Exploring Rural-Urban Divides in Science:
How Will Residential Pattern Affect Attitudes and Framing about Science and Scientists?

by

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For my mom, dad, and all of my friends and professors who have provided tremendous support during my long journey of pursuing the Ph.D. degree

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ABSTRACT

Previous studies examined many factors influencing how science is communicated and how public audiences form their attitudes toward scientific issues. Most of these approaches fall into three categories—1) the changing landscape of current media and political environments (e.g., increasingly fragmented and polarized media and publics, as well as the social cues and algorithm biases in social media and search engines that can reinforce such trends), 2) inherent complexities and uncertainties of scientific issues about risks, benefits, and social and ethical outcomes, and 3) individuals' personal value predispositions (e.g., religiosity, political ideology, deference to scientific authority).

All of these approaches provide useful frameworks to identify influential factors related to the effective communication of science. However, recent trends, as exemplified by Donald Trump's win in the 2016 election, signal an important missing piece to be examined —individual residential locations that constitute rural-urban divides. Residential locations are particularly significant in two respects.

First, from the perspective of the media environment, rurality is strongly associated with less availability of local news, including news about local politics and science in the local context. Because of the reduced availability of local news, the level of rurality can be also associated with the increased dependence on online sources for news, which is largely national in focus (Trussler, 2020).

Second, in terms of personal values, rurality has shown to be a root of a social- and class- identity (Walsh, 2012; Cramer, 2016). In fact, rurality functioned as a key explanation of the voting behavior in the 2016 presidential election (Scala & Johnson, 2017) as well as a

determinant of policy preferences (Blankenau & Parker, 2015) even after taking account of political predispositions, education level, and family income.

Given that value predispositions including political ideology and partisanship can determine media use, the pattern of information exposure, and perceived importance of issues (Stroud, 2011), these findings imply potential drawbacks for contemporary science communication. That is, rurality in the place of residence has not sufficiently explored as a foundation of social identity, which can affect the pattern of information exposure and information sharing, and attitude toward scientists and science value predisposition as a value predisposition. Consequently, there is a possibility that we are not fully aware of potential disparities between residents of rural and urban areas in their trust toward scientists and motivation to seek out information about scientific issues.

That is, because of rural resentment against “professional people” and “people in power” in urbanized areas, rurality in the place of residence can relate to more negative attitude toward scientists as intellectual authority and out-group. This can be a particular obstacle for people to seek out information about science, that can further lead to uneven opportunities based on residential patterns to participate in constructing public discourse and in decision-making process about policies regarding scientific issues. In addition, because less availability of local news about their own communities is associated with increased exposure to national news, residing in rural areas can raise reliance on political predispositions such as party identification in processing scientific news. Coupled with lower levels of news about politics and science in local context, dissimilar information environments in rural areas require additional attention to communicate effectively about scientific issues that have direct policy relevance, which include climate change, vaccinations, and COVID-19 as one of the most recent examples.

Based on these concerns related to rural-urban divides in science communication, this dissertation explores how residential patterns relate to individuals' attitudes toward scientists and scientific issues in Study 1-1. In Study 1-2, I further explore the underlying mechanisms of the significant association found between rurality and the attitude toward scientists, in terms of information environments in their local communities, along with variables measuring community-level educational and socioeconomic disparities. Following these studies, Study 2 examines public discourse about scientific issues on the Twitter platform. Specifically, this study conducted qualitative and quantitative analyses to investigate the associations of the narratives and topical frames used in tweets with the level of rurality. The dissertation thereby attempts to make a scholarly contribution to the intersection of science and political communication.

Chapter 1, Introduction

Background and Significance of This Research: Rural-Urban Divides and Science in the Current American Political Landscape.

