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Echo Chambers and Their Effects on Economic and Political Outcomes

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ABSTRACT

In this review, we survey the economics literature on echo chambers. We identify echo chambers as arising from a combination of two phenomena: (*a*) the choice of individuals to segregate with like-minded ones, i.e., the creation of chambers, and (*b*) behavioral biases that induce polarization when individuals exchange beliefs in these chambers, i.e., the echo. We summarize the literatures on these two phenomena and suggest how to combine the two literatures to gain insights about the effects of echo chambers on economic and political outcomes. We end by suggesting pathways for future research and discussing policy interventions to alleviate echo chambers.

Keywords

echo chambers (/search?option1=pub_keyword&value1="echo chambers"), **information silos (/search?option1=pub_keyword&value1="information silos")**, **polarization (/search?option1=pub_keyword&value1="polarization")**, **segregation (/search?option1=pub_keyword&value1="segregation")**, **correlation neglect (/search?option1=pub_keyword&value1="correlation neglect")**, **beliefs (/search?option1=pub_keyword&value1="beliefs")**

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1. INTRODUCTION

1.1. Echo Chambers: Motivation

The term echo chamber evokes the fate of Narcissus and his estranged lover, Echo; echo chambers have been blamed in recent years for many of our society's ailments.[1] They are thought of as the engine behind phenomena such as political gridlock and constitutional crises; the rise in violence, extremism, populism, and polarization; and economic outcomes such as lower social mobility and higher inequality. In politics, they have been repeatedly blamed for increased polarization and political fragmentation. **Bishop (2009)**, in his influential book *The Big Sort*, claims that the clustering of like-minded Americans "is tearing us apart." He makes the connection between the segregation of US citizens and the political polarization and gridlock of recent decades. **Barber & McCarty (2015)** argue that the resulting polarization undermines the legislative quality in the United States. **Sunstein (2001)** suggests ways in which echo chambers were partly responsible for the impeachment of President Clinton.

Turmoil in financial markets has also been attributed to echo chambers. In their book *Animal Spirits*, **Akerlof & Shiller (2009)** argue that the business cycle is tied to feedback loops between speculative economic activities and the discussions that these activities incite. A downward movement in stock prices, for example, generates chatter and media response and reminds people of long-standing pessimistic stories and theories. These stories, newly prominent in their minds, incline them toward gloomy intuitive assessments. As a result, the downward spiral can continue: Declining prices cause the stories to spread, causing still more price declines and further reinforcement of the stories. This phenomenon is empirically examined by **Jiao et al. (2016)**.

In this review, we explore the mechanism behind echo chambers: Chambers arise when individuals segregate with the like-minded; echoes happen when individuals fail to process the information that is correlated and repeated within the chambers. The combination of segregation and communication with those with similar beliefs can then induce extremism and polarization in society. Our focus is on the two-way relationship between segregation and beliefs.

This recent interest in echo chambers stems to a large degree from the dramatic technological changes in communication and media in the past few decades. However, environments and behavior that enable echo chambers are not new and have been around for centuries. We therefore focus the review on the general tendency of people to segregate, both offline and online. In fact, the evidence about the extent of echo chambers online is not conclusive, as online communication also facilitates communication of diverse opinions. While **Quattrociocchi et al. (2016)** find that there is very little communication between groups on Facebook, and **Del Vicario et al. (2016)** find that conspiracy theories and scientific news generate homogeneous and polarized communities, **Dubois & Blank (2018)** find, in contrast, that those who are interested in politics and those with diverse media diets tend to avoid echo chambers. Moreover, while the Internet is more segregated than offline media, it is significantly less segregated than face-to-face interactions, as **Gentzkow & Shapiro (2011)** show. **Boxell et al. (2017)** show that greater Internet use is also not necessarily associated with more political polarization. Specifically, they find that polarization has increased the most among the elderly, who are the least likely to use the Internet and social media, suggesting that the role of these factors is limited.

1.2. The Mechanics of Echo Chambers

An echo chamber is a metaphor based on the acoustic echo chamber, where sounds reverberate in a hollow enclosure. The term has been used to denote the phenomenon of the amplification and reinforcement of beliefs by communication and repetition inside a closed, like-minded community. The Cambridge English Dictionary defines echo chambers as, “An environment in which a person encounters only beliefs or opinions that coincide with their own, so that their existing views are reinforced and alternative ideas are not considered.”

To understand echo chambers and their influence, our framework decomposes the term into two:

1. Chambers: Individuals segregate with those who are like-minded in terms of preferences, beliefs, or attitudes.
2. Echo: Individuals are influenced in a nonrational manner by the beliefs of those with whom they communicate in their chamber.

To understand echo chambers, we first need to understand why people belong to different chambers. Individuals make many decisions that affect which sources of information or influence they are exposed to. These could be big and important decisions that we make only infrequently, such as location or career decisions, or smaller decisions that we make more frequently, such as when we decide what to read, who to talk to, and what to search for online. Sometimes we make these decisions without thinking about how they will affect us later; for example, when moving into a new city mainly because of the salary that we could make there, we may not anticipate the effect that this will have on our future political views. Other times we make a more informed decision, such as when we think about the schools that we want to send our children to. In this case, we might anticipate the role that the school will play in the beliefs and attitudes of our children.

Once people are in their chamber, which could be physical or virtual, the patterns of communication and influence shape and affect attitudes, opinions, and even preferences. The term echo reflects the idea that, within a chamber, information might be repeated and exaggerated, but also the fact that you might hear only a selection of opinions, those that are close to your initial views. This is especially a problem when people tend to segregate with other like-minded people.

Chambers and echoes are naturally connected and coevolve. The choice of chambers affects the types of echo effects that we are exposed to. It determines what kind of information will circulate in the chamber and the patterns of repetition and correlation between information sources. In turn, our beliefs, attitudes and preferences influence our choices in terms of future segregation. If you were brought up to fear or dislike other groups in society, then chances are you will choose to live in a neighborhood where these groups are not represented. Segregation and echo effects sometimes happen simultaneously. Psychologists have explored a tendency to avoid information or beliefs that do not agree with our own (**Bessi 2016**). For example, when weeding through the infinite stream of online content, individuals’ brains simply focus on content that they like and feel close to, given their beliefs or attitudes. This also happens when people buy and consume news that they know will fit with their biased views (**Mullainathan & Shleifer 2005**).

At other times, these effects happen sequentially. We can shape our children's beliefs by the school choices that we make for them, and later, when they make their own decisions, they choose who to segregate with. Segregation decisions are sometimes made according to aspects that are independent of the unintended consequences of echo effects; one cannot fully control the types of influences that one's children will be exposed to.

1.3. Plan of the Review

The review proceeds as follows. In Section 2, we discuss the literature on segregation. We illustrate the different reasons why individuals will segregate according to their preferences or their beliefs. In Section 3, we survey the relevant cognitive biases of information processing that imply that belief updating will lead to extremism and polarization. In particular, we focus on three prominent cognitive biases: correlation neglect, selection bias, and confirmation bias. We discuss why these biases arise naturally in the context of segregation. We also examine the normative implications of these cognitive biases. In Section 4, we illustrate why feedback effects between segregation and cognitive biases are important. We focus on a dynamic model in which segregation and polarized beliefs each fuel the other. In the context of a model of labor market discrimination, we discuss the long-term sustainability of segregation, polarization, and their harmful economic outcomes. In Section 5, we conclude by suggesting avenues for future research, theoretical as well as empirical.

