.

This is supported by findings which show that respondents who are asked to evaluate the government, indeed assess the performance of the incumbent parties and not the government as democratic institution (cf. Aydın and Cenker, 2012, for a study focussing Turkey). The theoretical literature suggests different approaches for explicating the changes of this specific government support: (1) socio-cultural, (2) ideological and (3) performance based explanations (e.g. see Chanley, 2002). For the case at hand and in absence of individual data, the first approach is rather unsuitable since the macroscopic sociocultural environment of Germany in the given time frame can be assumed to be stable (see Aydın and Cenker, 2012, for a similar argument).

To ascertain which factors within the other two explanation attempts are relevant, a steering towards the empirical literature is promising. Considering ideological explanations, there are empirical studies finding evidence for the significance of political values. Using an standard OLS estimation and individual data, Rohrschneider and Schmitt-Beck (2002, p. 44) as well as detects that value-based predispositions are relevant to explain satisfaction with a government. If these values and the persuasions of the government do not coincide, ceteris paribus a rather negative evaluation of the government can be expected. These individual values can be assumed to be stable over time Almond and Verba (1963), however the ideological orientation of the government can change. This consorts with the different levels of satisfaction of the three terms of office in the data at hand observed in Figure 3 which I denoted as *partisan foundation*. Thus, an ideology variable (e.g. dummy variables) should be included. Interestingly, variables concerning the voting behavior (e.g. support for incumbent parties) were found to not significantly explain government satisfaction (Rohrschneider and Schmitt-Beck, 2002, p. 51 and 53) and are therefore not considered in the following. The bulk of the empirical literature emphasizes the importance of performance-based explanations. Two dimensions of governmental performance were found to be relevant: (1) the economic and the (2) political performance. Employing an OLS regression and individual data from post-communist countries, Mishler and Rose (2001) show that the state of the economy (macro economy and household economy) has a significant influence on the evaluation of the government. Also changes of these variables were found to be significant (Mishler and Rose, 2001, p. 51). These results are supported by Rohrschneider and Schmitt-Beck (2002). Also the results of Enkelmann (2014) who analyzed German government satisfaction with the aid of an logistic regression (for the years 1991, 1992, 1998, and 2008) and the findings of Aydın and Cenker (2012) within the scope of a binary logistic regression of individual data from Turkey underline the im-

portance of this economic performance (see also Citrin and Luks, 2001; Chanley et al., 2000; Cheibub et al., 1996). Because the government seems to be regarded as responsible for economic outcomes, an *economic variable* should be incorporated as exogenous factor of influence. The second dimension of governmental performance, the political performance, indicates that not only economic outcomes, but also developments in other policy areas affect the evaluation of a government. Empirical analyses repeatedly portended that especially the performance in four[33] policy areas (in the following stated in any order) are crucial for government satisfaction (see Chanley, 2002, for an overview): Firstly, the governmental capability of protecting its citizens against foreign threats (*national security*) was found to positively influence the evaluation of the government (e.g. by Chanley et al., 2000; Chanley et al., 2001; Alford, 2001; Nye et al., 1997, Chapter 1). Secondly, the governmental performance ensuring *inner security*, especially the prevention of crime, was identified as significant determinant of administration assessment (see e.g. Kohut et al., 1998; Mansbridge, 1997). Thirdly, the perceived fairness or *social justice* in the political system was found to affect the governmental trust (see e.g. Mishler and Rose, 2001; Kluegel and Mason, 2004). Fourthly, the existence of *political scandals* associated with the government was shown to significantly worsen the evaluation of the administration (see e.g. Chanley et al., 2000; Orren, 1997; or also Mishler and Rose, 2001, who are considering corruption as specific political scandal).

4.1.2.2 Operationalizing Relevant Exogenous Factors using Web Scraping

Following the conclusion of the chapter above, the ideological orientation of the government as well as variables concerning the macroscopic economic and political conditions should be included. I will implement them parsimoniously in the model in order to maintain an good understanding of the dynamics (Weidlich, 2002, p. 36). As already indicated, the ideology variable is introduced by incorporating dummy variables, β_i, for the terms of office in order to take the different partisan foundations into consideration. I desist from including variables of voting behavior due to mixed results (see Rohrschneider and Schmitt-Beck, 2002, p. 51 and 53). As variable of the general economic condition, γ, objective macroeconomic data would be suitable as exogenous factor. Since these data are usually not available on a weekly basis[34], I use the perception of current state of the econ-

[33] As a matter of course, also other policy areas might be of importance, however, to parsimoniously implement exogenous factors (Weidlich, 2002, p. 36) they are not considered furthermore.

[34] Alternatively, stock market data could be used as proxy for the state of the economy (see Zinna, 2013).

omy as a proxy. These data are collected in the Forsa-Bus survey already considered in Section 4.1.1.2. Since these perception data might not be a valid proxy for objective macroeconomic quantities and due to the fact that is also possible to include variables of lower frequency (e.g. monthly) (cf. Lux, 2009, p. 647) a second operationalization is considered: Industrial production[35] (e.g. used by Lux, 2009) is utilized as alternative variable of the state of the economy. In accordance with the findings above, I expect a positive sign of this parameter. Later on, it will be investigated if the use of this alternative operationalizations changes the results.

Constructing a fairly objective variable for political conditions on a weekly basis in the four identified areas (national security, inner security, social justice, political scandals) is a difficult task. As one possible way, dummy variables could be implemented to take changes in the policy framework (e.g. via laws) into account. Since this would be a tough and hardly possible exercise for especially some areas (e.g. political scandals) another operationalization is chosen. I employ the quality media coverage to obtain a measure of political condition in the identified areas (δ_1, δ_2, δ_3, δ_4). Considering the findings of Engesser et al. (2014) which indicate a distinct media focus on negative occurrences, political problems and scandals in Germany, a comparatively high number of press articles in one of the four areas could advert to a rather questionable political condition. These findings are explained with reference to a susceptibility of customers for negative tidings and to the medial self-understanding as critical supervisor of executive organs. I obtain the number of press articles in the respective fields via *web scraping* (Schrenk, 2012), a tool of increasing popularity in political science. This implies the extraction of the respective number of hits from news websites. Two representatives of the print quality media (see Rudzio, 2011) were chosen for this endeavor: 'Die Welt' and 'Frankfurter Allgemeine Zeitung'[36]. R was used for the respective computations. For each of the four areas, corresponding search item were chosen and listed in Appendix E. These items were selected in a way that only articles explicitly focusing Germany were considered. Besides variables which focus the political conditions in the four identified fields, additional sub-variables for the areas of national security (variables 'irregular migration' and 'international terrorism')

[35]The monthly data can be found at `https://www.bundesbank.de/Navigation/EN/Statistics/Enterprises_and_households/Output/Tables/table_zeitreihenliste.html?id=24532`. The percentage deviations between output and the trend were considered (Franke, 2008, p. 313). The Hodrick-Prescott filter was applied with smoothing parameter $\lambda = 14400$.

[36]These media are two of the three quality newspapers with the widest circulation in Germany (Bahnsen et al., 2016, p. 114). One could argue that these newspapers rather reflect the conservative political spectrum in Germany. However, the consideration of other significant media were not possible due to limited free access to the respective paper editions via http://www.genios.de/presse-archiv/.

and of inner security (variables 'crime'[37] and 'national terrorism'). A major advantage of this procedure is the possibility to extract weekly data.

Certainly, there are limitations of this operationalization. It assumes that the political conditions on the macro level can be objectively determined. Naturally, among individuals there might be no consensus about the evaluation of political developments. Also, media houses tend to evaluate the political conditions dependent on their political orientation. However, following the findings of Engesser et al. (2014), it can be argued that high values of these variables indicate those incisive changes of the policy framework (e.g. sudden events, catastrophes, revelations) which are widely considered as negative ('temperature curve'). Low values would indicate the absence of those negative shifts of the political performance. The choice of the search items ensures that especially articles with a negative framing are considered. Thus, I expect a negative sign for the parameters of these variables. To weaken the influence of media orientation, several newspapers were considered.

One could argue that individuals are also the affected by the change of these economic and political macro variables (following the argumentation in Section 3.2.2.1.2 in which the momentum mechanism was introduced). Thus, also theses changes will be considered in Section 4.3. Furthermore, all variables were centered around 0 in order to interpret α_0 as predisposition parameter (cf. Franke, 2008, p. 309).

4.2 Estimation Framework

The aim is to estimate the parameters of the model by use of the selected data in order to investigate if these estimates coincide with the expectations expounded in Section 3.2.4. A systematic estimation approach was developed in the paper of Lux (2009), where a comprehensive presentation of this estimation framework is expounded (for related frameworks see Poulsen, 1999; Hurn et al., 2010). The respective idea is to find a solution of the Fokker-Planck equation (Equation 12) which describes the temporal evolution of the transient density, $\frac{\partial P(x;t)}{\partial t}$. If a time-dependent solution of the transient density, $P(x;t)$, could be obtained, a maximum likelihood approach can be employed. However, closed-form solutions of the Fokker-Planck equation are not available. Therefore, Lux (2009) solves

[37] Certainly, official crime rates would be of interest. However, for the case of Germany, they are just available on a yearly basis.

the Fokker-Planck equation numerically using a Crank-Nicolson finite difference scheme (see Appendix F for an elucidation of this finite difference scheme). This numerical solutions can then be used for a numerical maximum likelihood approach: Since discrete observations $x_0, ..., x_T$ are at hand, $P(x_i|x_{i-1}, \theta)$ can be evaluated, which is the value for the transient density at the times of observation x_i given the previous observation one unit time interval before x_{i-1} and the parameter vector θ.[38] For the likelihood function the following expression holds:

$$L = \prod_{i=0}^{T} P(x_i|x_0, ..., x_{i-1}, \theta) \overset{\text{Markov model}}{=} \left(\prod_{i=1}^{T} P(x_i|x_{i-1}, \theta) \right) P_0(x_0|\theta). \tag{21}$$

Taking logarithms yields the log-likelihood function:

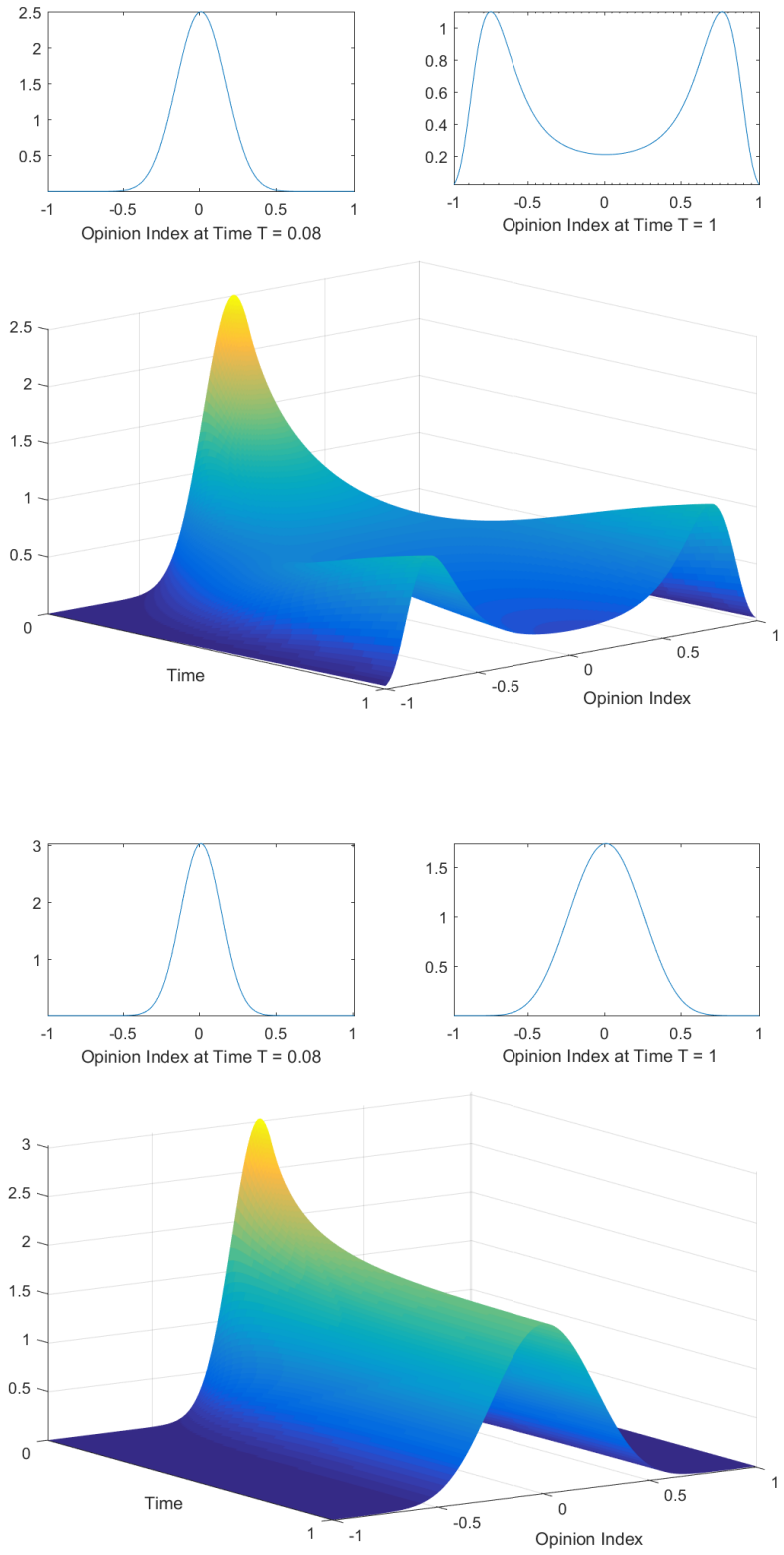
$$\log L = \sum_{i=1}^{T} \log P(x_i|x_{i-1}, \theta) + \log P_0(x_0|\theta). \tag{22}$$

The goal is then to find the parameter vector which is maximizing this log-likelihood function. In this framework, the unconditional density $P_0(x_0|\theta)$ for the first observation x_0 is typically skipped in the empirical estimation due to its negligible influence for the overall result (Lux, 2009, p. 643).