To date, previous studies have examined many factors influencing how science is communicated and how public audiences are forming their attitudes toward scientific issues. Most of these approach fall into the three categories, 1) the changing landscape of current media and political environments (e.g., increasingly fragmented and polarized media and publics, as well as the social cues and algorithm biases in social media and search engines that can reinforce such trends), 2) inherent complexities and uncertainties of scientific issues about risks, benefits, and social and ethical outcomes, and 3) individuals' personal value predispositions (e.g., religiosity, political ideology, deference in scientific authority).

All of these approaches provide us with the useful frameworks to consider factors related to the effective science communication. However, recent trends as exemplified by Donald Trump's win in the 2016 election implies an important missing piece to be examined--rural-urban divides. First, from the perspective of media environment, since rurality can be closely associated with the availability of local news about one's community (The News Desert Project, 2018), it (rurality) is likely to be related to "nationalization" (Hopkins, 2018). According to Das, Sinclair, Webster & Yan (2018), nationalization is conventionally conceptualized as 1) individuals' consistent voting preference of political candidates based on their evaluations of the national parties (i.e., partisanship) whether or not election is at national or local level, and 2) the phenomena that state and local elections are fought over national issues rather than local issues. Also, Das et al. (2018) point out that this nationalization can occur especially when we witness

changes in local media markets that prioritize national over local news (Hopkins, 2018; Martin & McCRAIN, 2019).

Here, we can find the interesting link between nationalization and rural-urban divides, both of which are affected by a similar information environment. That is, nationalization is likely to occur in rural regions where local media is declining due to a lack of economic sustainability, which we often observe in rural areas. As a result, rurality can be associated with more exposure to polarized media coverage and reliance on party cues regardless of election levels, whether national or local. In other words, in contemporary American society, based on residential patterns of individuals, there are dissimilar media environments and motivations to seek and process national news that can cause further polarization (Darr, Hitt, and Dunaway, 2018).

Such impacts of geographical factors on science communication might be even more emphasized than political communication considering the recent trend in the supply side of science communication. Science journalists have been experiencing economic pressures of lay-offs and shutdowns of their professional sections even in established meida companies (e.g., *New York Times*) (Dunwoody, 2014). That is, less human and financial resources to cover sciences (Schäfer, 2017) can make news reports about science and technologies based more on centralized sources, such as online news release from universities and policy debates among politicians in the central government, rather than voices from stakeholders in local communities.

Also, from the perspective of demand side (consumers of media), many Americans go online to seek information about science, and this trend has become increasingly dominant due to the increased younger online media natives. Because of the increased use of online media and exposure to news about science in online settings, following Trussler (2020)' s suggestion in

voting behavior, it is possible to expect that individuals can tend to be exposed to news with national contexts often including party cues rather than local contexts in science communication. However, the impacts of geographical factors have not been fully examined in science communication. Such potential lack of local contexts in science news both from supply and demand sides may function as a barrier to effective science communication across the rural-urban divide.

Second, in terms of personal values, rurality has shown to be a root of a social- and class-identity (Walsh, 2012; Cramer, 2016). Rurality has functioned as a key explanation of the voting behaviour in the 2016 presidential election (Scala and Johnson, 2017) as well as a determinant of policy preferences (Blankenau and Parker, 2015), even after taking account of political predispositions and social status (such as education and family income). As a result, considering that other social identities such as political predispositions and religiosity affect exposure to and processing of information (Hmielowski et al., 2014), the level of rurality in the place of residence can also influence these variables. Also, given that such value predispositions can determine risk and benefit perceptions about scientific issues and attitudes toward science (Gauchat, 2012) and scientists (Hmielowski et al., 2014), rurality can function as a significant predictor of these attitudinal variables as a salient social identity in today's American society.

These findings imply potential drawbacks in science communication in the currentg U.S context, given such an importance of rurality as a foundation of social identity and yet little scholarly attempts made exploring the roles of rurality in communitating about scientific issues. Rrural resentment has been fermented in comparioson with "professional people" and "people in power" in urbanized areas (Cramer, 2016). When the link is highlighted between these

"professional people" and "people in power" in urbanized areas with scientists as intellectual authority, it is possible that scientists are perceived as an out-group who disrespect values rural residents embrace. Such a perception of residents in rural areas can then lead to more negative attitude toward scientists and science than those in more urbanized areas.