2. THE CREATION OF CHAMBERS: SEGREGATION

Why do people segregate with those who are like-minded? This phenomenon has long been recognized in the social sciences. Sociologists have observed that, in many contexts, people tend to connect with and favor others who are similar (for a survey of the research on homophily, see **McPherson et al. 2001**). Sociologists find that people exhibit homophily based on demographic or psychological characteristics. Social psychologists have found that this tendency to segregate with similar individuals can be triggered even with minimal distinguishing differences between people.

Within economics, the key explanation for why people segregate is the existence of complementarities. Specifically, people will choose to segregate due to complementarities in preferences or in beliefs that enable better economic or political interactions. The models that we discuss below all share this feature: from traditional Tiebout sorting models that focus on complementarities in preferences for public goods to the more recent literature that considers complementarities through peer effects that enable better cultural transmission of preferences. Similarly, complementarities in beliefs exist when transmission of beliefs is important, when people wish to protect their belief system, or when individuals prefer to interact with those with similar beliefs to facilitate cooperation and communication. As we discuss below, people often misperceive these complementarities, and thus segregation can become excessive.

In this section, we first discuss the increase in segregation in recent decades and how it is linked to political and economic outcomes, such as political polarization and income inequality. We then put forward models that illustrate why individuals segregate with the like-minded. We describe segregation first according to preferences and then according to beliefs. Both models are important for the purpose of understanding echo chambers. The type of segregation, preference versus belief based, has different implications for dynamic analysis as preferences are typically fixed, while beliefs are relatively easy to change and mold.[2]

2.1. The Rise of Segregation and Its Consequences

The rise in the use of social media has certainly refueled the interest of scientists in the causes and consequences of segregation. For example, **Bakshy et al. (2015)** analyze how online networks influence exposure to perspectives that cut across ideological lines. They show that individuals' choices play an important role in limiting exposure to cross-cutting content. **Gilbert et al. (2009)** look at blogs and find that agreement outnumbers disagreement in blog comments by more than three to one.[3] However, offline segregation is as important, if not more. **Gentzkow & Shapiro (2011)** analyze the impact of the Internet on the segregation of information consumption based on aggregate and individual data. They use an isolation index to define the level of ideological segregation. They find that the Internet is more segregated than offline media but significantly less segregated than face-to-face interactions. They show that individuals' communication networks are segregated across work colleagues, friends, family, and neighborhood associations, according to socioeconomic parameters and political preferences.[4]

Indeed, empirical studies suggest that physical, offline segregation has increased in Western societies in the past decades. For example, in the United States, since 1970, residential segregation has been on the rise.[5] Moreover, this trend in residential choices seems to be correlated with important economic and political variables. **Reardon & Bischoff (2011)** study the relationship between income inequality and segregation according to income in the United States. They find that residential segregation and income inequality have been following a remarkably similar trend during the period 1970–2000. **Chetty et al. (2014)** look at the relationship between segregation in the United States and social mobility. They show large gaps between different localities, so that the more segregated areas have much lower social mobility. **Alesina & La Ferrara (2005)** survey the large literature that studies the relationship between segregation and economic outcomes such as growth. Relatedly, a large theoretical and empirical literature has also analyzed the effects of segregation according to ethnic groups on different measures of social cohesion, conflict, and social attitudes (see **Field et al. 2008**, **Putnam 2007**, **Sturgis et al. 2011**, **Uslaner 2012**).[6]

The effects of segregation (e.g., income segregation) on political outcomes have also been explored; **Bishop (2009)** coined the term the big sort to describe the patterns of residential segregation in the United States and their effects on polarization of political beliefs. According to **McCarty et al. (2008)**, there is a close correlation between economic inequality and polarization in the United States; specifically, increased growth in the top of the income distributi

on leads to higher inequality and demand for conservative legislators. In turn, this increases polarization and dam pens the political response, which further increases inequality. Indeed, **Bartels (2008)** and **Gilens (2012)** find that policies more often reflect the preferences of the wealthy than of those at the bottom of the income distribution.

Segregation can also affect economic opportunities in life through the availability of knowledge and information. **C alvó-Armengol & Jackson (2004)** show how segregation of individuals into different networks can benefit some a nd not others, as information about job opportunities flows only to selective network members. A similar mechani sm underlies the findings of **Curtis & Warner (1992)**, who study the benefits of the so-called old boys network. On e way of creating these types of networks is through school choices; school choices tend to be persistent and affect ed by parental background and beliefs. **Evans & Tilley (2012)** find that 43% of privately educated individuals in the United Kingdom who have children have sent them to private schools, nearly five times the rate for parents who we nt to state schools. Importantly, the different attitudes and beliefs about school graduates have real behavioral im plications for labor markets through occupational choice and employment decisions. For example, in the United Ki ngdom, male private school graduates are up to 10% more likely to be hired to top jobs than male state school grad uates with the same grades from the same university.[7] Indeed, 50% of private school students believe that people who attend their school will be very successful, compared to 9% of state school pupils (see **Nasiroglu 2016**). Simila rly, in the United States, private schools lead the tables in terms of placements at top universities, even though stu dents from private schools or selective state schools perform no better than those in standard state schools in achi evements tests.[8]

Above, we establish that segregation is an important aspect in determining political and economic outcomes; in thi s section, we proceed to explain why it happens. Below, we discuss the reasons for segregation with like-minded in dividuals, first according to shared preferences and then according to beliefs and attitudes. Our plan is to illustrate how segregation with like-minded individuals can affect beliefs and create the consequences discussed above.

2.2. Preference-Based Segregation

Many traditional models in economics consider sorting according to preferences. For example, Tiebout models, ori ginating from the work of **Tiebout (1956)**, consider environments in which communities choose the level of local p ublic goods provision and finance them via taxation. In this framework, those who care more about a particular set of goods are better off congregating in their own locality. Thus, preference complementarities can fuel segregation. Relatedly, club good models, as developed by **Iannaccone (1992)**, show how individuals sort themselves into religi ous groups to enjoy complementarities in the production of religious goods such as rituals and communal praying.

Recent contributions to this literature highlight the equilibrium effects that arise when individuals segregate accor ding to taste or income. **Bénabou (1996)** looks at the effect of segregation on growth. In his paper, agents interact t hrough local public goods, such as school funding, and economy-wide linkages, such as knowledge spillovers. Sort ing families into homogeneous communities often minimizes the cost of existing heterogeneity, but mixing increas es the speed at which heterogeneity is reduced. Integration therefore tends to slow down growth in the short run y

et raise it in the long run (see also **Durlauf & Seshadri 2017**). **Baccara & Yariv (2016)** study the formation of peer groups in an environment where each group can produce two distinct public goods that only give utility to people within a group. The agents are free to choose the size of the group and types of group members, along with their choice of public good contribution. When contribution costs are low relative to connection costs, mutually optimal groups are relatively homogeneous (see also **Peski 2008**). Relatedly, **Goyal et al. (2017)** look at environments in which individuals prefer to coordinate with others but differ in their preferred action, and examine what groups are formed. The theoretical model predicts different possibilities, some in which more sorting occurs and some in which individuals coordinate on a single action; their experiments show, however, that agents are more likely to inefficiently differentiate themselves.