All computations were executed in MATLAB (all 36 scripts and functions are attached to the enclosed CD). Inspired by (Lux, 2009, p. 644), two examples for the numerical solution of the transient density using the Crank-Nicolson scheme are shown in Figure 4 for illustrative purposes. The initial observation $x_0 = 0$ was approximated by a sharp normal distribution; one unit time interval is displayed. Additionally, the transient densities for t=0.08 and t=1 are featured. The momentum mechanism and exogenous factors were not incorporated. The upper figure was computed for parameters $\alpha_0 = 0, \alpha_1 = 1.3, v = 4, N = 30$. This picture neatly highlights the development towards a bimodal opinion distribution for $\alpha_1 > 0$ and a sufficiently large time interval. In the lower figure the transient density for $\alpha_1 = 0.7$ was computed; clearly no bimodality can be observed.

[38] Since the present model is a Markov model, just the previous observation x_{i-1} has to be considered.

Figure 4: Numerical solutions of transient densities from the Fokker-Planck equation employing the Crank-Nicolson scheme.



Note: The initial observation $x_0 = 0$ was approximated by a sharp normal distribution. For the upper figure, parameter values $\alpha_0 = 0, \alpha_1 = 1.3, v = 4, N = 30$ were chosen. For the lower figure, the value of the momentum parameter was changed to $\alpha_1 = 0.7$.

4.3 Results and Discussion

The results of the model validation are presented in four different sections. Firstly, the parameters of the model are estimated employing the FPO-data on German government satisfaction to investigate if significant social interaction effects can be detected. Secondly, it is examined if the parameter estimates of the exogenous factors of influence appear with meaningful signs. Thirdly, I explore if the social interaction effects behave as anticipated under the presence of opinion polls. Fourthly, I study whether the weekly levels of government support are likely results of the process given the data one week before (following Lux, 2009, p. 649 et. seqq.). Apart from this general validation, I seek to gain deeper insights in the dynamics of the opinion index by revealing its social interaction patters.

Within the scope of the following parameter estimations, I presume a "stable political psychology" (Weidlich, 2002, p. 173). That implies that the parameters of the opinion formation model are treated as constant in the observation period. Especially for the number of agents, N, the speed parameter, v, and the preference parameter, α_0, non-varying values are plausible. But also majority and momentum parameters, α_1 and α_2, may be considered as societal constants: As Weidlich (cf. 2002, p. 173) as well as Weidlich and Haag (1983, p. 46) argue, these values depend on the sociopolitical constitution of the system and just change during the transition from e.g. a democratic to a totalitarian regime (in fact, Weidlich, 2002, argues that the tendency of (non)conformity would rise in consequence of this societal shift due to increased group pressure). Similarly, Oesterreich (1993) ascribes the differences in opinion pressure between Eastern and Western Germany shortly after reunification to differences in former political and social structures. Because I consider a stable liberal and democratic political system the presumption of constant parameters is reasonable. Although for short and medium time-frames the strong assumption of constant parameters may be warranted, of course all parameters may change, also within a stable system, during a longer period of time.

4.3.1 Social Interaction Effects and the Dynamics of the Opinion Index

The aim of this chapter is to investigate if the presented model of social interaction is able to explain the dynamics of the FPO-data on German government satisfaction. In

this chapter, different variants of the social interaction model without exogenous factors are considered (entries of the parameter vector are elements of $\{\alpha_0, \alpha_1, \alpha_2, v, N\}$). In the subsequent section it is then examined if and which exogenous variables can contribute additional explanatory power (following Lux, 2009).

The results were obtained by employing the estimation framework expounded in Section 4.2. Within the scope of the numerical integration of the transient density $\Delta x = 0.01$ and $\Delta t = 1/70$ were used for discretization in space and time. Various starting values were chosen in the course of finding the parameters which maximize the likelihood function. For most of the presented models selecting very different starting values did not change the parameters.[39]

Table 3: Parameter estimates for opinion formation models with social interaction effects.

Parameter	Model I	Model II	Model III	Model IV
α_0 (predisposition param.)	0.005*** (0.001)	-0.747** (0.301)	-0.299*** (0.072)	-0.059 (0.106)
α_1 (majority param.)	1.089*** (0.001)	-1.110 (0.756)		0.808*** (0.032)
α_2 (momentum param.)			-9.722*** (1.619)	-7.895*** (1.287)
v (flexibility param.)	8.025*** (0.032)	0.005*** (0.001)	0.014*** (0.001)	0.021*** (0.001)
N (agents)	750	5	15	21
log L	30.455	623.148	642.044	644.597
AIC	-54.91	-1240.295	-1276.088	-1281.193
BIC	-43.121	-1228.507	-1260.369	-1265.475

Note: Results have been estimated via numerical integration of the transient density with $\Delta x = 0.01$ and $\Delta t = 1/70$. 376 observations in all models. ***p<0.01; **p<0.05; *p<0.10 judged by the t-statistic ($\alpha_1 = 0$).

Table 3 summarizes the parameter estimates for various models including social interaction effects and excluding exogenous factors of influence. In Model I the number of

[39] An exception are especially Model I an II of Table 4.2.

agents was fixed to $N = 750$ since the FPO data rest upon 1500 respondents ($2N$). The predisposition parameter, α_0, is significantly positive which is surprising in view of the time series described in Section 4.1.1.3. The flexibility parameter, v, is markedly high in comparison to following models. This can be explained by the high number of agents in these models which makes fluctuations less likely. A high frequency of opinion changes counteracts this tendency (cf. Lux, 2009). Note that v is significantly larger than 0 (as in all subsequent models) which is essential for obtaining non-zero transition rates and meaningful model dynamics. The examination of the social interaction effects are of special importance since it was hypothesized that they are pivotal for the opinion changes. As it turns out, the majority parameter is highly significant different from zero in both models like hypothesized. In fact, this parameter is even significantly larger than unity, indicating strong interaction which leads, as set out above, to a bimodal form of the limiting distribution. That α_1 is above the bifurcation value may especially be due to the high number of agents. Strong interaction enables the appearence of fluctuations even for a large population (Ghonghadze and Lux, 2012, p. 3076). Adding the momentum parameter, α_2, to Model I (not shown) gives rise to a distinct model improvement ($\log L \approx 35.021$) such that both information criteria as measures of the relative quality (AIC, BIC) prefer an incorporation of this mechanism. However, α_2 does not turn out significantly different from zero in this case. Note that the change of the opinion index between the current and previous was considered as variable for the momentum mechanism. Thus, the momentum variable is constant between two weeks.

This model framework allows to also estimate N which was defined as half of the population. It can be argued that the number of "effectively independent agents" (Lux, 2009, p. 640) is less than 1500 since respondents could change their opinions constantly together with a group of other respondents (cf. Lux, 2009). Estimating N would then give indication of the number of those groups whose members behave perfectly synchronized (cf. Lux, 2009, p. 651). In Model II to IV the number of agents is endogenized. In these and subsequent models, the number of agents was estimated and then fixed at the integer parameter value that maximized the likelihood function (usually this value was located close to the estimated digit). This is done in order to obtain standard errors: Endogenizing N can be accompanied by very large standard errors due to an approximate collinearity between the number of agents, N, the flexibility, v, as well as the majority parameter, α_1 (cf. Lux, 2012, p. 1292). As observed in Model II, a staggering model im-

provement is obtained after estimating N.[40] The number of effective agents is estimated at 10 ($2N$). Interestingly, this exactly corresponds to the number of German Sinus-milieus (see Flaig and Barth, 2014). These milieus are part of a social group model which classifies individuals according to their values and attitudes. Since Müller-Rommel and Poguntke (1991) propound that members of the same Sinus-milieu also tend to share a basic political orientation, a fairly synchronized evaluation and reevaluation of the government's performance within these groups is in principle conceivable. Also reasonable is the now expected significantly negative value of α_0 indicating a general predisposition to evaluate the government rather negatively. Focusing the social interaction effects, at which the interest is mainly aimed, it can be observed that the decrease of N comes along with a negative majority parameter (the trade off between N and v was described above, also see Ghonghadze and Lux, 2012, p. 3076). However α_1 does not turn out significant contrasting the assumed importance of this social interaction effect. Replacing the majority by the momentum mechanism (Model III) yields, on the contrary, a highly significant value for α_2 and a remarkable enhancement of the goodness-of-fit[41] while the number of agents triples and the values of α_0 as well as v slightly increase. Combining both mechanisms again leads to an increase of the log likelihood (Model IV) to the point that the information criteria AIC and BIC prefer this model over all variants investigated before.[42] N and v again marginally increase while α_0 becomes statistically insignificant from zero indicating that respondents do no longer have an natural propensity to evaluate the government rather negative. More important, both social interaction parameters α_1 and α_2 are now significantly different from zero in accordance to the theoretical assumption that both mechanisms are important drivers in the evolution of political preferences. Beyond that, the signs of parameters α_1 and α_2 reveal an interesting pattern: A positive value of α_1 below the bifurcation value indicates a weak bandwagon effect whereas the strongly negative value of α_2 points out a anti-momentum effect. It appears that respondents tend to join the current majority opinion ($\alpha_1 > 0$) while they lean towards the opinion which is losing support at the same time ($\alpha_2 < 0$). It may seem peculiar that conformity and

[40] Also in case of estimating the parameters of the model framework of a business climate survey, a remarkable enhancement of the model after treating N as a free parameter was found (Lux, 2009). However, in other cases the improvement was decidedly small Ghonghadze and Lux (2012).

[41] A similar improvement was found in the application of Lux (2009) while an essential advancement after the implementation of a momentum mechanism was not detected in the estimations of Ghonghadze and Lux (2012).

[42] Also alternative variants like models with no interaction parameters at all or models in which the predisposition parameter was omitted (according to the remark on collinearity betwenn α_0 and α_1 of Ghonghadze and Lux, 2012, p. 3072) were investigated. With respect to the log-likelihood and the values of AIC and BIC, these models are inferior to Model IV.

nonconformity effects work at the same time via different mechanisms but this possibility was explicitly not excluded when the implementation of these effects was theoretically justified.

Summarizing these first results, one can note that both mechanisms of social interaction could be identified since α_1 and α_2 turned out significant as hypothesized. Five observations can be made in this regard. First, the relative quality of the model does not improve if one of both social interaction effects is omitted: Hence a model (Model IV) that takes the interplay between both mechanisms into account gets the closest to the structure of the present data. Second, it is especially important to consider both effects since an exclusion of the momentum mechanism would let the majority parameter appear insignificant such that no support for social interaction effects would be found. In addition, the underdog effect ($\alpha_1 < 0$, Model II) turned into the opposite bandwagon effect ($\alpha_1 > 0$, Model IV) after the momentum mechanism was implemented, which is a dramatic parameter change. Thirdly, the momentum mechanism contributes distinctly more explanatory power than the majority mechanism. Also after consideration of the parameter values, a greater importance of the momentum mechanism becomes apparent: While α_2 reveals a strong negative value, the positive value of α_1 is significantly smaller than unity which implies weak interaction (see Section 3.2.3). Fourthly, a bandwagon effect ($\alpha_1 > 0$) and a anti-momentum effect ($\alpha_2 < 0$) were found, implying that conformity and nonconformity effects work at the same time in the observation period. Fifthly, apart from the majority and momentum mechanism, endogenizing N leads to a remarkable improvement of the model - the resulting enhancement is by far more meaningful than gains obtained by the majority or momentum mechanism. This indicates that there is a relatively small number of groups ($2N \approx 42$) among the respondents whose members exhibit synchronized behavior (cf. Lux, 2009). These strong ties between the groups' members could be interpreted as result of strong interaction which would then again support the hypothesis that social interaction is of great concern for describing the dynamics of government satisfaction as a special manifestation of political preference.