If rurality relates to lower trust and negative attitude toward scientists, it can be a particular obstacle for them to seek out information about science. Such disparities in infomration about scientific issues can further lead to ignorance and uneven motivations based on residential patterns to understand science and to participate in constructing public discourse and in decision-making process about public policies regarding scientific issues. In addition, because of the lower availablility of local news in rural areas (The News Desert Project, 2018), regardless of needs among rural residents, ruralty can be associated with increased exposure to national news (Hopkins, 2018) to a certain extent by limiting the available local news. As a result, residing in rural areas can raise reliance on political predispositions such as party identification in processing scientific news.

Also, considering the shrinking human and financial resources in science journalism, even in legacy media, including *New York Times* (Dunwoody, 2014), news reports about science and technologies based more on centralized sources, such as online news releases from universities and policy debates among politicians in the central government, rather than voices from stakeholders in local communities. As a result, news about science might be covered mainly with the national and centralized contexts regardless of the availability of local news and the level of rurality in the place. Based on potentially less availability of news about local politics in rural areas (The News Desert Project, 2018) and scarcity of resources in science

journalism in general (Schäfer, 2017), dissimilar information environments in rural areas compared to suburban and metro areas suggest one possibility. Rurality may contribute to the dissimilar level of vulnerability to the politicization of science.

Suppose the media coverage about science is similar in local news regardless of the place, or local news does not cover scientific issues. In this case, the exposure to national news and reliance on party cues, which can be associated with less availability of local news (Hopkins, 2018), can escalate the politicization of science. Therefore, rurality requires additional consideration and attention from scholars and practitioners to communicate effectively about scientific issues as a catalyst of the politicization of science. This is especially true for controversial politicized issues, including climate change and vaccine mandate.

Based on the importance of rurality suggested by previous findings about the roles of rurality in voting behavior and the availability of local newspapers and increased access to national news and reliance on party cues (Hopkins, 2018), I explore how residential patterns (i.e., the level of rurality in the place of residence) relate to 1) individuals' attitudes toward scientists and scientific issues and 2) the public discourse about sciences in social media (i.e., Twitter). By doing so, this study aims to make a scholarly contribution in the intersection of science and political communication, and to improve strategies to communicate about scientific issues between lay audiences, journalists, politicians, and scientists, by pointing out the potential adverse effects of rurality in politicalization of science.

To be concrete, in Study 1-1, I explore how the level of rurality in the place of residence is related to individuals' attitudes toward scientists and science and how attention to media coverage of politics may affect the association between them, even after controlling for the

effect of partisanship. By employing the 2016 American National Election Survey (ANES) data, I examine these associations within a politically charged environment driven by a recent presidential election. This study, thus, seeks to contribute to a better understanding of the intersection of science and political communication and to the improvement of strategies to communicate about scientific issues across the diversity of views driven by rurality.

The results of Study 1-1 demonstrate a general tendency that rurality is significantly associated with less positive attitudes toward scientists and the federal funding on science and technology, even after controlling the following variables: individuals' education level, religiosity, partisanship, and attention to political news. Specifically, there was a significant difference in the attitude toward scientists between the residents of small metro, micropolitan metro, and non-core (most rural) areas relative to large central metro areas. In a similar vein, when predicting the attitude toward the federal funding on science and technology, compared to residents of large central metro areas, people residing in medium metro, small metro, and micropolitan metro areas, but not non-core areas, showed a significantly less positive attitude. Meanwhile, there was no significant interaction effect of rurality and attention to political news in predicting these attitudinal variables.

Meanwhile, the interaction term of partisanship and attention to political news was significant in predicting the attitude toward federal funding on science and technology. Such outcomes confirmed the existence of rural-urban divides in the attitudes surrounding scientific issues; residents of more rural areas tended to show less positive attitudes toward science and scientists. However, the effect of rurality on these attitudinal variables was not reinforced by

attention to political news. In this regard, science has not been politicized (yet) based on rurality, at least at the time of the 2016 ANES data collection.