2.2.1. Complementarities in networks: information flows and learning.

The literature on social networks has produced many results pertaining to the study of segregation (for a survey, see **Jackson 2011**). One strand of this literature focuses on complementarities in the ability to communicate with others. From the literature about strategic communication (**Crawford & Sobel 1982**), we know that the level of communication is inversely related to the distance in preferences. As a result, we expect high levels of homogeneity in communities in terms of preferences to imply higher levels of information sharing. This kind of complementarity is formalized by **Galeotti et al. (2013)**, who study a model of multiplayer communication in networks. Privately informed decision makers have different preferences about the actions that they take and communicate to influence each others' actions in their favor. **Galeotti et al. (2013)** show that clusters of individuals with similar preferences will facilitate information transmission and will create complementarities in information and thus efficient decision making.

Similarly, **Giovanniello (2018)** shows how people choose to exchange information with like-minded individuals to the effect that chambers are created. Specifically, she shows that, while it is necessarily the case that information will travel through networks of those with similar preferences, this is not sufficient to create a chamber. She considers a model in which voters can be ideologically close but still biased toward different parties. In that case, information, e.g., about the quality of political candidates, will not be exchanged between such voters. Thus, voters have to be both close in their preferences and biased in the same direction to exchange information.[9]

The papers discussed above, while focusing on preference-based segregation, show that this type of segregation also has implications for what information is shared and thus for the beliefs of individuals in the network.

2.2.2. Cultural transmission of preferences.

Another important channel that encourages individuals to segregate is cultural transmission, first analyzed by **Bisin & Verdier (2001)**. Specifically, if parents realize that their offspring's preferences are affected by the community and not just by upbringing, then they may choose to live in neighborhoods where others share the same preferences. Thus, complementarities arise through peer effects on transmission of values. **Advani & Reich (2015)** show how cultural transmission may hinder economic activity and foster segregation. They assume that individuals face a tra

de-off between cultural and economic incentives: Individuals prefer to maintain their cultural practices, but doing so can inhibit interaction and economic exchange with those who adopt different practices. Advani & Reich find tha t a small minority group will adopt majority cultural practices and integrate. In contrast, minority groups above a c ertain critical mass may retain diverse practices and may also segregate from the majority. They also test their pred ictions using data on migrants to the United States in the era of mass migration and find support for the existence o f a critical mass of migrants above which the social structure in heterogeneous populations changes discretely tow ard cultural distinction and segregation. **García-Alonso & Wahhajz (2018)** analyze the dynamic effects of an increa se in cultural diversity within a population, due, for example, to an immigration wave. They analyze how the pace o f change affects the level of segregation.

2.3. Belief-Based Segregation

In this section, we consider the mechanisms behind why individuals who share similar beliefs might segregate toge ther. These mechanisms and the segregation that they create feed into our dynamic models of echo effects in Secti on 3.

2.3.1. Cultural transmission of beliefs.

We see above that, when parents consider the values that they transmit to their children, they may be inclined, due to peer effects, to segregate with individuals who share similar cultural traits. A similar argument can be applied to segregation according to beliefs rather than according to preferences. To give an example, imagine the thought pro cess of parents who are deciding to which school to send their child. There might be many trade-offs involved in thi s decision, depending on the characteristics of these schools. However, one thing that the parents might have in mi nd is how each school will affect their child's beliefs, through socialization with friends or through teachers (for exa mple, one school might be secular, while the other is a religious school). The parents might be worried that their ch ildren's beliefs are amenable to influence. **Levy & Razin (2017)** incorporate this scenario into a model that studies segregation in schooling (private versus state) and labor market discrimination. They show that the parents' dilem ma leads to segregation into different schools, according to parents' beliefs about the merits of education in the pri vate versus the state school, and discrimination in the labor market.

2.3.2. Segregation to maintain beliefs: religious segregation.

A related reason for segregation is that individuals or groups may seek to actively avoid knowledge or beliefs that a re counter to their own. One important environment in which this can arise is religious segregation. Religion plays an important role in the observed patterns of residential location. **Berman (2000)** and **Razin (2018)** document ho w the ultra-Orthodox Jews in Israel segregate away from the secular Jewish population both physically and throug h their lack of participation in the labor market and military service. In present-day London, **Brimicombe (2007**, p. 884) finds that "The landscape of religion is found to be more highly segregated in contrast to the landscape of eth nicity." **Field et al. (2008)** find that more than 70% of the population in Ahmedabad in 2002 lived in completely ho mogeneous neighborhoods.

While religious individuals may segregate for many reasons, for example, due to complementarities in behavior, one of the most important reasons is the desire to maintain religious beliefs. **Levy & Razin (2012)** suggest an informational reason for segregation: Religious beliefs might be eroded by observing others' behaviors or beliefs. Specifically, **Levy & Razin (2012)** model a theology of reward and punishment in relation to behavior in the social sphere. In particular, the theology of the religion makes a connection between the actions of a deity and the behavior of individuals in their day-to-day social interactions. Holding these beliefs allows the religious to sustain cooperative outcomes that may not be available otherwise. However, religious beliefs are not static, and they may evolve given the personal experiences of the believer. Religious beliefs must be maintained and protected if they are to be sustained in the long run. To sustain religious beliefs, individuals should be guarded from observing behaviors and outcomes that do not agree with their belief system. By segregating in closed communities, the religious can sustain their beliefs by not observing the (possibly good) fortunes of those who sin.

Attempts to protect communities from information can be seen more generally when organizations wish to protect a belief system that may not be immune to updating in the face of real events. Censorship of books, media, or Internet content is familiar in many authoritarian regimes, creating de facto segregation according to beliefs.

2.3.3. Segregation due to prejudice about others' behavior.

Segregation may also arise when the beliefs of individuals are prejudiced against a particular population, and individuals segregate to avoid interaction with this population. As a result, people with different beliefs or prejudices segregate, as they all share a similar incentive to do so. **Bradford & Kelejian (1973)** were the first to document what they call the White flight from inner-city neighborhoods and toward predominantly White areas; **Cantle & Kauffman (2016)** document dynamic patterns in the United Kingdom from 2001 to 2011 and show strong evidence for this concept. They observe that, "Between 2001 and 2011 the White British population in England reduced as a percentage of the total population from 86.8% to 79.8%—a decrease of 8%. Although there was a decrease in the proportion of the population who were white in most areas, the decrease was much greater in the areas which had a low proportion of White British in 2001 than in areas which had a high proportion.… This does indicate support for 'more mixing and more clustering,' but they are not equivalent trends, the clustering is noticeably more marked." **Kaufmann & Harris (2015)** find that, in London between 2001 and 2011, many White British people left the city, most of whom moved to Whiter areas; Whites left London at three times the rate of minority individuals.