4.3.2 Exogenous Factors and the Dynamics of the Opinion Index

This chapter pursues, firstly, the examination if exogenous variables can contribute additional explanatory power and if their parameters are significantly different from zero (cf. Lux, 2009) since it is reasonable that the fluctuations of the opinion index are not solely

governed by social interaction effects. Secondly, it is of interest if the social interaction mechanisms can still turn out significant if exogenous factors are included.

Table 4: Parameter estimates for models with exogenous factors of influence.

Parameter	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII	Model VIII
α_0	-0.059	-0.223	-0.164	-0.050	-0.117	-0.059	-0.059	-0.160
(predisp.)	(0.106)	(0.158)	(0.115)	(0.106)	(0.111)	(0.104)	(0.104)	(0.114)
α_1	0.808***	0.407	0.486	0.837**	0.635*	0.808**	0.808**	0.491
(majority)	(0.297)	(0.398)	(0.328)	(0.299)	(0.314)	(0.292)	(0.292)	(0.326)
α_2	-7.895***	-7.241***	-7.924***	-8.015***	-7.876***	-7.895***	-7.820***	-7.862***
(momentum)	(1.287)	(1.245)	(1.278)	(1.301)	(1.278)	(1.277)	(1.284)	(1.266)
v	0.021***	0.022***	0.021***	0.021***	0.021***	0.020***	0.020***	0.021***
(flexibility)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
N	21	22	21	21	21	21	21	21
(agents)								
β_1		-0.012						
(Merkel II)		(0.012)						
β_2		0.291						
(Merkel III)		(0.193)						
γ_{unemp}			-0.125*					-0.119**
(economy)			(0.054)					(0.055)
δ_1				-0.011				
(nat. sec.)				(0.012)				
δ_2					-0.004			
(inner sec.)					(0.003)			
δ_3						-0.021*		-0.020**
(soc. just.)						(0.010)		(0.009)
δ_4							0.011	
(scandals)							(0.013)	
log L	644.597	645.967	647.348	645.008	645.900	647.216	645.031	649.610
AIC	-1281.193	-1279.933	-1284.697	-1280.015	-1281.800	-1284.432	-1280.062	-1287.221
BIC	-1265.475	-1256.356	-1265.049	-1260.368	-1262.152	-1264.784	-1260.414	-1263.643

Note: Results have been estimated via numerical integration of the transient density with $\Delta x = 0.01$ and $\Delta t = 1/70$. Parameters for the following exogenous factors were estimated. β_1, β_2: dummy indication periods of office. γ_{unemp}: unemployment rate. $\delta_1, \delta_2, \delta_3, \delta_4$: political 'temperature curves'. 376 observations in all models. ***p<0.01; **p<0.05; *p<0.10 judged by the t-statistic ($\alpha_1 = 0$).

In total 26 different exogenous variables were considered, which can be assigned to three different domains as described in Section 4.1.2.2: (1) the political periods of office (variables β_i), (2) economic conditions (parameters γ_i) and (3) political conditions (parameters

δ_i). The third area is further divided into political conditions regarding national security (parameters $\delta_{1,i}$), inner security (parameters $\delta_{2,i}$), social justice (parameters $\delta_{3,i}$) and scandals (parameters $\delta_{4,i}$). Variables of these six areas were successively added to Model IV of Table 3 (coincides with Model I of Table 4) which was favored by the log-likelihood as well as the AIC and BIC information criteria. Table 4 summarizes the estimation results. Models with those variables of each domain are displayed which were favored by the AIC criterion (all other models are presented in Appendix G). Note that I also tried different lags of the variables which almost did not influence the estimation results.

Model II incorporates dummies indicating the periods of office (β_1 for cabinet Merkel II and β_2 for cabinet Merkel III) since it was previously assumed that different partisan foundations of governments lead to shifts of government support. The coefficients of Model II are in accordance with the expectations and previous findings (see Bytzek, 2011; Rohrschneider and Schmitt-Beck, 2002): The predisposition towards the "$-$"-opinion (dissatisfaction with government) is the strongest during the CDU/CSU-FDP coalition from October 2009 till December 2013 whereas the bias is shifted more towards the "$+$"-opinion (satisfaction with government) in times of both grand coalitions (Merkel I and Merkel III). In the third Merkel cabinet, even a slight total predisposition towards the "$+$"-opinion can be observed which was expected when considered Figure 3). Although the signs of β_1 and β_2 are meaningful, the parameters are not significant. Moreover, just a minor increase of the log-likelihood and higher values for the AIC as well as BIC criteria are observed. This allows the assessment that the consideration of both dummies does not add substantial explanatory power. Also alternative dummies indicating different legislature periods instead of the periods of office were tested since voters might already evaluate newly forming governments right after elections. However, the results did almost not differ from those of Model II. Moreover, it could be assumed that not just the predisposition differs between the periods of office but also other parameters. Table 5 shows the parameter estimations for the observations of each different cabinet.[43] Note that within the observation period only the third Merkel cabinet is completely contained (214 weeks) whereas the other terms of office are just partly covered (Merkel I: 94 weeks; Merkel II: 68 weeks). Except for the small sample sizes of the Merkel I and Merkel II periods, the results may not reflect the typical patterns during those governments since opinion dynamics could behave differently at the beginning and the end of periods of

[43]The parameter set of Model IV (Table 3) was used ($\theta = (\alpha_0, \alpha_1, \alpha_2, v, N)'$). In addition, the different parameter set $\theta = (\alpha_0, \alpha_1, v, N)'$ was considered. Also in this case all three submodels exhibited similar features.

office.[44] However, the results are alike in their general features: v is of similar magnitude during the three different cabinets; N is in all periods between 20 and 30 and thus distinctly smaller than 750. α_0 is insignificantly different from 0 as in the complete model with all observations between 2008 and 2015. The momentum parameter, α_2 is in all three submodels significantly smaller than zero whereby just the sizes of these effects differ. α_1 is positive and significantly different from zero for Merkel II and statistically not different from zero for Merkel I and III, which underlines the relative importance of the momentum mechanism in comparison to the majority mechanism. It is not surprising that the estimates of the complete model resemble those of the Merkel II model which contains 60% of all observations.

Table 5: Parameter estimates for different terms of office (Merkel I/ Merkel II/ Merkel III)

Parameter	Model I (Merkel 1)	Model II (Merkel II)	Model III (Merkel III)
α_0 (predisposition param.)	-0.047 (0.199)	-0.988 (0.412)	-0.041 (0.070)
α_1 (majority param.)	0.134 (1.356)	0.882* (0.375)	0.412 (0.345)
α_2 (momentum param.)	-3.182** (1.386)	-12.555*** (2.115)	-2.206*** (0.279)
v (flexibility param.)	0.024*** (0.004)	0.016*** (0.002)	0.041*** (0.007)
N (agents)	21	20	30
log L	157.986	383.655	108.696
AIC	-307.972	-759.310	-209.392
BIC	-297.799	-745.846	-200.514
Observations	94	214	68

Note: Results have been estimated via numerical integration of the transient density with $\Delta x = 0.01$ and $\Delta t = 1/70$. 376 observations in all models. ***p<0.01; **p<0.05; *p<0.10 judged by the t-statistic ($\alpha_1 = 0$).

[44] It could e.g. be assumed that the flexibility of voters might increase right before elections.

In Model III of Table 4 the monthly unemployment rate (parameter γ_{unemp}) was added as an indicator of the economic condition. The significantly negative sign is meaningful since it indicates that the respondents' evaluation of the government is negatively influenced by rising unemployment rates which indicate an economic downturn (in keeping with Citrin and Luks, 2001; Chanley et al., 2000; Cheibub et al., 1996). The incorporation of this economic variable is accompanied by a moderate increase of the log-likelihood such that the information criteria give different recommendations: The AIC criterion prefers the consideration of γ_{unemp} while the BIC criterion, which penalizes the implementation of additional parameters more than the AIC criterion, is in favor of the model without γ_{unemp}. Instead of the unemployment rate, also the other indicators of economic conditions were considered: Table 8 in Appendix G summarizes alternative models which consider the change of the unemployment rate (parameter $\gamma_{unemp,\Delta}$), the industrial production (parameter γ_{ip}), change of the industrial production (parameter $\gamma_{ip,\Delta}$), economic perception (parameter $\gamma_{ec.perc}$), change of the economic perception $\gamma_{ec.perc,\Delta}$. Their parameters exhibit meaningful signs[45] which are, however, not significantly different from zero. Moreover, their implementation leads to a lower rise of the log-likelihood than the incorporation of the unemployment rate. In direct comparison to the model with purely intrinsic feedback ($\theta = (\alpha_0, \alpha_1, v, N, \alpha_2)'$) the BIC and AIC criteria do not prefer the incorporation of these variables.

The subsequent models consider news about political conditions which could exogenously influence the respondents' evaluation of the government. The respective variables were constructed via web scraping as described in Section 4.1.2.2. In total 24 different variables were taken into account. Models IV to VII display the parameter values corresponding to the 'temperature curve'-variables for the policy areas of national security, δ_1, inner security, δ_2, and social justice, δ_3, as well as for political scandals, δ_4 indicating the quantity of negative news in the respective fields. As it turns out, parameter δ_3 (Model VI) exhibits an expected significantly negative sign. This is in line with the findings of Mishler and Rose (2001) and Kluegel and Mason (2004) that individuals' assessment of the government performance is negatively influenced by rising social injustice. The model improvement, measured by the log-likelihood, is comparable with the enhancement associated with the incorporation of the unemployment rate. Accordingly, the AIC and BIC values are in favor of incorporating this variable. In contrast, the parameters δ_1, δ_2 and δ_4

[45] Accordingly, $\gamma_{unemp,\Delta}$ has a negative sign whereas the other parameters display positive values. An exception is γ_perc which is negative. However, this parameter is, like the others, insignificantly different from zero.

are not significantly different from zero, such that the AIC and BIC values of Models IV, V and VII are higher or approximately the same (Model V) as the model with exclusively intrinsic feedback. In other models also the changes of those variables (parameters $\delta_{1,\Delta}$, $\delta_{2,\Delta}$, $\delta_{3,\Delta}$, $\delta_{4,\Delta}$) were considered. However, the respective parameters neither do turn out significantly different from zero nor do the models exhibit a substantial increase of the log-likelihood (Table 9 in Appendix G). In addition, dummies were constructed for each of the four different areas which take the value 1 if the particular 'temperature curve'-variable exceeds the mean by one standard deviation (parameters δ_1^d, δ_2^d, δ_3^d, δ_4^d). Following the argumentation of Section 4.1.2.2, these dummies then indicate presence of a high number of presumably negative news in the respective fields. In accordance with the results of Table 4, only the dummy parameter for news about social justice, δ_3^d, shows a significant value with the expected negative sign (Table 10 in Appendix G).[46] The increase of the log-likelihood is comparable to the improvement associated with the Model VI which incorporated the 'temperature curve'-variable for the field of social justice. Besides this general focus on news about political conditions in the four considered field, also topic-specific news were regarded. For the policy area of national security, news about irregular and illegal migration (parameter δ_1^{migr}) as well as international terrorism (parameter $\delta_1^{i.terr}$) were regarded separately since the importance of these topics were emphasized by Chanley et al. (2001) and Alford (2001). Also the changes of these variables were regarded (parameters $\delta_{1,\Delta}^{migr}$ and $\delta_{1,\Delta}^{i.terr}$). However, the respective variables neither do exhibit significant parameter estimates nor does their incorporation eventuate in an noteworthy adding of explanatory power (Table 12 in Appendix G). For the field of inner security, news about crime (parameter δ_2^{crime}) and national terrorism (parameter $\delta_2^{n.terr}$) as well as the changes of these quantities (parameters $\delta_{2,\Delta}^{crime}$ and $\delta_{2,\Delta}^{n.terr}$) were separately focused on (inspired by the findings of Kohut et al., 1998, and Mansbridge, 1997). An implementation of these variables comes along with an almost unchanged log-likelihood and insignificant values of the respective parameters (Table 13 in Appendix G).

Model VIII combined several exogenous factors. Starting with the model featuring purely intrinsic feedback the addition of that variable was realized whose implementation eventuated in the strongest decrease of the AIC value and a significant parameter of the subjoined variable. This proceeding was continued till no exogenous factor could be

[46] Also dummies were constructed which signify if the 'temperature curve'-variables exceed the mean by two standard deviations (parameters δ_1^{d2}, δ_2^{d2}, δ_3^{d2}, δ_4^{d2}). However, the values of these parameters do not statistically differ from zero while the log-likelihood almost does not change (Table 11 in Appendix G).

added anymore by this means.[47] Eventually, the unemployment rate and the 'temperature curve'-variable for the policy area of social justice were integrated. The parameter values γ_{unemp} and δ_3 barely changed in comparison to Model III and Model VI. The increase of the log-likelihood is distinct but not excessively large: the implementation of the momentum parameter was accompanied by a considerably greater gain (difference between Model II and IV of Table 3).