Following this Study 1-1, Study 1-2 concerns the underlying mechanisms that might contribute to rural/urban differences in attitudes toward scientists based on residential pattern, by considering the effect of "nationalization", more reliance on party cues (Hopkins, 2018), specifically. That is, it is necessary to consider that geographical factors (rurality) may not only serve as a basis of the social identity of individuals (Cramer, 2016), but also may be a determinant of the information environment and the level of nationalization in regions, because of the availability of local news. As News Desert Report (2018) pointed out, market size, which is often determined by population size, is an important predictor of the decline in the number of and the quality of local newspapers available in each region. Consequently, there is a possibility that rurality is also closely associated with the news deserts where residents are experiencing a decreased number or lack of local newspapers (The News Desert Project, 2018).

Such an information environment in the news desert can facilitate exposure to national news via both online and offline media outlets, and lead to increased reliance on party cues in evaluating political candidates regardless of national or local level (Hopkins, 2018). These effects of "nationalization" can be found in urbanized areas too, when the availability of local news is low. However, given that rurality is associated with less availability of local newspapers and being a news desert (The News Desert Project, 2018), the availability of local news can be one of the underlying mechanisms of rural-urban divides in the attitudes surrounding sciences.

By incorporating the datasets of circulation of local newspapers from the News Desert Project with the 2016 ANES survey data, the RQs in Study 1-2 chapter examines whether

nationalization relates to geographical factors (e.g., rurality). Specifically, I examine 1) if the association between the level of rurality in the place of residence and the attitude toward scientists will be mediated by the availability of local news, and 2) how individuals' party identification will moderate this mediated association.

In addition to the availability of local newspapers, based on Suk et al. (2020), this study further examines other county-level variables as the potential factors explaining the dissimilar level of negativity in the attitudes toward scientists. According to Suk et al. (2020), the interaction effects of contextual factors (i.e., the changes in population size and unemployment rate, and community health) and party identification and digital media use are the significant predictors of the evaluations toward political elites (Scott Walker and Obama). Considering that rural consciousness is deeply rooted in perceived unfairness of redistribution (Cramer, 2016), these variables indicating socioeconomic relative deprivations can explain the link between rural-urban divides in the attitude toward scientists, as intellectual elites and the out-group. To explore such a possibility, this study also analyzes the county-level change in the Gini index as the measure of socioeconomic disparities *within* the county since the contextual variables included in Suk et al. (2020) can capture the disparities *between* the counties.

Moreover, following Cramer (2016)'s findings, this study explores the psychological and physical distance from higher education. Another central perception forming rural consciousness is that rural residents feel that their values are not respected by and shared with "people in power" and professional people in urbanized areas. Higher education is the most salient factor differentiating scientists from lay audiences including rural residents. Thus, psychological distance from higher education can be considered as a variable contributing to rural-urban

divides in the attitudes surrounding sciences. In particular, this study employed the percentage of bachelor's degree holders as the measure to psychological distance and accessibility to higher education in general.

In short, I explore if these county-level variables (i.e., change in 1) population size, 2) unemployment rate, and 3) Gini Index in 2012-2016, as well as the share of bachelor's degree holders and the availability of local newspapers), can mediate the effect of rurality in predicting the attitude toward scientists, and if partisanship can moderate these potential mediating processes. In particular, this study conducted a two-level multi-level Structural Equation Modeling (SEM) to test these mediation and moderation effects simultaneously.

Consequently, the multi-level Structural SEM results indicate significant mediating processes between rurality and the attitude toward scientists via the share of bachelor's degree holders and change in population size in 2012 to 2016. The effect of rurality became insignificant in this model, suggesting that the share of bachelor's degree holders and change in population size fully mediated the link between rurality and the attitude toward scientists. Based on these outcomes, I discuss implications for scholars and practitioners about the importance of considering such community-level variables in addition to individual-level variables to communicate and discuss effectively scientific issues.