While the reasons for this type of segregation could be correlated with income inequality, as richer White individuals may move to bigger houses away from inner cities, there is also direct evidence about different views that individuals hold conditional on their location choice. Causality is, of course, not clear-cut; it may be that individuals' views change for the worse after they have already moved. However, a more direct explanation is that the people who moved are the ones with more prejudiced beliefs. After they move, the information that they exchange with each other in their daily interaction might change their beliefs to be even more prejudiced. Indeed, **Dustmann & Preston (2007)** find strong evidence that racial or cultural prejudice is an important component to attitudes toward immigr

ation in their study using the British Social Attitudes Survey. Similarly, **Vertier & Viskanic (2018)** show that, in areas in France in which refugees were settled (which were randomly assigned), locals had more positive views on foreigners and were less likely to vote for the Front National, the extreme right-wing anti-immigration party. These results provide evidence for the existence of prejudice.[10]

Levy & Razin (2018b) consider an environment in which individuals in the home society are prejudiced against foreign immigrants and are suspicious of their ability to cooperate in economic interactions or of their productivity. As a result, interactions between home-society individuals and immigrants are inefficient, which makes it worthwhile for prejudiced individuals to segregate away from immigrants. Specifically, it is those with the most prejudiced beliefs against immigrants that will segregate away.

We discuss in this section how individuals are motivated to segregate with like-minded people. While the traditional literature has looked at segregation according to preferences, segregation according to beliefs or attitudes has been only recently explored. Within these chambers of like-minded individuals, echoes can easily be created; this is the topic of the next section.

3. THE CREATION OF THE ECHO: BEHAVIORAL BIASES IN BELIEF UPDATING

A large body of literature shows that segregation affects beliefs. In social psychology, contact theory posits that beliefs are affected by segregation through the different interactions between people from different groups (see **Allport 1954**, **Hewstone 2009**, **Hewstone & Brown 1986**, **Lowe 2018**, **Pettigrew & Tropp 2006**). **Boisjoly et al. (2006)**, **Algan et al. (2015)**, **Burns et al. (2016)**, and **Vertier & Viskanic (2018)** show how interacting with individuals from different groups affects one's attitudes toward those groups. **Kaufmann & Harris (2015)** find significant effects of segregation on attitudes about the benefits of immigration.

How beliefs are affected by others' beliefs about us or by observing other pieces of information is, of course, a more general problem and not specific to segregation. Throughout each day, we are exposed to large amounts of information, some of which we seek actively and some that we consume more passively. How good are we at aggregating all of these pieces of information? In economics, the traditional assumption of rationality implies that individuals are efficient in gleaning information from their surroundings. However, both political scientists and psychologists have typically taken a more pessimistic view of our ability to process information. In political science, for example, a large literature documents the incompetency of voters in collecting and processing information. Voters have been shown to be poorly informed about what they vote on (**Bartels 1996**, **Campbell et al. 1960**, **Delli Carpini & Keeter 1996**, **Kinder & Sears 1985**) and to use the information that they do have incorrectly (**Achen & Bartels 2004**, **Healy et al. 2010**, **Huber et al. 2012**, **Lau & Redlawsk 2001**, **Leigh 2009**, **Wolfers 2007**). As **Bartels (1996**, p. 195) writes:

> One of the most striking contributions to the political science of half a century of survey research h as been to document how poorly ordinary citizens approximate a classical ideal of informed demo cratic citizenship.

Psychologists have also taken a grim view of individuals' abilities to make sense of the information presented to th em. A good example of this is the strong response to the rationality assumption in economics in a series of papers b y Daniel Kahneman and Amos Tversky (e.g., **Tversky & Kahneman 1981**). These papers reveal different biases that impact individuals who are exposed to different pieces of information (see **Rabin 1998**). More recently, these result s have spurred new research in economics, particularly in behavioral economics and bounded rationality, that inco rporates some of these biases into economic models.

In this section, we survey a few of these cognitive biases as they relate to the creation of echo chambers. A good sta rting point to think about this issue would be to imagine yourself in your daily interactions with the people around you. You spend your day reading newspapers and online news content, talking to friends and family, and talking to colleagues at work, and you might spend some time on social networks. Daily, this might amount to large quantitie s of information that you may want to sit back and process before you go to bed.

If individuals are rational and have correct beliefs about the nature of interactions in their network, then no echo e ffects will exist. On average, people will hold correct beliefs, and there will be a limit to how polarized or extreme b eliefs might be. In this survey, instead, we are interested in the types of cognitive biases that might arise when peo ple interact and glean information within their chambers.

A few aspects of your interactions outlined above imply that it is not easy to aggregate all of this information prope rly. For one thing, the network of interactions in your social milieu might imply that you cannot really follow where the information that a friend is telling you came from. For example, a friend, Amir, might be telling you something. However, Amir might have also talked with Neeve, and you told Neeve something similar the previous day. How th en should you weigh what Amir tells you? Often, in these situations, we might err by simply treating what Amir tells us as an independent piece of information. This is what we term correlation neglect.

However, there is another problem that could make your inference complicated; this problem is related to the com position of your social network. In particular, as we see above, one reason that you like talking to Amir or Neeve is t hat they are very much like you. Therefore, Amir and Neeve will most likely say things that agree with your own vie ws. In these cases, some individuals might err by overweighing what Amir and Neeve say due to a selection bias.

Finally, every now and then, perhaps at your workplace, you encounter other individuals, such as Francesco, that h ave very different things to say than do Amir and Neeve. In these situations, do you fully take into consideration wh at Francesco says? Psychologists have documented a confirmation bias in which not only will you put too low a wei

ght on what Francesco says, but you might also become stronger in your opposing conviction after the encounter.[1]

[1]

The key mechanism that we explore in this review is how segregation and cognitive biases work together to create the effects of echo chambers. For this reason, we focus on these three cognitive biases, which are tightly related to the features of segregation. Below, we discuss the mechanisms through which cognitive biases exacerbate polarization in the presence of segregation.

3.1. A Basic Model to Introduce Biases

The simplest way to think of the cognitive biases that we consider is to assume that individuals do directly observe the information of others but have difficulties interpreting this information. Consider the following model. Individuals try to learn about the state of the world, ω, which could be low or high, $\omega \in \{l, h\}$. They all have a common prior that the states are equally likely.

For example, the state could correspond to the fate of the United Kingdom after Brexit, where a low state implies low growth, and a high state implies high growth. Knowing the state informs the group about its policies. In the Brexit example, information about the state will inform voters how to vote in a referendum about Brexit.

Individuals start with some beliefs about the states. Let q^i denote the belief of individual i that the state is high, with $1 - q^i$ denoting the belief of that individual that the state is low. The individual's belief could have been generated by receiving a signal $s \in \{l, h\}$ with an accuracy $\Pr(s = h|\omega = h) = \Pr(s = l|\omega = l) = q \geq 1/2$. In this case, the Bayes' rule implies that receiving a signal h will yield the (high) belief $q = \Pr(\omega = h|s = h)$, and receiving a signal l will yield the (low) belief $\Pr(\omega = h|s = l) = 1 - q$. For example, this signal could be generated by reading an informative newspaper article about the effects of Brexit on the United Kingdom labor market.

When individuals interact in their social network, they share their opinions with each other. To focus attention on cognitive biases, rather than any strategic considerations, let us assume that individuals share their true beliefs with each other. When exposed to these different opinions, how do individuals update their beliefs? This is what we consider in the sections below. Note that, while we focus on three biases that relate to the creation of echo chambers, correlation neglect, selection bias, and confirmation bias, this is in no way an exhaustive list of relevant biases. Alternatives include models in which individuals manipulate their own beliefs, as in the motivated beliefs literature (**Bénabou 2013**; **Bénabou & Tirole 2011**, **2016**; **Le Yaouanq 2018**), which we discuss in Section 3.8.