The consequences of implementing exogenous factors for the parameters of the initial model can be condensed as follows: For all considered models, the predisposition parameter, α_0, remains insignificant, implying the absence of a natural skepticism towards the government. The flexibility parameter, v, meaningfully keeps its significantly positive value and the number of effectively independent agents remains relatively stable between 40 and 44 ($2N$). Looking at the social interaction effects, it is apparent that also the momentum parameter, α_2, stays very firm at its distinct negative value. In contrast, the value for the majority parameter, α_1, occasionally turns insignificant; especially in the AIC-prefered Model VIII. While α_1 indicated at least an weak bandwagon effect ($0 < \alpha_1 < 1$), an significant majority mechanism cannot be identified anymore after considering exogenous factors. Already in the previous section the greater importance of the momentum mechanism was emphasized when the likelihood gains resulting from the implementation of the social interaction mechanisms were compared. Although one may have inhibitions to disregard α_1 due to its traditional and systemic importance for the model approach (cf. Franke, 2008, p. 318), the present findings allow to conclude that the respondents are influenced by the average opinion rather via the momentum mechanism.[48] Meanwhile, the negative sign of the momentum parameter further on indicates the presence of an underdog effect.

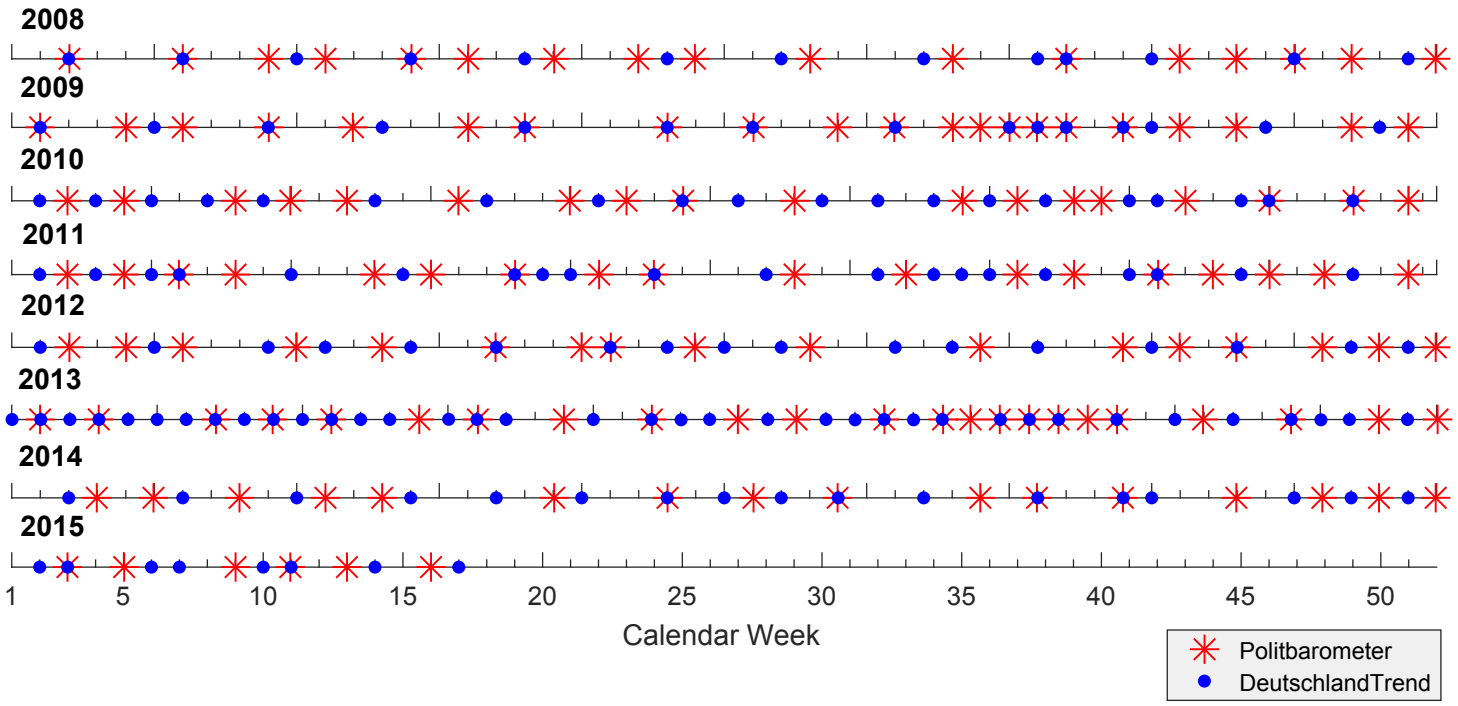
4.3.3 Social Interaction Effects and the Presence of Opinion Polls

It was argued above that the magnitude of social interaction effects positively depend on the visibility of the majority opinion and its change. In this chapter, the nexus between social interaction effects and the presence of opinion polls is analyzed. It was reasoned that opinion polls ensure an increased visibility of the majority opinion and its development.

[47] Also variables added in Appendix G to G were considered.

[48] Excluding α_1 from Model VIII is accompanied by a modest decrease of the log-likelihood to 646.522 with parameters (standard errors): $\alpha_0 : 0.090(0.047); \alpha_2 : -7.991(0.368); v : 0.020(0.002); N : 21; \gamma_{unemp} : -0.059(0.049); \delta_3 : -0.019(0.009)$.

Figure 5: Weeks of publication of Politbarometer and DeutschlandTrend



Source: Own representation.

Figure 5 depicts the weeks in which public opinion polls were published which contained government satisfaction. In 2013, in 90% of all weeks polls were published. In contrast, opinion polls were just published in 59% of all weeks in 2012 and in 57% of all weeks in 2014. The reason for this discrepancy is presumably the federal election in year 2013. To investigate the social interaction effects in these three different years, I estimated the model parameters separately for every year. As exogenous factors, I included the variables which were found to be significant in Chapter 4.3.2. The results are presented in Table 6.

Table 6: Parameter estimates and the publication of opinion polls

Parameter	Model I (2012)	Model II (2013)	Model III (2014)
α_0 (predisposition param.)	-0.421 (0.352)	-0.845 (0.534)	-0.053* (0.031)
α_1 (majority param.)	0.623 (0.895)	0.810 (0.939)	0.512 (0.423)
α_2 (momentum param.)	-13.257*** (1.145)	-12.234*** (1.462)	-2.336*** (0.314)
v (flexibility param.)	0.021*** (0.004)	0.032*** (0.020)	0.057*** (0.009)
N (agents)	20	21	29
γ_{unemp} (economy)	-0.032 (0.052)	-0.599 (0.619)	-1.444 (0.927)
δ_3 (soc. just.)	-0.023** (0.011)	-0.045*** (0.010)	-0.023** (0.009)
log L	99.030	93.597	92.352
AIC	-186.060	-175.193	-172.704
BIC	-174.353	-163.486	-161.113
Observations	52	52	52
Weeks with published polls	30 (59%)	46 (90%)	29 (57%)

Note: Results have been estimated via numerical integration of the transient density with $\Delta x = 0.01$ and $\Delta t = 1/70$. Parameters for the following exogenous factors were estimated. γ_{unemp}: unemployment rate. δ_3: 'temperature curve' for social justice. ***p<0.01; **p<0.05; *p<0.10 judged by the t-statistic ($\alpha_1 = 0$).

The values of parameters α_0, v, N, γ_{unemp}, δ_3 roughly correspond to the findings of the section above. Notable is e.g. that in all models parameter value γ_{unemp} is not significantly different from 0; however, it exhibits the correct negative sign. The main focus is on the behavior of the social interaction effects. The majority parameter is in all three models insignificantly different from zero. Thus, the magnitude of this social interaction effect is not found to be significantly larger for the year 2013 in which distinctly more polls were

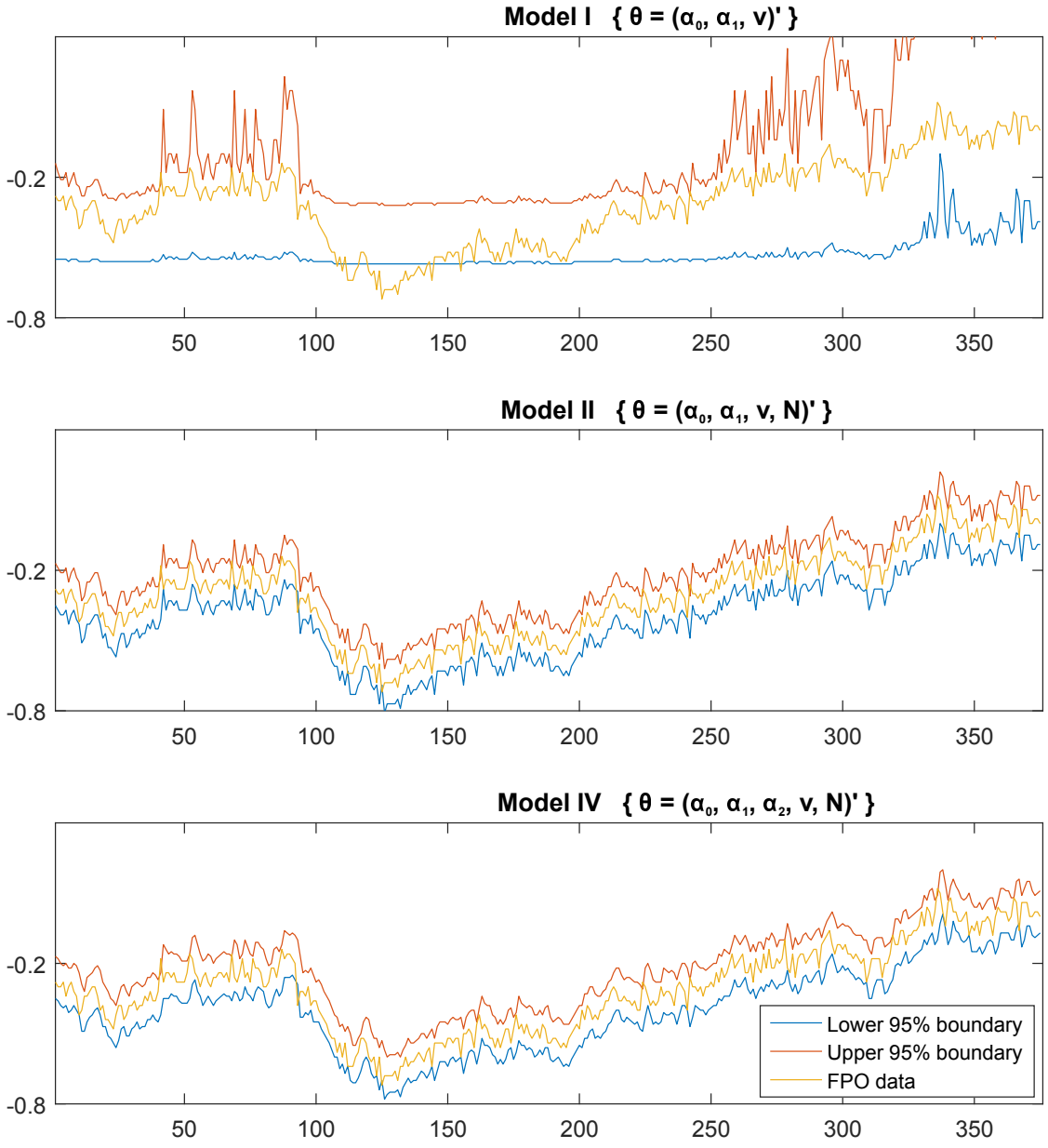
published. Also the momentum parameter is not significantly larger in year 2013 than in the preceding year. The values for α_2 are very similar for the years 2012 and 2013; in year 2014 the value is distinctly smaller. However, on the basis of these results it can not be concluded that the magnitude of social interaction effects in year 2013 are larger than in years in which less polls were published.

It should be pointed out that the number of observations is comparatively small for all three years (52 observations). A larger sample size would be preferable (**?**, cf.) but daily observations are not available as pointed out in Section 4.1.1. Further note that the weekly unpublished data provide opportunities for further investigation on how the presence of opinion polls influences the evolution of political preferences which would go beyond the scope of this paper. For test purposes, I e.g. implemented a dummy indicating if a poll was published in the respective week. Interestingly, I found that the predisposition parameter is significantly shifted towards a more positive evaluation of the government after polls were published. Detailed investigations of the general role of opinion polls should be subject of a separate investigation.