Following these, this study moves to the exploration of online public discourse on Twitter, using climate change as an example of politicized scientific issues. To be concrete, in Study 2, I analyze Twitter data posted about climate change from January 31 to April 30, 2020, the very first stage of the COVID-19 pandemic, to examine the shares of and topical frames used in the public discourse on the Twitter platform. Specifically, first, I mapped the shares of

tweets about climate change and visualized from which tweets about climate change were posted in the United States. This map vividly showed most of the tweets were posted in large cities in liberal-leaning states such as New York, San Francisco, Boston, and Washington D.C. In addition, the qualitative analysis of the randomly selected tweets from urban, suburban, and rural areas illuminated unique characteristics of tweets from these areas, respectively. Among them, the most striking feature of tweets among rural areas is its infrequent use of third-party information to support their opinions and blames against liberal politicians (Barnie Sanders), polities, and organizations (e.g., Green Peace).

In contrast, the representative tweets from suburban areas were posted mainly from college towns such as Ann Arbor, Michigan, and Boulder, Colorado, introducing scientific findings and online articles created by liberal/mainstream media. Also, calling for actions to mitigate climate change was frequently observed in tweets from suburban areas, especially related to local contexts. In this sense, suburban users who posted tweets about climate change can be considered "issue publics." Topics and arguments found in the representative tweets from urban areas are relatively similar to those from suburban areas. However, a call for actions to mitigate climate change was made at a more general and national level. In particular, the narratives linking climate change and gender equality were found only in the tweets from urban areas, suggesting that depending on the level of rurality, how citizens frame climate change can greatly differ.

Furthermore, by conducting Structural Topic Modeling (Roberts, Stewart, and Tingley, 2014), Study 2 detected the topics used in public discourse about climate change on Twitter. As a result, eight upper topics were detected: 1) Scientific facts, 2) the 2020 presidential election, 3)

the 2020 primary election, 4) skepticism toward the government and establishment, 5) sustainability of the society, 6) skepticism toward climate change, 7) behavioral change related to climate change under the pandemic, and 8) energy and economy. Following this STM text analysis, I investigate the associations of the topical prevalence of these topics with contextual factors and user-level variables. As contextual factors, by relying on the stated place of residence in users' profile, I explore the impacts of the level of rurality, the availability of local newspapers in a city/town, and the place-level vote share for Democrat/Republican presidential candidates in the 2020 election as the variables predicting the topical frames about climate change. By doing so, this study examine how rurality and the availability of local newspapers can relate to how people (more specifically, Twitter users who tweeted about climate change) talk about climate change. Meanwhile, as the user-level variables, I explore the effects of estimated political ideology based on followees' information (Barberá et al., 2015) and the number of followers. Such an analytic scheme will shed lilght on how the contextual factors and individual factors interact with each other and how these different levels of factors can relate to the content of public discourse on politicized scientific issues in the current political landscape in the U.S.

As discussed above, rurality is a foundation of place-based social identity and a factor that can relate to the availability of local newspapers, and "nationalization" (i.e., the increased access to national news and more reliance on party cues in forming attitudes and processing information). Consequently, rurality can escalate the vulnerability of the politicization of science too. Therefore, rurality and the scarcity of local newspapers can affect the ways people discuss and express their opinions (frames) on a social media platform, where people can be exposed to news and find other users to interact on the basis of keywords they search.

Results of multi-level analyses indicate some significant associations between the prevalence of the aforementioned eight topics and individual-level and contextual factors, as well as their cross-level interactions. Among them, several interesting findings emerge. First, rurality was significantly associated with decreased prevalence for not purely political topics, such as skepticism toward the government and establishment sustainability of the society, skepticism toward climate change, and behavioral change. Such results suggest that rural users may be less interested in these topics than urban and suburban users. However, rurality was significantly associated with a higher topical proportion of scientific facts for all the political ideology groups. This result is somewhat inconsistent with Study 1-1 and Study 1-2, a less positive attitude toward scientists and science among rural residents than people residing in urban areas. I discuss these seemingly inconsistent results about the association of rurality and the topical prevalence of scientific facts in terms of the multifaceted characteristics of rurality.