3.2. Correlation Neglect

As discussed above, there are many reasons to believe that, in social networks, individuals' sources of information are correlated in complex ways. Correlation neglect is a cognitive bias where individuals simply ignore such correlation structures. Therefore, individuals with correlation neglect treat all sources of information as conditionally independent. This is a simple way to combine information sources into a unique prediction.

A recent empirical and experimental literature has shown that, in complex environments, decision makers indeed ignore correlations to some degree. For example, **Ortoleva & Snowberg (2015)** use data from the 2010 Cooperative Congressional Election Study to show how correlation neglect shapes political views. **Eyster & Weizsäcker (2011)**, **Kallir & Sonsino (2009)**, **Bai et al. (2015)**, and **Enke & Zimmermann (2019)** provide experimental evidence for correlation neglect. **Jiao et al. (2016)** provide evidence for correlation neglect in stock prices that are discussed in online discussion groups.[12]

Below, we formally define correlation neglect in the context of our model. To define correlation neglect, assume that N individuals exchange their beliefs q^i. In reality, these beliefs might stem from a complex web of correlation relations. However if individuals neglect this correlation, then their new correlation neglect belief, q^{CN}, will be uniquely determined as

$$q^{\mathrm{CN}} = \frac{\prod_{i=1}^{N} q^i}{\prod_{i=1}^{N} q^i + \prod_{i=1}^{N} (1 - q^i)}. \tag{1.}$$

Thus, for example, if a share α of N individuals had received the h signal and has belief $q > 1/2$, and a share $1 - \alpha$ had received the l signal and has belief $1 - q < 1/2$, then, if all exchange their beliefs, we have

$$q^{\mathrm{CN}} = \frac{q^{\alpha N}(1-q)^{(1-\alpha)N}}{q^{\alpha N}(1-q)^{(1-\alpha)N} + (1-q)^{\alpha N}(q)^{(1-\alpha)N}},$$

with $q^{\mathrm{CN}} \to 1$ for a large N and $\alpha > 1/2$, and $q^{\mathrm{CN}} \to 0$ for a large N and $\alpha < 1/2$. If, for example, the true information structure that had generated these initial beliefs involves correlation, so that all those that received the same signal had the same information source, then postcommunication beliefs would become excessively extreme.

More generally, it is easy to see from **Equation 1** that the belief updating function satisfies the following properties. First, confident individuals are very persuasive. For example, if $q^i = 1$ (or alternatively $q^i = 0$) for some i, so that some individual has extreme beliefs, then the individual fully convinces all others. Second, beliefs are monotone: They increase in peers' beliefs. Finally, belief updating can also exhibit extremism and polarization: For a set of beliefs where all are higher (lower) than one-half, updated beliefs would be higher (lower) than the maximum (minimum) belief in the set. For example, if $q^i > 1/2$ for all i, then the correlation neglect belief q^{CN} will satisfy $q^{\mathrm{CN}} > \max_i q^i$. If $q^i < 1/2$ for all i, then $q^{\mathrm{CN}} < \min_i q^i$. Thus, observing a selection of similar beliefs will induce extreme beliefs. Moreover, if society segregates into two groups, one made up of people who have high beliefs and the other made up of those with low beliefs, then polarization will arise.

The above definition captures individuals who fully neglect the possibility of correlation. Some individuals might be concerned about the correlation neglect that is implicit in this naive Bayes approach or simply have misspecified models of the correlation. **Ellis & Piccione (2017)** provide an axiomatic characterization of individuals that cannot

account for correlation (or complexity, in their terminology). **Levy & Razin (2018a)** propose a model in which individuals neglect correlation to some degree. Specifically, if we think of a modified correlation neglect belief that allows for some correlation, then **Levy & Razin (2018a)** show that it can be written as

$$q_{\lambda}^{\mathrm{CN}} = \frac{\lambda_h \prod_{i=1}^{N} q^i}{\lambda_h \prod_{i=1}^{N} q^i + \lambda_l \prod_{i=1}^{N} (1-q^i)} = \frac{\lambda_h q^{\mathrm{CN}}}{\lambda_h q^{\mathrm{CN}} + \lambda_l (1-q^{\mathrm{CN}})}, \quad \textbf{2.}$$

where λ_h, λ_l are parameters that capture degrees of correlation across the information in the different states, high or low. However, when $N \to \infty$, in many environments, we would have $q^{\mathrm{CN}} \to 1$ or $q^{\mathrm{CN}} \to 0$. If, in addition, λ_h, λ_l are bounded, i.e., $\lambda_h, \lambda_l > 0$, and $\lambda_h, \lambda_l < \infty$, we have $q_{\lambda}^{\mathrm{CN}} \to q^{\mathrm{CN}}$. In other words, correlation neglect can arise when we face big data, the naive interpretation of which according to the q^{CN} is sufficiently precise (but not necessarily correct). Thus, in complex environments, full correlation neglect is likely to arise. Even if individuals consider some degree of correlation, a large data set will overwhelm this, and they will behave as if they have full correlation neglect.[13]

3.3. Selection Bias

When the information that you are exposed to is not randomly assigned, selection bias might arise. For example, suppose everyone in your vicinity has $q^i > 1/2$. You might take this observation to mean that there is large evidence that the state is probably high. However, in reality, your observation might be a result of the fact that you and the people around you all chose to interact with one another. If the latter is the case, you should decrease the weight that you put on the opinions of those close to you. Failure to do this to the right degree is termed selection bias, which we now define in the context of our model.

Below, we introduce a formulation of selection bias used by **Levy & Razin (2017)** to model socialization in schools. In the context of our simple information model, suppose that all those with the high signal h and thus the high beliefs q, a share α among the N individuals, communicate only between themselves, and similarly, all with the low signal l and thus low beliefs $1-q$, a share $1-\alpha$, communicate only with each other. Selection bias arises because individuals do not take this segregation into account. Rather, individuals assume that the opinions that they see were generated uniformly from opinions in the population. In these two groups, beliefs involving selection bias will differ and will depend on the signal l or h:

$$q^{\mathrm{SB}}(h) = \frac{q^{\alpha N}}{q^{\alpha N} + (1-q)^{\alpha N}} > q^{\mathrm{SB}}(l) = \frac{(1-q)^{(1-\alpha)N}}{(1-q)^{(1-\alpha)N} + (q)^{(1-\alpha)N}}. \quad \textbf{3.}$$

Frick et al. (2018) use a similar notion of selection bias, which they term assortativity neglect, and provide a theoretical foundation for it as a model of misperception in a segregated society.

Note that selection bias is related to correlation neglect and will thus give rise to similar dynamics. In particular, within each group, we will have a process of extremism in which beliefs become more extreme when individuals exchange information. The different composition of groups will result in polarization of opinions across groups. To under

stand exactly the patterns of extremism and polarization, one would have to combine the analysis of endogenous s egregation discussed in Section 2 with the evolution of beliefs modeled in this section. This is the topic of Section 4.