4.3.4 Is the Empirical Time Series a Likely Realization of Social Interaction Processes?

In this chapter it is analyzed whether the empirical time series of government satisfaction could have been produced by the estimated models. Especially it is of interest sudden changes of the opinion on government satisfaction are consistent with social interaction models. Therefore, I follow Lux (2009, p. 649) to investigate if a week's government satisfaction is a likely realization of the social interaction processes given last week's government satisfaction and macro influences. Hence, I computed one-step iterations of the transient density and considered the 95 percent bound around the median after this step. The parameter values of the estimated models of Table 3 were used. The results are displayed in Figure 6.

Figure 6: 95%-boundaries for one-step iterations of transient densities.



For Model I, the empirical time series clearly leaves the 95 percent bounds between week 100 and 150 and often comes very close to the bounds. Thus it seems unlikely that the empirical record was produced by this process of social interaction. Although the majority parameter lies above the bifurcation value of unity fluctuations between modes

are not likely because of the high number individuals (N was not endogenized in this Model). This becomes especially apparent between week 100 and 200 in which the 95 percent boundaries of the transient densities almost do not change. In Model II, N was endogenized. In contrast to Model I, the empirical time series stays mostly inside of the 95 percent boundaries. Once more it can be observed that endogenizing N leads to a remarkable improvement of the Model. The fit even further improves after implementing the momentum mechanism in Model VI. Table 7 accordingly shows that the the number of transgressions of the 95 percent bounds are the lowest for Model VI. The incorporation of exogenous factors of influence (especially the unemployment rate and the policy variable for social justice) further reduces the number of transgressions; however the behavior of the bounds almost does not differ from the results obtained for Model IV.

Table 7: Sum of weeks with transgression of 95% bounds

	Model I	Model II	Model IV
Weeks transcending lower 95%-boundary	32	5	5
Weeks transcending upper 95%-boundary	3	10	6
Total transgressions	35	15	11

Based on these analyses of the 95 percent bounds, it can at least not be ruled out that models of social interaction considered above (especially models which endogenized the number of respondents N) are data-generating processes of the empirical data on government satisfaction.

4.3.5 Discussion

The aim of the prior empirical investigation was to test whether a process of social interaction is able to explain the evolution of government satisfaction. For this endeavor an agent-based model was applied which explicitly takes social interaction effects into account (via a majority and a momentum mechanism).

Evidence is obtained which supports the conjecture that this agent-based model of social interaction describes the ups and downs of the opinion on government satisfaction. Firstly, the social interaction parameter for the momentum mechanism are found to be highly significant and exhibit a large magnitude. This observation also holds true for ev-

ery single legislative period considered. Thus, the estimated models state that social interaction plays a significant role for the evolution of government satisfaction. Secondly, the significant parameters of the exogenous factors of influence (namely the unemployment rate and the 'temperature curve'-variable for the policy area of social justice) display empirically sensible signs and the estimated low number of societal groups partially comes close to the number of Sinus-milieus. Is is also sensible that the predisposition parameter is insignificantly different from zero: Since a stable political system is considered, it makes sense that there is no predisposition to distrust the government. These meaningful parameter estimates are indicative of the empirical validity of the model variants. Thirdly, the likelihood gains resulting for the implementation of exogenous factors of influence are rather small in comparison to the improvements achieved by endogenizing the number of respondents and the incorporation of the momentum mechanism. Notably, most exogenous factors did not turn out significant. This underlines that especially the social ties between groups' members and social interaction effects are important for the goodness of fit of the model and rather not exogenous variables. Fourthly, the computation of 95 percent bounds for one-step iterations of transient densities display that the empirical time series of government satisfaction barely leaves these bounds. In this light, almost every week's opinion index of government satisfaction is a likely realization. Once again this underscores that the model of social interaction is capable of explaining the partly sudden fluctuations of government satisfaction.

While these results demonstrate the explanatory power of the tested social interaction model, some results are less clear in their support of the validity of the model. Although the parameter value for the majority mechanism significantly differed from zero in models which just considered intrinsic feedback, the value turned occasionally insignificant after incorporating exogenous factors. Especially after incorporation of exogenous variables which turned out to have significant parameter values, the parameter for the majority mechanism turns insignificant. Thus, it can be concluded that this mechanism of social interaction is rather dispensable for the evolution of the analyzed political preference. This however does by no means imply that social interaction effects are not relevant for the fluctuations of government satisfaction since the momentum mechanism exhibits significant parameter values in every considered model. Beside it, the social interaction effects do not behave as anticipated under the presence of opinion polls. Contrary to my expectation, the parameter values of the social interaction effects did not significantly increase in their magnitude under the presence of opinion polls. However, the respective

analyses were carried out with a very small number of observations. Other attempts (e.g. with more data points) may be successful in obtaining significant results.

Taken together, these results still point out that the tested agent-based model of social interaction exhibits marked explanatory power for the development of German government satisfaction. This result is in line with the comprehensive literature, which claims that social interaction plays a significant role in the evolution of political preferences (e.g. Bartels, 1985). Certainly, the results stand in marked contrast to considerations which state that political preferences are stable and most widely unaffected by social interaction (Heath and Evans, 1994) but also to contributions which state that social interaction is only relevant in the evolution of voting intentions via strategic considerations (Blais et al., 2006). Last-mentioned studies usually investigate party preferences. The discrepancies between their and my results could be ascribed to the possibility that stable beliefs in respect of government satisfaction are less distinct; at the latest individuals will reevaluate their opinion concerning the government performance after a new government is formed. Consequentially, the effects of social interaction on government satisfaction may be bigger than on other political preferences. However, the differences may arise from different methodologies since I did not employ a purely statistical analysis.

While the main focus of the paper at hand is on *whether* a model of social interaction can explain the ups and downs of political preferences, results were obtained which yield further insights in *how* these social interaction effects work. For one thing, as already indicated, the momentum mechanism seems to play a more considerable role than the majority mechanism. Thus, individuals would rather respond to changes of the general opinion than to the majority situation. This is of particular interest since most investigations do not differentiate between both mechanisms. It further confirms the validity of separating both mechanisms. The prevalence of horse race journalism could be one possible explanation for this observation: Changes of political opinion and their potential reasons are often discussed more intense than the actual level of public opinion (e.g. Faas, 2017). For another thing, the significantly negative momentum parameter strongly indicates a tendency of nonconformity rather than a propensity to conformity. This is in line with the literature indicating the existence of an underdog/anti-momentum effect[49] (e.g. Sanders, 2003). In the ongoing debate about whether this or the bandwagon/momentum effect dominates, my results would side with the dominance of the nonconformist anti-

[49]This notation indicates that most conceptualizations of the underdog effect include my definition of the anti-momentum effect (see Section 2.2).

momentum effect. Interestingly, in those cases in which the parameter for the majority mechanism turned out significant, it was positive and indicating a tendency of conformity. If both a propensity of conformity and an inclination of nonconformity are at work at the same time via different mechanism (majority and momentum) one possible explanation for the inconclusive empirical evidence could be obtained. However, my results do not allow this interpretation since the majority mechanism turned out insignificant after the incorporation of exogenous factors of influence.

Limitations of these interpretations were already partially mentioned. For one, their generalization is certainly not self-evident. Not only do other political preferences may exhibit other interaction patterns e.g. because other opinions may be associated to more stable beliefs. These patterns are probably also changeable over time; already in the current sample, the parameter estimates varied in parts between legislative periods. While these objections may be valid, the results at hand can at least be employed as counterexample against the blanket neglect of social interaction in the evolution of political preferences. Another limitation is the absence of other models to which the performance of the model at hand could be compared to. Perhaps a simpler model would provide similar results. Since the majority parameter indicates weak interaction and following the results of (Lux, 2012, p. 1298), a simpler process could display a similar fit to the data as the model used. On the other side, it can be contended that the model with its assumptions is too simple to explain the complex process of political opinion formation in a stable liberal system (cf. Weidlich, 2002, p. 173). Naturally, every model can be criticized in this respect. According to my research question, a model was considered which is able to explicitly incorporate social interactions between agents. To ensure fruitful insights in the structural properties and dynamics of social system, a parsimoniously designed model may have advantages (Weidlich, 2002, p. 36). In addition, I also incorporated exogenous factors of influence to capture relevant forces besides the effects of social interaction. Certainly it could be noted that there are unobserved relevant exogenous forces which were not included. Further, it could be argued that the identified social interact effects can be attributed to especially these unobserved factors. As Lux (2009, p. 651) states, individual data is necessary to differentiate between both explanations. Moreover, individual data is also essential to explain the observed tendency of nonconformity which was expressed by the negative sign of the momentum mechanism. This propensity on the aggregate level could be generated by many different (psychological) causes on the individual level. For instance, at least some individuals could also exhibit a desire to conform to the majority opinion. Thus, at

this point I am not able to make statements about the motivations of individual agents (Weidlich, 2002, p. 38).

5 Conclusion

The aim of the present work was to formulate and test an agent-based model of social interaction which claims to explain the dynamics of political preferences. I argued that the effect of social influence on political preferences is significant: Natural affiliations to political organizations decrease and at the same time intense communication via different media channels is increasing. The goal was to contribute to the literature on political preferences and social influence in two ways. On the one hand, the employed agent-based model incorporates two social interaction effects: a majority and a momentum mechanism. Hence, the model considers that individuals might not only be influenced by the prevalent majority opinion but also by changes of the majority situation. Many formal models of political opinion formation do not differentiate between both mechanism or consider them as synonymous. The direction of both incorporated social interaction effects is not predetermined in the present model which is convenient since the previous empirical literature is inconclusive regarding whether conformity or nonconformity effects dominate. On the other hand, I tested this model on government satisfaction in Germany which increases the small number of opinion dynamics model that were empirically validated employing real-life data.

Empirical evidence was obtained which supports the conjecture that the model of social interaction explains the dynamics of German government satisfaction. First of all, a highly significant social interaction mechanism could be identified. In addition, the significant parameters of the exogenous factors of influence displayed meaningful signs; also the estimated number of effectively independent agents is meaningful since it partly comes close to the quantity of Sinus-milieus. The fact that just rather small likelihood gainings were observed after incorporating exogenous factors underlines the importance of social interaction effects for the dynamics of the investigated political opinion. Furthermore, it could be shown that week's levels of government satisfaction are likely realizations of the employed process given the data of the previous week.

In addition to these results which support the empirical validity of the model, interesting interaction patterns could be revealed: On the one hand, social interaction seems to work via the momentum and not via the majority mechanism which would imply that individuals are rather not affected by the level of the majority opinion but by opinion changes which are often highlighted in the widespread horse race media coverage. On the other hand, my findings support the literature which claims the dominance of nonconformity over conformity effects. Studies of individual data have to be employed in order to detect which specific individual motivations produce this tendency of nonconformity.

The presented findings suggest that the release of social information might trigger effects of social interaction which then could alter preference distributions. While this could inhibit an inefficient voter coordination, other examinations should focus the specific role of opinion polls for social dynamics in greater detail in order to establish clarity. To what extent publications of those opinion polls could be used for political purposes by parties or candidates is a further-reaching question. Since the identified anti-momentum effect would manifest in oscillatory tendencies, the strategically guided use of these social interaction effects seems difficult.

One limitation of the present work is the generalization of my findings. Future studies could investigate social interaction patterns in other countries. Conveniently, government satisfaction is a concept which is applicable to countries independent of the configuration of the political system. But also the dynamics of other political preferences could be investigated such as party preferences in two party systems. At any rate, the results of the present paper can be used as an example to illustrate the presumed significant role of social interaction in the evolution of political preferences.