Meanwhile, the availability of local newspapers was significant only when predicting the prevalence of the topic about the primary election, as an interaction effect with the place-level Democrat vote share. More availability of local newspapers led to the divergence of using this topic between liberal, moderate, and conservative users; liberal users increased mentioning this topic while the opposite happened among conservative users. Generally, such results and the insignificant effect of the availability of local newspapers on the prevalence of the topic of scientific facts suggest that Twitter did not fill the gap caused by the decline of local newspapers to disseminate information about scientific facts, especially with local contexts.

All in all, results in Study 2 illuminate how rurality and the scaricity and/or decline of local newspapers are related to the ways people discuss and express their opinions on a social

media platform, where people can be exposed to news and find other users to interact on the basis of keywords of their interests. Framing is one of the primary research agenda in science communication in reation to media effects in communication studies, because how information is presented or framed about issues (i.e., frames) will influence individuals' schema called upon to process that information. Consequently, frames can affect how audiences evaluate the issues as well as options of policies about them. In particular, emphasis framing, which is based on the conceptualization of Entman (1993) serves as a useful framework in this study. Emphasis framing examines the meaning (i.e., a particular way of understanding the issue in question) that is emphasized in a message. For instance, a news story covering a politician's campaign rally might emphasize the policy positions espoused by the candidate or might emphasize the candidate's strategic approach to campaigning. In turn, the meaning that is emphasized in the message may influence audience understanding and subsequent responses.

Given such critical roles of framing in forming attitudes toward social actors, including politicians and public issues, rurality should be paid more attention as a variable influencing framing as a foundation of place-based social identity (Munis, 2020) and a structural factor closely related to inequalities in the availability of local newspapers (The News Desert Project, 2018) and socioeconomic and education disparities. Nonetheless, to date, the potential effect of rurality on framing used in public discourse has not been sufficiently uncovered. This is possibly because the divide between Democrat/Liberal and Republican/Conservative was of the most interest in political communication. Moreover, the divide between those who are Democrat/Liberal and Republican/Conservative is often conceptualized as a divide between the residents in blue states and red states, ignoring the importance of divides between rural and urban areas even though some research has shown it to be the basis of social identity and a

strong determinant of both voting behavior (Monnat and Brown, 2017; Scala and Johnson, 2017) and values (Walsh, 2012), even after controlling socioeconomic status and partisanship.

Similar to the exploration of significant predictors in the attitudes toward social actors such as scientists and politicians as well as public issues, disentangling the effect of rurality from partisanship can add new findings in studies in framing. Examining the multifaceted aspects of rurality (i.e., as a foundation of social identity and the structural and geographical factors closely related to social, economic, (local) information, and educational disparities) should also illuminate how contextual factors can explain potential differences in framing as well. The residential pattern should be explored as a crucial factor that can affect how people frame messages intended as public discourse.

In sum, by shedding light on the effects of residential patterns of individuals, my research will add new knowledge to science communication and studies about framing about how geographical factors can affect attitudes toward scientists and scientific issues, as well as the topical frames in the public discourse in social media. By doing so, this study aims to find the causes of uneven motivation (more negative attitudes toward scientists and science) to seek out information about science both online and offline, potentially caused by geographical factors. Such unequal motivations and interests to understand scientific issues can further result in the uneven amount of voices heard and different frames used to express opinions in the online media environment in the forms of social media posts and comments made by users. By exploring and alarming these possible outcomes resulting from rurality, this study explores ways to promote a healthy environment for democratic decision-making informed by science.