3.4. Confirmation Bias

While selection bias arises because of our choices of with whom to interact, confirmation bias arises from the way i n which we interpret what we see. Confirmation bias refers to the propensity to ignore or misinterpret information that runs counter to one's own belief. One of the first experiments that is associated with confirmation bias is the o ne by **Lord et al. (1979)**. They show that individuals exposed to the same information can polarize their beliefs in d ifferent directions. Thus, information must be interpreted differently.[14]

Using our model, we can represent confirmation bias in the following way. In a sense, for confirmation bias to arise, we do not need segregation per se, as the segregation arises cognitively, through the misinterpretation of certain pi eces of information. Suppose again that a share α observed the signal h and have high beliefs $q > 1/2$, and that a sh are $1-\alpha$ observed the low signal l and have low beliefs $1-q < 1/2$. Suppose that the individual who has posterior q , so they had observed the signal h, as in the work of **Rabin & Schrag (1999)**, misperceives low posteriors as high o nes with probability $\beta > 0$. Thus, given such confirmation bias and their signal h, they end up with the following be lief:

$$q^{\mathrm{CB}}(h) = \frac{(q)^{(\alpha+(1-\alpha)\beta)N}(1-q)^{(1-\alpha)(1-\beta)N}}{(q)^{(\alpha+(1-\alpha)\beta)N}(1-q)^{(1-\alpha)(1-\beta)N} + (1-q)^{(\alpha+(1-\alpha)\beta)N}(q)^{(1-\alpha)(1-\beta)N}}.$$

In contrast, an individual with posterior $1-q$ who had observed the signal l will interpret high posteriors as low one s with probability β, and thus will end up with beliefs

$$q^{\mathrm{CB}}(l) = \frac{(q)^{\alpha(1-\beta)N}(1-q)^{((1-\alpha)+\alpha\beta)N}}{(q)^{\alpha(1-\beta)N}(1-q)^{((1-\alpha)+\alpha\beta)N} + (1-q)^{\alpha(1-\beta)N}(q)^{((1-\alpha)+\alpha\beta)N}}.$$

Again, when N is large enough, we have $q^{\mathrm{CB}}(h) \to 1$, and we have $q^{\mathrm{CB}}(l) \to 0$ when β is large enough (compared with α). Thus, confirmation bias is sufficient to create two chambers with polarization.

In this case, segregation is not physical, but rather is created by selective interpretation of information: If, when bro wsing online, individuals interpret the content in their own way, by way of confirmation bias, then they are de facto segregating away from others who interpret information differently. This makes individuals become more convince d of their views and thus creates polarization.

3.5. Environments that Facilitate Biases

A question one may want to ask is when we should expect the above biases to arise. For example, when an individu al reads news from different outlets, online or offline, if this news is made up of truly independent pieces of inform ation, then the individual still behaves optimally even if they suffer from correlation neglect. Therefore, to understa

nd the relevance of correlation neglect, we need to understand the sources of correlation in our environment. In thi s section, we discuss several environments in which we expect the above biases to be more prominent.

3.5.1. Online replication of news.

One avenue through which correlation neglect might arise is the replication of online (as well as offline) news cont ent. There is a good reason to think that consumers of news media are likely to suffer from correlation neglect to so me extent. For one thing, news items are constantly copied and repackaged across outlets. **Cagé et al. (2017)** stud y copyright in news media, following pieces of news as they trickle through different outlets, including social medi a. They document how pieces of news are often copied multiple times and across different outlets. In addition, the y find that only 32% of online content is original. Still, despite the prevalence of copying, media outlets rarely name the sources that they copy. Thus, readers are exposed to repeated news, potentially without being aware of it.

News aggregation websites are another example of how media is copied and the sources of information made hard er to trace. These sites publish their own news as well as links to similar news in other sites, and therefore expose i ndividuals to repetition of news.

3.5.2. Exposure to multiple sources of information.

It is also clear that people read multiple sources of information. Individual-level survey data on 18 countries from R euters Institute for the Study of Journalism show that the average news consumer uses approximately five news so urces per week. More generally, **Kennedy & Prat (2017)** and **Prat (2018)** document the consumption patterns of ne ws consumers and show that individuals use multiple outlets to learn about news (see also **Pew Res. Cent. 2012**). Communication among individuals also implies that, indirectly, they are exposed to even more sources.

3.5.3. Segregation and complexity of communication in networks.

As we discuss in Section 2, segregation, be it physical or online, is an inherent trait of society. Segregation patterns are very complex and imply that individuals might have multiple social networks to which they belong. This compl exity implies that it is hard to follow both the selection that is involved in what you are exposed to and the correlati on structures between the pieces of information that you consume.

Repeated communication in groups and more generally in networks is often considered to impose large informatio nal requirements on individuals. Individuals may be unaware of the structure of the network, so that, while they kn ow with whom they communicate, they might not know their neighbors' neighbors. This implies that it may be ver y difficult to trace the path that a piece of information takes in an environment with repeated communication.

The network literature has typically taken one of two avenues. The first is the fully rational approach, which assum es that individuals are fully aware of the network and the equilibrium and update using the Bayes' rule (see **Acemo glu et al. 2014**). The second is to assume that individuals follow a particular heuristic when updating. A leading exa mple is the DeGroot heuristic, where individuals average their and others' beliefs, as in the work of **Golub & Jackso n (2010)** and **De Marzo et al. (2003)**. **De Marzo et al. (2003)** analyze a model of multiple rounds of communication

(in a network) when players have correlation neglect. They show that multiple rounds of communication together with correlation neglect imply that views will become concentrated on a one-dimensional conflict. **Jackson (2011)** provides a survey of social networks and information diffusion in networks.

These avenues are two polar ways to model information diffusion, one based on full rationality and the other base d on an ad hoc heuristic. A third avenue, which **Levy & Razin (2018c)** explore, is to account for correlation neglect. Note that the DeGroot heuristic does not lead to polarization of beliefs, as beliefs are averaged; however, using q^{CN} as above leads to polarization and extreme beliefs.[15]

In the literature on social learning in networks, some have identified correlation neglect with a redundancy bias (**G agnon-Bartsch & Rabin 2016**), whereas **Eyster & Rabin (2010)** use a form of neglect of one's action from the infor mation of others in their naive herding model. **Bohren (2016)** also considers model misspecification in the context of herding (see also **Guarino & Jehiel 2013**, **Mueller-Frank & Neri 2013**).

3.5.4. Machine learning and artificial intelligence.

Online browsing has become more and more complex through the years. Today, the algorithms used by search eng ines and other stakeholders on the Internet have implications for the creation of online echo chambers. The term fi lter bubbles is used to describe the propensity of search engines to match individuals with content that would app eal to them. New machine learning and artificial intelligence (AI) algorithms have been shown to amplify existing bi ases in our society. Recent examples are the experience of Microsoft with Tay, a Twitter chatbot, and the experimen t of Massachusetts Institute of Technology researchers with an AI algorithm called Norman, showing how very diffe rent outcomes result from feeding the application with different information (see **O'Brien 2018**). Moreover, algorit hms of news and content aggregation, which are complex and nontransparent, muddy the waters in terms of our u nderstanding of the correlation structures behind the multitude of pieces of information we are exposed to.

Bakshy et al. (2015) analyze how online networks influence exposure to perspectives that cut across ideological li nes. They examine how 10.1 million US Facebook users interact with socially shared news. They directly measure i deological homophily in friend networks and examine the extent to which heterogeneous friends could potentially expose individuals to cross-cutting content. They then quantify the extent to which individuals encounter compara tively more or less diverse content while interacting via Facebook's algorithmically ranked News Feed and further s tudy users' choices to click through to ideologically discordant content. They show that both the algorithmic ranki ng and, to a larger degree, individuals' choices played a role in limiting exposure to cross-cutting content.