A Derivation of the Fokker-Planck Equation as Approximation of the Master Equation

The Master equation reads

$$\begin{aligned}\frac{dp(x;t)}{dt} =& w_{\downarrow}\left(x+\frac{1}{N}\right)p\left(x+\frac{1}{N};t\right)+w_{\uparrow}\left(x-\frac{1}{N}\right)p\left(x-\frac{1}{N};t\right)\\ &-(w_{\uparrow}(x)+w_{\downarrow}(x))p(x;t).\end{aligned} \tag{23}$$

We assume that the transition rates $w_{\downarrow}$ and $w_{\uparrow}$ are continuous functions of x and that x is a continuous variable (implying that N is large). We then can consider the Taylor expansions for

$$w_{\uparrow}\left(x-\frac{1}{N}\right)p\left(x-\frac{1}{N};t\right) \quad \text{around} \quad x_0 = x+\frac{1}{N} \tag{24}$$

$$w_{\downarrow}\left(x+\frac{1}{N}\right)p\left(x+\frac{1}{N};t\right) \quad \text{around} \quad x_0 = x-\frac{1}{N}. \tag{25}$$

The approximations via Taylor series up to second order are then:

$$\begin{aligned}w_{\uparrow}\left(x-\frac{1}{N}\right)p\left(x-\frac{1}{N};t\right) \approx& w_{\uparrow}(x)p(x;t)+\frac{\partial}{\partial x}[w_{\uparrow}(x)p(x;t)]\left(-\frac{1}{N}\right)\\ &+\frac{1}{2}\frac{\partial}{\partial x^2}[w_{\uparrow}(x)p(x;t)]\left(-\frac{1}{N}\right)^2\end{aligned} \tag{26}$$

and

$$\begin{aligned}w_{\downarrow}\left(x+\frac{1}{N}\right)p\left(x+\frac{1}{N};t\right) \approx& w_{\downarrow}(x)p(x;t)+\frac{\partial}{\partial x}[w_{\downarrow}(x)p(x;t)]\left(\frac{1}{N}\right)\\ &+\frac{1}{2}\frac{\partial}{\partial x^2}[w_{\downarrow}(x)p(x;t)]\left(\frac{1}{N}\right)^2.\end{aligned} \tag{27}$$

Inserting (26) and (27) into (23) yields

$$\begin{aligned}\frac{\partial p(x;t)}{\partial t} =& -\frac{\partial}{\partial x}[(w_{\uparrow}(x)-w_{\downarrow}(x))p(x;t)]\frac{1}{N}\\ &+\frac{\partial}{\partial x^2}[(w_{\uparrow}(x)+w_{\downarrow}(x))p(x;t)]\frac{1}{2N^2}.\end{aligned} \tag{28}$$

B Summary: Survey on Government Satisfaction of the Federal Press Office

forsa.

Zufriedenheit mit der Arbeit der Bundesregierung und der Bundeskanzlerin

Datenbasis:	**1.501 Befragte**
Erhebungszeitraum:	**17. bis 21. Februar 2014**
Statistische Fehlertoleranz:	**+/- 3 Prozentpunkte**
Auftraggeber:	**Presse- und Informationsamt der Bundesregierung**

37 Prozent der Bundesbürger (- 4 Prozentpunkte) sind mit der Arbeit der Bundesregierung zufrieden.

Mit der Arbeit der Bundeskanzlerin sind 62 Prozent der Bundesbürger (- 1 Prozentpunkt) zufrieden.

- **Zufriedenheit mit der Arbeit der Bundesregierung und der Bundeskanzlerin**

		Es sind zufrieden mit der Arbeit der		
		Bundesregierung %	Bundeskanzlerin %	Prozentdifferenz Kanzlerin-Regierung
2013	Dezember	42	67	+ 25
2014	Januar	39	66	+ 27
	Woche 4	41	65	+ 24
	Woche 5	41	65	+ 24
	Woche 6	41	63	+ 22
	Woche 7	41	63	+ 22
	Woche 8	**37**	**62**	**+ 25**
Ost		28	65	+ 37
West		39	61	+ 22
Anhänger der:	CDU/CSU	58	90	+ 32
	SPD	44	53	+ 9
	Linkspartei	9	29	+ 20
	Grünen	22	48	+ 26

forsa.

Mit der Arbeit der CDU/CSU in der Bundesregierung sind 41 Prozent der Bundesbürger (+ 2 Prozentpunkte) zufrieden.

Mit der Arbeit der SPD sind 34 Prozent der Bundesbürger (- 5 Prozentpunkte) zufrieden.

- **Zufriedenheit mit der Arbeit der Regierungsparteien**

		Es sind zufrieden mit der Arbeit der	
		CDU/CSU %	SPD %
2014	Januar	43	35
	Woche 4	44	34
	Woche 5	42	39
	Woche 6	41	40
	Woche 7	39	39
	Woche 8	**41**	**34**
Ost		37	30
West		42	35
Anhänger der:	CDU/CSU	77	33
	SPD	23	61
	Linkspartei	13	16
	Grünen	23	35

C Government Satisfaction Survey: Summary for Federal Government

AMBIVALENTES GESAMTURTEIL ÜBER DIE ARBEIT DER GROSSEN KOALITION

Kurz vor dem Ende der Legislaturperiode zieht die Bevölkerung ein ambivalentes Urteil über die Regierungsbilanz der letzten vier Jahre. 30 Prozent der Bevölkerung attestieren der großen Koalition eine erfolgreiche Politik, 33 Prozent halten sie für nicht erfolgreich, 37 Prozent der Bevölkerung enthalten sich der Stimme. Dieses ambivalente Urteil geht nicht zuletzt darauf zurück, dass die Anhänger von vier der im Bundestag vertretenen Parteien ein überwiegend kritisches Urteil fällen – auch die Anhänger der SPD. Während 47 Prozent der Anhänger der CDU/CSU die Arbeit der Koalition als erfolgreich bewerten, teilen nur 23 Prozent der SPD-Anhänger diese Ansicht. 19 Prozent der Anhänger der CDU/CSU, aber 40 Prozent der SPD-Anhänger sind mit der Politik der großen Koalition unzufrieden. Über die ganze Legislaturperiode hinweg ähnelte das Urteil der SPD-Anhänger über die Arbeit der Regierungskoalition weitaus eher dem Urteil der Oppositionsparteien als dem Urteil der Anhänger der CDU/CSU. Während die SPD die Regierungsverantwortung teilte, empfanden sich viele Anhänger der SPD angesichts einer CDU-geführten Regierung eher in der Oppositionsrolle:

Ambivalente Bewertung der Arbeit der großen Koalition

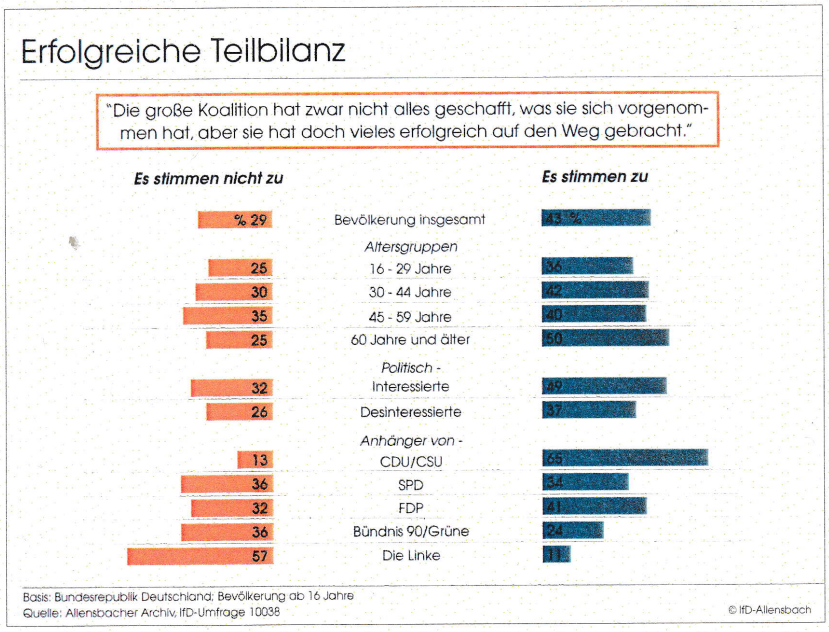
Frage: "Wenn Sie einmal auf die vergangenen vier Jahre zurückblicken, was würden Sie sagen: war die Politik der großen Koalition alles in allem erfolgreich oder nicht erfolgreich?"

	Bevölkerung insgesamt	Anhänger von - CDU/CSU	SPD	FDP	Bündnis 90/ Die Grünen	Die Linke
	%	%	%	%	%	%
Erfolgreich	**30**	**47**	**23**	**32**	**15**	**4**
Nicht erfolgreich	**33**	**19**	**40**	**38**	**38**	**50**
Unentschieden, keine Angabe	**37**	**34**	**37**	**30**	**47**	**46**
	100	100	100	100	100	100

Basis: Bundesrepublik Deutschland, Bevölkerung ab 16 Jahre
Quelle: Allensbacher Archiv, IfD-Umfrage 10038

Quelle: Institut für Demoskopie Allensbach „Bilanz der Regierungsarbeit am Ende der Legislaturperiode – Eine Repräsentativbefragung der Bevölkerung ab 16 Jahre“

Auch wenn die Kritik im Gesamturteil der Bevölkerung leicht überwiegt, ist eine starke relative Mehrheit durchaus bereit zu konzedieren, dass die große Koalition zwar nicht alles geschafft hat, was sie sich vorgenommen hat, aber doch in weiten Bereichen durchaus erfolgreich gearbeitet hat. Insgesamt 43 Prozent der Bevölkerung teilen diese Auffassung, nur 29 Prozent widersprechen dezidiert. Überdurchschnittlich positiv äußern sich die 60-Jährigen und Älteren, die politisch interessierten Bevölkerungskreise und die Anhänger der CDU/CSU. Während auch hier nur jeder dritte Anhänger der SPD bereit ist, der großen Koalition zumindest auf einigen Politikfeldern gute Arbeit zu attestieren, tun dies zwei Drittel der Anhänger der CDU/CSU. Mit Abstand am kritischsten äußern sich die Anhänger der Linken. Von ihnen ist nur jeder Neunte bereit, der großen Koalition zumindest partiell eine erfolgreiche Politik zu bescheinigen:



D Sketchy Derivation of Macroscopic Quantities for the Baseline Model

Thorough steps of the derivation of a model similar in nature can be found in Lux (1997).[50] The subsequent derivation remains sketchy. Firstly, the time change of the mean

$$\frac{d\bar{x}}{dt} = \sum_x x \frac{P(x;t)}{dt} \tag{29}$$

$$= \sum_x x \sum_{x^*} (w(x^* \to x)P(x^*;t) - w(x \to x^*)P(x;t)) \tag{30}$$

is considered, where $\frac{P(x;t)}{dt}$ represents the Master equation. This differential equation for the mean-value of x can be expressed in terms of the *first jump moment* (which is shown by Lux, 1997, p. 31, for a similar model)

$$a_{x,1} = \sum_{x^*} (x^* - x) w(x \to x^*) \tag{31}$$

so that one yields:

$$\frac{d\bar{x}}{dt} = \sum_x a_{x,1} P(x;t) = \overline{a_{x,1}} \tag{32}$$

[50] Further see the slides of the lecture on "Agent-Based Models in Economics and Finance" (chapter "A Dynamic Stochastic Framework for Socio-Economic Interactions") which Professor Lux gave in the summer term 2016 at the University of Kiel. They contain the subsequent formulas as well as the interim stages which are not shown in this appendix.

Recalling the assumption that in an infinitesimal unit of time no more than one agent changes its opinion and considering the concrete transition rates for the baseline model, one gets via transformation of expressions:

$$
\begin{aligned}
a_{x,1} &= \sum_{x^*}(x^* - x)w(x \to x^*) && (33)\\
&= \frac{1}{N}\left[w_{\uparrow}(x) - w_{\downarrow}(x)\right] && (34)\\
&= \frac{1}{N}\left[N(1-x)ve^{\alpha_0+\alpha_1 x} - N(1+x)ve^{-\alpha_0-\alpha_1 x}\right] && (35)\\
&= (1-x)ve^{\alpha_0+\alpha_1 x} - (1+x)ve^{-\alpha_0-\alpha_1 x} && (36)\\
&= ve^{\alpha_0+\alpha_1 x} - ve^{-\alpha_0-\alpha_1 x} - xve^{\alpha_0+\alpha_1 x} - xve^{-\alpha_0-\alpha_1 x} && (37)\\
&= 2v(\sinh(\alpha_0+\alpha_1 x) - x\cosh(\alpha_0+\alpha_1 x)) && (38)\\
&= 2v(\tanh(\alpha_0+\alpha_1 x) - x)\cosh(\alpha_0+\alpha_1 x). && (39)
\end{aligned}
$$

Note that the definition and properties of the hyperbolic functions were used to obtain the latter expression. Because $\overline{a_{x,1}}$ cannot be solved without complete cognizance of the probability distribution $P(x;t)$ a first-order Taylor-series expansion around $\bar{x}$ is considered:

$$
\begin{aligned}
\frac{d\bar{x}}{dt} &= a_{x,1}(\bar{x}) && (40)\\
&= 2v(\tanh(\alpha_0+\alpha_1\bar{x}) - \bar{x})\cosh(\alpha_0+\alpha_1\bar{x}) && (41)
\end{aligned}
$$

A second-order Taylor-series expansion around $\bar{x}$ yields:

$$
\begin{aligned}
\frac{d\bar{x}}{dt} &= \mathrm{E}\Big[a_{x,1}(\bar{x}) + a'_{x,1}(\bar{x})(x-\bar{x}) + \frac{1}{2}a''_{x,1}(\bar{x})\underbrace{(x-\bar{x})^2}_{\sigma_{\bar{x}}^2}\Big] && (42)\\
&= a_{x,1}(\bar{x}) + \frac{1}{2}\sigma_x^2 a''_{x,1}(\bar{x}) && (43)\\
&= 2v(\tanh(\alpha_0+\alpha_1\bar{x}) - \bar{x})\cosh(\alpha_0+\alpha_1\bar{x})\\
&\quad + v\sigma_x^2((\alpha_1^2 - 2\alpha_1)\sinh(\alpha_0+\alpha_1\bar{x}) - \bar{x}\alpha_1\cosh(\alpha_0+\alpha_1\bar{x})). && (44)
\end{aligned}
$$