Chapter 2: Politicized Science and Rural-Urban Divides: Evidence from a Nationally Representative Survey

Study 1-1, Politicized Science and Rural-Urban Divides: Exploring How Rurality in the Place of Residence and Attention to Political News Relate Views toward Science and Scientists

To date, both the scholarly community have paid much attention to individuals' personal value predispositions such as religiosity, party identification, political ideology, and deference to scientific authority as the determinants of attitudes toward scientific issues and ways to communicate science. In addition, especially after U.S. President Donald Trump's win in the 2016 election, another important factor has emerged: the level of rurality in one's place of residence, which has been attributed to different values and voting behaviors known as the rural-urban divide.

Ostensibly reacting to the feeling of being abandoned by "people in power" and urban professionals, rural residents often display a sense of societal unfairness and embrace a different social and class identity (Cramer 2016). Such a rural consciousness had been found to relate to policy preferences independent of political predispositions even before the 2016 election (Blankenau and Parker 2015) and has functioned as a key driving force for Republican presidential candidates since 2000, a pattern highlighted in the 2016 presidential election (Scala and Johnson 2017). Dissimilar values inherent between the rural and urban areas thus, are not a recent trend but a more foundational one that deserves study.

Previous studies have demonstrated that value predispositions are crucial determinants of the pattern of information exposure about scientific issues, and of trust toward scientists (Hamilton et al. 2015) and science (Gauchat 2012). In line with these findings, rurality could also have a significant influence on these variables.

In addition, especially in the context of the 2016 presidential election cycle, it is possible that the effects of level of rurality on these variables were prompted in part by a series of attempts to politicize science by conservative politicians, including candidate Trump. During the election campaign, Trump had expressed skepticism toward science and scientists by denying the legitimacy of findings in studies of climate change (Goode 2016). Given that social scientists pointed out that rurality in the place of residence was one of the crucial predictors of voting behavior in the 2016 presidential election and that residents in rural areas voted for the Republican candidate (Oberhauser et al. 2019; Scala and Johnson 2017), the message denigrating science and scientific community may have resonated with not only the partisanship stemming from being Republican but also one's social identity as a resident of a rural area.

Following the establishment of the Trump administration, concern about the prospect of drastic budget cuts to support scientific research led to the March for Science in 2017, in which scientists rallied to advocate for science and to call for evidence-based policies in the public interest (March for Science 2017). Since then, scientists have increased their participation as stakeholders in the political arena, and their roles and discourses have been increasingly politicized, especially amid the coronavirus pandemic and Trump administration efforts to force policy changes that ignore scientific evidence. In short, the efforts of science and scientists to challenge conservative Republican politicians including the Trump administration have been highlighted in the eyes of the public specifically via conservative media coverage, by depecting a series of conflicts between them (Hmielowski et al. 2014).

Under such circumstances, the confluence of the increased politicization of science in recent years (Chinn et al. 2020) and a growing rural-urban divide in voting behaviors since the

2016 presidential election (Munis 2020) may be linked to increasingly negative attitudes toward scientists and science among rural residents by affecting their social identity based on the place of residence. Social identity is "the self-concept that is formed by one's membership in groups that are defined by some shared attribute such as language, religion, or race" (Kalin and Sambanis 2018). As Cramer (2016) depicts, rural consciousness is a class- and place-based social identity rooted in the feeling of being abandoned by "people in power" and those who both reside in cities and are engaged in professional occupations, as well as stemming from a sense of societal unfairness in the distribution of public resources. Such a social identity based on place was shown to contribute to support of Republican and conservative candidates (Oberhauser et al. 2019; Scala and Johnson 2017). Also, given that scientists can be considered "people in power" as scientific and intellectual authority who often reside in city areas, scientists and scientific findings as their products can be targeted by rural consciousness.

It is also important to note that place-based social identity is different from partisanship, based on Cramer's observation and conceptualization (2016). Place-based identity is "a sense of belonging to a group whose membership is defined by living in a particular place and having a psychological attachment of group-based perception with other group members" (Munis 2020). On the other hand, partisanship reflects how people think about political platforms or party candidates, as well as how citizens psychologically identify themselves with political parties via a sense of belongingness (Kalin and Sambanis 2018).