3.5.5. Concentration of ownership implies correlation.

The intervention of owners in the editorial decisions of their news outlets has always been an important issue in th e debate about the regulation of the media industry.[16] It is one of the reasons behind a common call to have indep endent editorial boards. For example, in the United Kingdom, in June 2017, the culture secretary decided to refer 2 1st Century Fox's £11.7 billion bid to seize full control of satellite broadcaster Sky to the Competition and Markets A

uthority for a fuller, phase two investigation. **Bond (2017)** reports that behind this decision was the fact that, “Whil e Fox and News Corp are separate companies, the Murdoch Family Trust has material influence across both compa nies.” To secure the deal, 21st Century Fox had to take some measures that “include setting up a separate editorial board with a majority of independent members to oversee Sky News and a commitment to maintain Sky-branded news for five years at current funding levels.”

3.6. Strategic Manipulation of Cognitive Biases

The existence of the cognitive biases that we survey above opens the door for interested parties to take advantage of consumers or voters. A recent example is the use of Facebook by Cambridge Analytica and its partner organizati ons to affect different political campaigns across the world. One way in which the Facebook data were used was for the creation of targeted messages tailored to the characteristics of users. In addition, Cambridge Analytica allegedl y shared its data with other organizations working on the same campaigns to create repeated messaging to the sa me individuals under different frames. Another example is the use of real-time information about which messages were resonating to shape Donald Trump's travel schedule during the 2016 election campaign. If there was a spike i n clicks on an article about immigration in a county in Pennsylvania or Wisconsin, then Trump would visit the place and deliver an immigration-focused speech (see **Illing 2018**).

Recently, literature in economics and political science has shed light on strategic influence in the presence of cogni tive biases. **Levy et al. (2018a,b)** analyze how interested parties can influence an individual who has correlation ne glect and apply their results to the media market. **Giovanniello (2018)** analyzes a model of informative campaign a dvertising and shows how the ability of voters to strategically communicate with each other shapes the advertising strategies of two competing parties. **Mullainathan & Shleifer (2005)** analyze equilibrium in the market for news un der the assumption that individuals like to read news items that agree with their views or confirm their bias. They s how how this leads firms to slant their news reports in the direction of such bias. **Prat (2018)** develops a measure o f media power that is based on fully impressionable readers with correlation neglect.

3.7. Are Cognitive Biases (and Polarization) Necessarily Harmful?

The above discussion shows evidence for the existence and prevalence of cognitive biases in acquiring informatio n. These biases will lead to individuals holding wrong and biased beliefs. But what are the costs of having such wro ng, and sometimes polarized, beliefs?

While, intuitively, we might think that cognitive biases are bad for voters, a recent literature in behavioral political e conomy shows that these biases might sometimes also have some positive impact on aggregate welfare. **Levy & R azin (2015a)** analyze a voting model with heterogeneous voters and a common value shock. All voters prefer the p olicy on the right when the common shock is to the right and the policy on the left when the common shock is to th e left, albeit with different intensities. Each voter receives signals about the state of the world and makes voting de cisions given this information and their preferences. Signals are correlated, but behavioral voters neglect the correl ation in these sources, while rational voters do not. The key result in this paper is that correlation neglect can be—a

nd is, in many standard environments—beneficial for information aggregation: Even if each behavioral voter does n ot vote optimally from their own point of view (compared to a rational voter), the whole electorate may reach bette r, more informed outcomes (compared to a rational electorate). Intuitively, correlation neglect magnifies the effect of information on individuals' behavior. Individuals who might otherwise stick with the policy that accords with the direction of their political preferences may be swayed to change their vote if they believe that their information is s ufficiently strong in the opposite direction. This implies that individuals base their vote more on their information t han on their preferences. Thus, while correlation neglect is harmful for individuals, it may be better for society on a verage. **Levy & Razin (2015b)** show, in the context of political polarization, that polarization in voter opinions that i s due to correlation neglect does not necessarily translate to polarization in the political platforms of parties.

Lockwood (2019) shows the implications of confirmation bias in a political agency setting. In his paper, as oppose d to the rest of the literature that focuses on behavioral voters, either voters or politicians can have this bias. In the baseline case, where voters have this bias and where only the politician's actions are observable before the electio n, confirmation bias decreases pandering by the incumbent and can raise voter welfare as a consequence. Similarl y, **Ashworth & Bueno de Mesquita (2014)** show that voter incompetence, modeled as the voter's lack of ability to be properly informed, can sometimes improve politicians' incentives to choose the right policies (due to a reduced signaling motivation).

The key idea in the literature surveyed above is that the political system, even without taking into consideration co gnitive biases, is already flawed. It sometimes blocks information from being aggregated efficiently, or its electoral incentives induce politicians to behave in ways that are not in line with voters' preferences. When there are other ty pes of inefficiencies in the political system, it is sometimes useful for voters to be overconfident or for voters to ign ore in some way their information and therefore induce less distortive behavior by politicians.

However, different cognitive biases might imply very different normative results. **Levy & Razin (2015a)** show that, when voters have confirmation bias, the election aggregates less information than when voters have correlation ne glect. Therefore, it is important to empirically understand what is the underlying cognitive bias that voters have.

3.8. Other Biases

Above, we consider models in which individuals are restricted from updating information properly, which implies t hat echo chambers can arise. This failure of belief updating arises, for example, when the environment is too comp lex to understand (e.g., networks of communication) or when individuals face some cognitive constraints. Other m odels in the literature instead analyze how individuals may be compelled to manipulate their own beliefs to affect t heir behavior. For example, if individuals believe that hard work induces high rewards, then they know that they wi ll work harder; in turn, they may be motivated to influence their beliefs in this direction. This motivated beliefs ince ntive, explored for example by **Bénabou & Tirole (2006**, **2011)**, can then also create clusters of individuals with sim ilar beliefs. For example, **Bénabou (2013)** considers how complementarities in group activities compel individuals to manipulate beliefs in the same way.

4. THE DYNAMICS OF ECHO CHAMBERS

Sections 2 and 3 survey the literatures on segregation (chambers) and cognitive biases (echoes). In this section, we analyze the feedback effects between segregation decisions and the effects of segregation on beliefs. Intuitively, our perceptions about the world are shaped, in part, by where we live and with whom we interact. However, our decisions about where to live and who to talk to are also shaped by our beliefs. Therefore, to fully understand the implications of echo chambers, one has to understand how they evolve. This feedback effect is also important for empirical work; if we fail to take it into account, then we might make wrong inferences about causality. For example, **Dustmann & Preston (2001)** analyze how segregation in neighborhoods affects attitudes toward minorities. They show that earlier studies that have only looked at one direction of causality, i.e., how segregation and social exclusion affect beliefs and attitudes toward minorities, have biased results due to neglecting location choices, which depend on these beliefs.