The change of the second moment, $\frac{d}{dt}\overline{x^2}$, may be expressed in terms of the *second jump moment*, $a_{x,2}$, and the first jump moment, $a_{x,1}$ (see Lux, 1997, p. 32):

$$
\frac{d}{dt}\overline{x^2} = \overline{a_{x,2}} + 2\overline{xa_{x,1}} \qquad (45)
$$

where the second jump moment is defined as

$$a_{x,2} = \sum_{x^*}(x^* - x)^2 w(x \to x^*). \tag{46}$$

This property can be used for studying the dynamics of the variance:

$$\begin{aligned}
\frac{d\sigma_x^2}{dt} &= \frac{d}{dt}(\overline{x^2} - \bar{x}^2) && (47)\\
&= \frac{d}{dt}\overline{x^2} - \frac{d}{dt}\bar{x}^2 && (48)\\
&= \overline{a_{x,2}} + 2\overline{x a_{x,1}} - 2\bar{x}\overline{a_{x,1}} && (49)\\
&= \overline{a_{x,2}} + 2\overline{(x - \bar{x})a_{x,1}} && (50)
\end{aligned}$$

Considering the concrete opinion formation process at hand, the second jump moment becomes:

$$\begin{aligned}
a_{x,2} &= \sum_{x^*}(x^* - x)^2 w(x \to x^*) && (51)\\
&= \frac{1}{N^2}(w_\uparrow(x) + w_\downarrow(x)) && (52)\\
&= \frac{2v}{N}(\cosh(\alpha_0 + \alpha_1 x) - x\sinh(\alpha_0 + \alpha_1 x)) && (53)
\end{aligned}$$

The first-order Taylor-series expansion around $\bar{x}$ then reads (for simplification, the case $\alpha_0 = 0$ is considered) (shown by Lux, 1997, p. 33, for a similar model):

$$\begin{aligned}
\frac{d\sigma_x^2}{dt} &= a_{x,2}(\bar{x}) + 2\sigma_x^2 a'_{x,1}(\bar{x}) && (54)\\
&= \frac{2v}{N}(\cosh(\alpha_1 x) - x\sinh(\alpha_1 x)) \\
&\quad + 2\sigma_x^2(2v((\alpha_1 - 1)\cosh(\alpha_1 \bar{x}) - x\alpha_1 \sinh(\alpha_1 \bar{x})) && (55)
\end{aligned}$$

Equations (41) (instead also equation (44) could be considered which contains the second-order term) and (55) constitute a simultaneous system of differential equations. One can show (via equation (41)) that the condition for an equilibrium of the mean value dynamics

$$\frac{d\bar{x}}{dt} = 0 \tag{56}$$

yields $\overline{x}^* = \tanh(\alpha_1 \overline{x}^*)$. The steady state condition for the variance dynamics

$$\frac{d\sigma_x^2}{dt} = 0 \tag{57}$$

yields (via equation (55))

$$\sigma_x^2 = -\frac{\cosh(\alpha_1 \bar{x}) - \bar{x}\sinh(\alpha_1 \bar{x})}{2N((\alpha_1 - 1)\cosh(\alpha_1 \bar{x}) - \bar{x}\alpha_1 \sinh(\alpha_1 \bar{x})} \tag{58}$$

which for $x^* = \tanh(\alpha_1 x^*)$ reads as

$$\sigma_x^2(\overline{x}^*) = \frac{1}{2N\cosh^2(\alpha_1 \overline{x}^*) - \alpha_1} \tag{59}$$

Using the properties of the hyperbolic tangent (and studying its intersections with the first respectively third quadrant of the two-dimensional Cartesian system), it can be concluded that the system has an unique and stable steady state at 0 for $\alpha_1 \leq 1$. For $\alpha_1 > 1$ two stable steady states (which differ from 0) and one unstable steady state at 0 are observable. Nonzero values of α_0 shift the hyperbolic tangent which leads to the results described in section 3.2.3.

E Search Items used for Web Scraping

For operationalizing the concept of political performance, the number of search results for each of the four identified political areas is considered (as argued in Section 4.1.2.2). In the following search items are stated. They are expound in the way they were inserted in the search engine of http://www.genios.de/presse-archiv/.

Inner Security:

- *Deutschland und ("Innere Sicherheit" oder "Öffentliche Sicherheit" oder Kriminalität oder "Terror in Deutschland" oder "Terrorgefahr in Deutschland")*

Crime:

- *Deutschland und ("Öffentliche Sicherheit" oder Kriminalität)*

National Terrorism:

- *Deutschland und ("Terror in Deutschland")*

National Security:

- *Deutschland und ("Nationale Sicherheit" oder "äußere Sicherheit" oder "Verteidigungspolitik" oder "Sicherheitspolitik" oder "Illegale Migra*" oder "Illegale Einwander*" oder "Ireguläre Migra*" oder "Internationaler Terror*" oder Umweltkatastroph*)*

Irregular Migration:

- *Deutschland und ("Illegale Migra*" oder "Illegale Einwander*" oder "Ireguläre Migra*")*

Social Justice:

- *Deutschland und ("Soziale Gerechtigkeit" oder "Soziale Ungerechtigkeit" oder "Soziale Teilhabe" oder "Soziale Sicherung" oder Armut oder "Soziale Chance*")*

Political Scandals:

- *Deutschland und ("Politisch* Skandal*" oder "Politische Affäre*" oder "Polit-Skandal*" oder "Polit-Affäre*")*

F Crank-Nicolson Finite Difference Scheme

The idea of the Crank-Nicolson finite difference scheme is to numerically solve differential equations by approximating derivative expressions with difference quotients (see e.g. Lux, 2012, for an comprehensive overview over these finite difference schemes in one, two and three dimensions). Since the Fokker-Planck equation is a special partial differential equation (Lux, 2009, p. 642), the Crank-Nicolson finite scheme can be applied for numerical approximation. Recapitulating, the Fokker-Planck equation reads

$$\frac{\partial P(x;t)}{\partial t} = \frac{\partial}{\partial x}[C(x,\theta)P(x)] + \frac{\partial^2}{\partial x^2}[D(x,\theta)P(x)]. \tag{60}$$

$P(x;t)$ is the transitory density of x; additionally $C(x,\theta) = -A(x,\theta)$ and $D(x,\theta) = \frac{1}{2}B(x,\theta)$, where $A(x,\theta)$ and $B(x,\theta)$ are the respective drift and diffusion terms.

The *flux*, $F(x)$, is defined in order to reformulate the Fokker-Planck equation:

$$F(x) = D(x)\frac{\partial P(x;t)}{\partial x} + \left(C(x) + \frac{\partial D(x)}{\partial x}\right) P(x;t). \tag{61}$$

Standard calculations using the product rule for derivatives yields:

$$\frac{\partial P(x;t)}{\partial t} = \frac{\partial F(x;t)}{\partial x}. \tag{62}$$

Subsequently, space and time domains are discretized with grid points $x_n = x_0 + nh$ and $t_m = mk$, where $n = 0, 1, ..., N_x$ and $m = 0, 1, ..., N_t$. h is the distance in space between grid point, whereas k is the distance in time between those points.[51] As addressed before, the Crank-Nicolson scheme employs difference quotients. Different finite difference equations are conceivable, which are known as forward or backward differences. The Crank-Nicolson scheme combines both forward and backwards approximations and considers central differences at intermediate grid points. These midpoints are given by the following values in space and time:

$$x_{n+1/2} = \frac{x_n + x_{n+1}}{2} \tag{63}$$

$$t_{m+1/2} = \frac{t_{m+1} + t_{m+1}}{2}. \tag{64}$$

The transient density at space and time coordinates (x_n, t_m) is denoted by P_n^m (analogously F_n^m is defined). Accordingly, the expressions C_n and D_n indicate discrete evaluations of $C(x)$ and $D(x)$ at x_n. Then one gets:

$$P_{n+1/2}^m = \frac{P_n^m + P_{n+1}^m}{2} \tag{65}$$

$$F_n^{m+1/2} = \frac{F_n^m + F_n^{m+1}}{2} \tag{66}$$

$$C_{n+1/2} = \frac{C_n + C_{n+1}}{2} \tag{67}$$

$$D_{n+1/2} = \frac{D_n + D_{n+1}}{2}. \tag{68}$$

[51] The accuracy of the Crank-Nicolson scheme depends on h and k, since its local truncation error reads $\mathcal{O}(k^2) + \mathcal{O}(h^2)$ (cf. Lux, 2012, p. 1300).

The flux (Equation 62) can then be approximated at half-step points (m+1/2)k using the Crank-Nicolson scheme:

$$\frac{P_n^{m+1} - P_n^m}{k} = \frac{F_{n+1/2}^{m+1/2} - F_{n-1/2}^{m+1/2}}{h} \tag{69}$$

According to Equation 67, the right-hand side of Equation 69 can be rewritten:

$$\frac{F_{n+1/2}^{m+1/2} - F_{n-1/2}^{m+1/2}}{h} = \frac{1}{h}\left[\frac{F_{n+1/2}^{m} + F_{n+1/2}^{m+1}}{2} - \frac{F_{n-1/2}^{m} + F_{n-1/2}^{m+1}}{2}\right]. \tag{70}$$

Considering Equation 61, the expressions $F_{n+1/2}^m, F_{n-1/2}^m, F_{n+1/2}^{m+1}, F_{n-1/2}^{m+1}$ can be formulated as:

$$F_{n+1/2}^m = D_{n+1/2}P_{n+1/2}'^m + (C_{n+1/2} + D_{n+1/2}')P_{n+1/2}^m \tag{71}$$

$$F_{n-1/2}^m = D_{n-1/2}P_{n-1/2}'^m + (C_{n-1/2} + D_{n-1/2}')P_{n-1/2}^m \tag{72}$$

$$F_{n+1/2}^{m+1} = D_{n+1/2}P_{n+1/2}'^{m+1} + (C_{n+1/2} + D_{n+1/2}')P_{n+1/2}^{m+1} \tag{73}$$

$$F_{n-1/2}^{m+1} = D_{n-1/2}P_{n-1/2}'^{m+1} + (C_{n-1/2} + D_{n-1/2}')P_{n-1/2}^{m+1} \tag{74}$$

The derivatives contained in Equations 71 to 74 can be approximated by (cf. Lin, 2010, p. 202):

$$P_{n+1/2}'^m = \frac{P_{n+1}^m - P_n^m}{x_{n+1} - x_n} \tag{75}$$

$$D_{n+1/2}' = \frac{D_{n+1} - D_n}{x_{n+1} - x_n}. \tag{76}$$

The expressions $P_{n-1/2}'^m, P_{n+1/2}'^{m+1}, P_{n-1/2}'^{m+1}$ and $D_{n-1/2}'$ can be rewritten in an analogous way. Equations 75 and 76 (as well as the analogous equations) are then plugged in into Equations 71 to 74 which in turn are inserted into Equation 70. Equation 70 then contains the expressions $P_{n-1}^{m+1}, P_n^{m+1}, P_{n+1}^{m+1}, P_{n-1}^m, P_n^m$ and P_{n+1}^m. Thus, Equation 70 can be formulated in the following form for $n = 0, 1, ..., N_x$:

$$a_n P_{n-1}^{m+1} + b_n P_n^{m+1} + c_n P_{n+1}^{m+1} = d_n P_{n-1}^m + e_n P_n^m + f_n P_{n+1}^m, \tag{77}$$

where[52]

$$a_n = -d_n = -\frac{t_{m+1} - t_m}{x_{n+1} - x_{n-1}} \left[\frac{D_{n-1/2}}{x_n - x_{n-1}} - \frac{C_{n-1/2} + D'_{n-1/2}}{2} \right] \tag{78}$$

$$b_n = 1 + \frac{t_{m+1} - t_m}{x_{n+1} - x_{n-1}} \left[\frac{D_{n-1/2}}{x_n - x_{n-1}} - \frac{C_{n-1/2} + D'_{n-1/2}}{2} + \frac{D_{n+1/2}}{x_{n+1} - x_n} + \frac{C_{n+1/2} + D'_{n+1/2}}{2} \right] \tag{79}$$

$$c_n = -f_n = -\frac{t_{m+1} - t_m}{x_{n+1} - x_{n-1}} \left[\frac{D_{n+1/2}}{x_{n+1} - x_n} - \frac{C_{n+1/2} + D'_{n+1/2}}{2} \right] \tag{80}$$

$$e_n = 1 - \frac{t_{m+1} - t_m}{x_{n+1} - x_{n-1}} \left[\frac{D_{n-1/2}}{x_n - x_{n-1}} - \frac{C_{n-1/2} + D'_{n-1/2}}{2} + \frac{D_{n+1/2}}{x_{n+1} - x_n} + \frac{C_{n+1/2} + D'_{n+1/2}}{2} \right] \tag{81}$$