To illustrate the feedback effect between segregation and beliefs, we focus on the example of schooling. **Levy & Razin (2017)** analyze how echo chambers in schools can sustain polarized beliefs that imply labor market discrimination. The model describes a society with nonoverlapping generations, infinite periods, and three stages in each period. In the peer influence (echo) stage, segregation affects beliefs. In this stage, individuals' beliefs about schools are shaped by their parents' beliefs and by their school peers, and they ignore selection bias. In the labor market stage, discrimination may arise based on such beliefs. Employers decide whether to hire an employee based on the school that the potential employee graduated from and their own beliefs about the schools' effect on productivities. Labor market experience also entails learning about true productivities. In the school choice (chambers) stage, beliefs and labor market discrimination affect segregation choices. In this stage, parents choose to which school—state or private—to send their offspring. Thus, the model explicitly describes the feedback effect between echoes and chambers.

The model uses imperfect empathy in parental school choice, as in the work of **Bisin & Verdier (2001)**. Parents base their decisions on their expectations about how their children will fare in the labor market. However, their child's labor market experience will be shaped both by what others will think of them and by their own beliefs. Therefore, parents have to form expectations about how the school will affect their child's future beliefs and behavior. The imperfect empathy assumption means that parents evaluate their child's welfare using their own beliefs, not the belief that their child will end up holding. This creates homophily; that is, parents would rather their children segregate with like-minded others so that their child's belief does not stray too far from their own. This endogenous homophily, along with selection bias, will lead beliefs to become polarized.

Levy & Razin (2017) find a simple necessary and sufficient condition that characterizes when segregation, polarized beliefs, and discrimination persist in the long run. When the condition is satisfied, in all equilibria, there are polarized beliefs about the productivity of graduates from the different schools (over and above actual productivity differences). Parents who send their children to a private school believe that the difference between the schools is great

er than it really is. Parents who send their children to a state school realize that there is discrimination, believe that it is not justified, and are priced out of private school. Finally, those who went to private (state) school will also sen d their children to a private (state) school. Thus, the old boys network is endogenously formed.

The analysis centers on the race between echo chamber effects and true learning.[17] First, history matters; to create long-run segregation and polarized beliefs, those in the private school have to start from a relatively low opinion of state school graduates. Second, the higher is the intensity of socialization in schools, the easier it is to create segreg ation and polarization. Finally, polarized beliefs are easier to sustain the less that individuals learn about others fro m their labor market experience. Importantly, the cycle of segregation and polarized beliefs can also be broken do wn. This occurs in the model when those who segregate into the private school have sufficiently mixed beliefs that belief polarization cannot arise.

In the dynamic model above, the school choices of parents affect the beliefs of their children, and these in turn affe ct their schooling choices when they are parents themselves. Some papers have taken an alternative approach to model this feedback effect in a static model. **Frick et al. (2018)** analyze a model in which individuals segregate into different interaction groups but could hold misperceived beliefs about what happens in other groups. Their equilib rium notion, termed local perception equilibrium, has an observational consistency requirement, so individuals' p erception about those with whom they interact must be correct. **Frick et al. (2018)** then show that misperceptions similar to our notion of selection bias, discussed above, have the property that they are part of an equilibrium no matter the environment. Similarly, **Windsteiger (2018)**, who analyzes segregation in a political economy model, su ggests a notion of equilibrium that also demands that beliefs about one's interaction group are always correct. Mor eover, **Windsteiger (2018)** adds an additional requirement about the misperceived beliefs about other groups. She assumes that beliefs must be consistent with the observation that people in neighboring groups chose to stay in th eir groups and not to switch groups. She shows that this additional restriction refines the set of equilibria in a usefu l way.

5. FUTURE RESEARCH

In this section, we conclude our survey by pointing out potential avenues for future research stemming from the di scussion above. We consider relevant issues for empirical as well as experimental and theoretical work.

A central empirical challenge at the heart of studying echo chambers is causality. As we see above, there are feedba ck effects between the formation of chambers and the kind of beliefs that they instill in their occupiers. How can w e disentangle whether individuals in segregated neighborhoods have polarized beliefs due to self-selection or due to a different process of belief formation that occurs once segregation has arisen?

Even when we focus on analyzing how beliefs evolve in a chamber following segregation, empirical challenges rem ain. Specifically, consider the case of prejudice against immigrants or foreigners. Contact theory focuses on interac tions among individuals as the vehicle by which stereotyping and prejudice can be reduced (**Allport 1954**, **Hewsto**

ne & Brown 1986). According to this theory, individuals who interact with other groups start using information gle aned from personal experiences rather than stereotypes. **Pettigrew & Tropp (2006)** show how interaction betwee n different groups can substantially reduce attitudinal and behavioral measures of negative evaluation.[18]

Whether contact is helpful, however, may depend on the specific interactions among individuals. One needs more data about the nature of interactions between the groups (see **Cantle 2001**). For example, data about residential s egregation might not be enough. We might want to gather data about the distribution of interactions between diffe rent groups. Is group A interacting with group B mainly as employers versus employees, or are they engaged in mor e cooperative interactions? A recent study by **Lowe (2018)** shows how different types of integration, collaborative a nd adversarial, may have different effects. Lowe recruited 1,261 young Indian men and randomly assigned men fro m different castes to participate in month-long cricket leagues; he shows that collaborative contact reduces discri mination, leading to more cross-caste friendships and 33% less own-caste favoritism, while adversarial contact gen erally has no effect or even harmful effects.

For policy making, it is important to understand the sources and mechanisms that drive echo chambers. For exam ple, are online echo chambers supply or demand driven? Papers such as that of **Bakshy et al. (2015)** point to dem and-driven effects, showing that individuals' choices play an important role in limiting exposure to cross-cutting co ntent. As we see above, understanding the types of biases that drive these effects is also important, as potential re medies depend on the particular biases. More research along these lines is needed to inform our strategies for tack ling echo chambers and their effects. To this end, experiments can provide a valuable way to understand in what e nvironments behavioral biases of information processing can be mitigated. A recent paper by **Enke (2017)** provide s results about how selection biases can be mitigated. Similarly, **Laudenbach et al. (2017)** conduct experiments sh owing how correlation neglect can be overcome in different ways depending on the context, framing effects, and th e complexity of the problem.

From a theoretical point of view, there are a few methodological issues to consider in addition to policy implication s. Methodologically, equilibrium analysis in situations where individuals have wrong beliefs has to be adapted. Rec ent advances provide equilibrium notions for misperception or misspecified models. These include behavioral equi librium notions such as cursed equilibrium (**Eyster & Rabin 2005**) and analogy-based equilibrium (**Jehiel 2005**). **E sponda & Pouzo (2016)** provide a solution concept for games with players who have misspecified models of the w orld (Berk-Nash equilibrium).

An important extension of current research is the role for government intervention. There are several ways in which governments can intervene to improve outcomes. Some government interventions can be targeted at preventing e choes and some at preventing segregation. To prevent echoes, one option is public campaigns to inform and corre ct individuals' wrong beliefs, as well as to reduce polarization. A second, less direct, role for governments in the con text of echo chambers is regulation of media markets. Concentration of media ownership can allow for strategic m anipulation of correlation neglect, as **Levy et al. (2018a)** show, which provides another reason for the break-up of

media conglomerates. Targeted algorithms can facilitate provision of information that is already aligned with individuals' views rather than unbiased information, and these algorithms may be regulated to prevent online segregation. For example, ensuring that algorithms are transparent is consistent with recent European Union regulation and will help clarify how information is generated and targeted. Finally, to prevent physical segregation, governments may target the role that the private market plays in creating opportunities for segregation, such as segregated schools or neighborhoods.

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