Equation 77 (for $n = 0, 1, ..., N_x$) can be written in matrix form:

$$\begin{aligned} &\begin{bmatrix} b_0 & c_0 & 0 & ... & ... & 0 \\ a_1 & b_1 & c_1 & 0 & ... & 0 \\ 0 & ... & ... & ... & ... & 0 \\ ... & ... & ... & ... & ... & 0 \\ ... & ... & ... & a_{n-1} & b_{n-1} & c_{n-1} \\ 0 & ... & ... & 0 & a_n & b_n \end{bmatrix} \times \begin{bmatrix} P_0^{m+1} \\ P_1^{m+1} \\ ... \\ P_{n-1}^{m+1} \\ P_n^{m+1} \end{bmatrix} \\ &= \begin{bmatrix} e_0 & f_0 & 0 & ... & ... & 0 \\ d_1 & e_1 & f_1 & 0 & ... & 0 \\ 0 & ... & ... & ... & ... & 0 \\ ... & ... & ... & ... & ... & 0 \\ ... & ... & ... & d_{n-1} & e_{n-1} & f_{n-1} \\ 0 & ... & ... & 0 & d_n & e_n \end{bmatrix} \times \begin{bmatrix} P_0^m \\ P_1^m \\ ... \\ P_{n-1}^m \\ P_n^m \end{bmatrix} \end{aligned} \tag{82}$$

To keep the probability mass in the rage $[x_0, x_0 + hN_x]$, the following boundary condition has to hold for every m $\in \{0, 1, ..., N_t\}$ (cf. Lux, 2012, p. 1300):

$$F_{-1/2}^m = F_{N_x - 1/2}^m = 0 \tag{83}$$

[52] Recall that $x_{n+1} - x_n = h$ and $t_{m+1} - t_m = k$ hold.

G Parameter Estimates for Different Exogenous Variables

Table 8: Parameter estimates for different variables of economic conditions.

Parameter	Model I	Model II	Model III	Model IV	Model V
α_0	-0.057	-0.053	-0.059	-0.066	-0.053
(predisp.)	(0.106)	(0.109)	(0.106)	(0.106)	(0.100)
α_1	0.814**	0.825**	0.808**	0.793**	0.829**
(majority)	(0.300)	(0.310)	(0.298)	(0.299)	(0.282)
α_2	-7.835***	-7.902***	-7.895***	-7.896***	-7.171***
(momentum)	(1.282)	(1.286)	(1.302)	(1.291)	(1.235)
v	0.021***	0.021***	0.021***	0.021***	0.022***
(flexibility)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
N	21	21	21	21	22
(agents)					
$\gamma_{unemp,\Delta}$	-0.443				
(economy 1)	(0.334)				
γ_{ip}		0.002			
(economy 2)		(0.014)			
$\gamma_{ip,\Delta}$			0.000		
(economy 3)			(8.612)		
$\gamma_{ec.perc}$				-0.319	
(economy 4)				(0.386)	
$\gamma_{ec.perc,\Delta}$					0.929
(economy 5)					(1.349)
log L	645.466	644.615	644.597	644.938	644.756
AIC	-1280.932	-1279.230	-1279.193	-1279.876	-1279.512
BIC	-1261.284	-1259.582	-1259.545	-1260.228	-1259.864

Note: Results have been estimated via numerical integration of the transient density with $\Delta x = 0.01$ and $\Delta t = 1/70$. 376 observations in all models. Parameters for the following exogenous factors were estimated. $\gamma_{unemp,\Delta}$: change of the unemployment rate. γ_{ip}: industrial production. $\gamma_{ip,\Delta}$: change of industrial production. $\gamma_{ec.perc}$: perception of the state of the economy. $\gamma_{ec.perc,\Delta}$: change of the economic perception. ***p<0.01; **p<0.05; *p<0.10 judged by the t-statistic ($\alpha_1 = 0$).

Table 9: Parameter estimates for changes of the policy variables.

Parameter	Model I	Model II	Model III	Model IV
α_0	-0.059	-0.059	-0.069	-0.058
(predisp.)	(0.106)	(0.106)	(0.110)	(0.110)
α_1	0.808**	0.808**	0.782*	0.805**
(majority)	(0.297)	(0.298)	(0.308)	(0.309)
α_2	-7.895***	-7.895***	-7.996***	-8.242***
(momentum)	(1.286)	(1.287)	(1.343)	(1.327)
v	0.021***	0.021***	0.020***	0.019***
(flexibility)	(0.002)	(0.002)	(0.002)	(0.002)
N	21	21	21	20
(agents)				
$\delta_{1,\Delta}$	0.004			
(nat. sec.)	(0.010)			
$\delta_{2,\Delta}$		0.001		
(inner sec.)		(0.003)		
$\delta_{3,\Delta}$			-0.008	
(soc. just.)			(0.009)	
$\delta_{4,\Delta}$				0.031
(scandals)				(0.016)
log L	644.684	644.643	645.003	646.368
AIC	-1279.368	-1279.285	-1280.007	-1282.736
BIC	-1259.720	-1259.637	-1260.359	-1263.088

Note: Results have been estimated via numerical integration of the transient density with $\Delta x = 0.01$ and $\Delta t = 1/70$. 376 observations in all models. Parameters for the following exogenous factors were estimated. $\delta_{1,\Delta}$: change of media coverage of national security. $\delta_{2,\Delta}$: change of media coverage on inner security. $\delta_{3,\Delta}$: change of media coverage on social justice. $\delta_{4,\Delta}$: change of media coverage on political scandals. ***p<0.01; **p<0.05; *p<0.10 judged by the t-statistic ($\alpha_1 = 0$).

Table 10: Parameter estimates for policy dummies (1st version).

Parameter	Model I	Model II	Model III	Model IV
α_0	-0.049	-0.097	-0.017	-0.114
(predisp.)	(0.109)	(0.114)	(0.106)	(0.112)
α_1	0.815**	0.758**	0.761**	0.719**
(majority)	(0.298)	(0.302)	(0.292)	(0.303)
α_2	-7.944***	-7.879***	-7.893***	-7.724***
(momentum)	(1.298)	(1.283)	(1.274)	(1.279)
v	0.021***	0.021***	0.020***	0.021***
(flexibility)	(0.002)	(0.002)	(0.002)	(0.001)
N	21	21	21	21
(agents)				
δ_1^d	-0.059			
(nat. sec.)	(0.168)			
δ_2^d		0.130		
(inner sec.)		(0.143)		
δ_3^d			-0.366*	
(soc. just.)			(0.154)	
δ_4^d				0.235
(scandals)				(0.170)
log L	644.658	645.011	646.464	645.548
AIC	-1279.315	-1280.021	-1282.928	-1281.098
BIC	-1259.668	-1260.373	-1263.280	-1261.450

Note: Results have been estimated via numerical integration of the transient density with $\Delta x = 0.01$ and $\Delta t = 1/70$. 376 observations in all models. Parameters for the following exogenous factors (dummies) were estimated. δ_1^d: media coverage of national security. δ_2^d: media coverage on inner security. δ_3^d: media coverage on social justice. δ_4^d: media coverage on political scandals. ***p<0.01; **p<0.05; *p<0.10 judged by the t-statistic ($\alpha_1 = 0$).

Table 11: Parameter estimates for policy dummies (2nd version).

Parameter	Model I	Model II	Model III	Model IV
α_0	-0.066	-0.050	-0.053	-0.083
(predisp.)	(0.106)	(0.107)	(0.102)	(0.108)
α_1	0.803**	0.819**	0.803**	0.774**
(majority)	(0.297)	(0.298)	(0.297)	(0.299)
α_2	-7.870***	-7.914***	-7.896***	-7.914***
(momentum)	(1.285)	(1.288)	(1.289)	(1.287)
v	0.021***	0.021***	0.021***	0.021***
(flexibility)	(0.002)	(0.002)	(0.002)	(0.002)
N	21	21	21	21
(agents)				
δ_1^{d2}	0.150			
(nat. sec.)	(0.286)			
δ_2^{d2}		-0.141		
(inner sec.)		(0.282)		
δ_3^{d2}			-0.103	
(soc. just.)			(0.218)	
δ_4^{d2}				0.277
(scandals)				(0.248)
log L	644.735	644.720	644.707	645.217
AIC	-1279.470	-1279.441	-1279.414	-1280.434
BIC	-1259.822	-1259.793	-1259.766	-1260.786

Note: Results have been estimated via numerical integration of the transient density with $\Delta x = 0.01$ and $\Delta t = 1/70$. 376 observations in all models. Parameters for the following exogenous factors (dummies) were estimated. δ_1^{d2}: media coverage of national security. δ_2^{d2}: media coverage on inner security. δ_3^{d2}: media coverage on social justice. δ_4^{d2}: media coverage on political scandals. ***p<0.01; **p<0.05; *p<0.10 judged by the t-statistic ($\alpha_1 = 0$).

Table 12: Parameter estimates for variables of topic-specific news (policy field of national security).

Parameter	Model I	Model II	Model III	Model IV
α_0	-0.057	-0.059	-0.050	-0.059
(predisp.)	(0.106)	(0.106)	(0.106)	(0.106)
α_1	0.809**	0.808**	0.831**	0.808**
(majority)	(0.298)	(0.297)	(0.298)	(0.298)
α_2	-7.875***	-7.895***	-7.936***	-7.895***
(momentum)	(1.288)	(1.289)	(1.292)	(1.288)
δ_1^{migr}	-0.018			
(migrat. 1)	(0.064)			
v	0.021***	0.021***	0.021***	0.021***
(flexibility)	(0.002)	(0.002)	(0.002)	(0.002)
N	21	21	21	21
(agents)				
$\delta_{1,\Delta}^{migr}$		-0.001		
(migrat. 2)		(0.049)		
$\delta_1^{i.terr}$			-0.236	
(int. terr. 1)			(0.201)	
$\delta_{1,\Delta}^{i.terr}$				0.000
(int. terr. 2)				(0.153)
log L	644.639	644.597	645.267	644.597
AIC	-1279.279	-1279.194	-1280.534	-1279.193
BIC	-1259.631	-1259.546	-1260.886	-1259.545

Note: Results have been estimated via numerical integration of the transient density with $\Delta x = 0.01$ and $\Delta t = 1/70$. 376 observations in all models. Parameters for the following exogenous factors were estimated. δ_1^{migr}: media coverage on irregular migration. $\delta_{1,\Delta}^{migr}$: change of media coverage on irregular migration. $\delta_1^{i.terr}$: media coverage on international terrorism. $\delta_{1,\Delta}^{i.terr}$: change of media coverage on international terrorism. ***p<0.01; **p<0.05; *p<0.10 judged by the t-statistic ($\alpha_1 = 0$).

Table 13: Parameter estimates for variables of topic-specific news (policy field of inner security).

Parameter	Model I	Model II	Model III	Model IV
α_0	-0.103	-0.059	-0.069	-0.061
(predisp.)	(0.110)	(0.106)	(0.106)	(0.106)
α_1	0.677*	0.808***	0.783**	0.802**
(majority)	(0.309)	(0.298)	(0.298)	(0.298)
α_2	-7.884***	-7.895***	-7.833***	-7.871***
(momentum)	(1.279)	(1.287)	(1.282)	(1.288)
v	0.021***	0.021***	0.021***	0.021***
(flexibility)	(0.002)	(0.002)	(0.002)	(0.002)
N	21	21	21	21
(agents)				
δ_2^{crime}	0.005			
(crime 1)	(0.003)			
$\delta_{2,\Delta}^{crime}$		0.001		
(crime 2)		(0.004)		
$\delta_2^{n.terr}$			0.111	
(nat. terr. 1)			(0.138)	
$\delta_{2,\Delta}^{n.terr}$				0.025
(nat. terr. 2)				(0.108)
log L	645.698	644.608	644.920	644.624
AIC	-1281.396	-1279.216	-1279.840	-1279.248
BIC	-1261.749	-1259.568	-1260.193	-1259.600

Note: Results have been estimated via numerical integration of the transient density with $\Delta x = 0.01$ and $\Delta t = 1/70$. 376 observations in all models. Parameters for the following exogenous factors were estimated. δ_2^{crime}: media coverage on crime. $\delta_{2,\Delta}^{crime}$: change of media coverage on crime. $\delta_2^{n.terr}$: media coverage on national terrorism. $\delta_{2,\Delta}^{n.terr}$: change of media coverage on national terrorism. ***p<0.01; **p<0.05; *p<0.10 judged by the t-statistic ($\alpha_1 = 0$).

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