The two concepts have often been conflated in recent scholarship, as the rural share of the Republican base and urban share of the Democratic base have been rising continuously (Scala and Johnson 2017), But consistent with the distinction between these identities, Blankenau and

Parker (2015) found that, even after controlling for partisanship, level of rurality in one's place of residence was a significant predictor of policy preferences across several issues. Theese include, prayer and sex education in public schools, gun control, assisting the poor when times are bad, and choosing to reduce services rather than to raise taxes. Due the possibility that scientists and science can be a target of rural consiciousness, rurality can also lead to more negative attitude toward scientists and science among rural residents, independent of the effect of partisanship. Ignoring the distinction between place-based identity and partisanship can result in over-estimation of the effect of partisanship in attitude formation about scientific issues, as well as underestimation of inequalities in the access to science based on residential patterns as an outcome of masked effect of rurality by partisanship.

Therefore, in this study, I explore a hypothesis that rural residents will feel more negatively about scientists and science compared to urban and suburban residents independently of partisanship. I also examine a research question that attention to political news will moderate the effect of rurality in the place of residence in predicting these attitudinal variables. If this hypothesis is find significant, it suggest that people in rural areas could refrain from seeking information about science and even deny scientific findings because of decreased trust toward scientists and science. Lack of knowledge about and interest in science among rural residents could further lead to uneven motivation to participate in constructing public discourse and in decision-making processes about policies regarding scientific issues. As a result, special attention and strategies may be required to communicate with residents in rural areas effectively about scientific issues that have direct policy relevance, including climate change, vaccinations, and COVID-19.

This analysis explores how the level of rurality in the place of residence is related to individuals' attitudes toward scientists and science and how attention to media coverage of politics may affect the association between them, even after controlling for the effect of partisanship. By employing the 2016 American National Election Survey (ANES) data, I examine these associations within a politically charged environment driven by a recent presidential election. This study, thus, seeks to contribute to a better understanding of the intersection of science and political communication and to the improvement of strategies to communicate about scientific issues across the diversity of views driven by rurality.

Survey data gathered during the 2016 election campaign allows us to assume that both the amount of and attention to political news was at a higher level because of various election-related activities and events made by politicians and media coverage about them. The politically charged environment in 2016 also provides an ideal setting to examine the politicization of science. Increased attention to political news likely makes both place-based identity and partisanship salient, strengthening their influences on the process of information seeking, processing, and attitude formation in relation to science.

Rurality in the Place of Residence as a Determinant of Voting Behavior and Attitudes Toward Scientists and Science

Place-based identity and rural-urban divides

Individuals' value predispositions, such as religiosity and political predispositions, have been shown to be crucial factors influencing exposure to and processing of information, and to have impacts on risk and benefit perceptions and attitudes toward scientific issues and scientists

(Hmielowski et al. 2014; Hamilton et al. 2015; Gauchat 2012).

A report issued by the Pew Research Center (2018) suggests adding a candidate to this list of value predispositions that can function as a determinant of attitudes about various issues: place-based social identity, based on one's place of residence. Individuals seem to maintain different views about society, politics, and their future based on their level of residential rurality. In a similar vein, recent studies in political science points to the need to assess geographical (rural-urban) divides among voters in terms of their values and the electoral outcomes (for example, Scala and Johnson 2017).

For example, using the case of Nebraska as a homogenous and primarily red state, Blankenau and Parker (2015) showed that rural-urban divides are significant predictors of attitudes toward gun control and tax policies, even after controlling for respondents' party identification, age, and family income. Similarly, Oberhauser et al. (2019) found that rurality, but not economic distress and religiosity, mattered in determining voting for Trump in the 2016 presidential election in Minnesota. Scala and Johnson (2017) also confirmed these trends at the national level, adding a new finding that residential patterns had been significant predictors of voting behavior in the 2012 and 2016 presidential election that led to the second term of the Obama administration.

It is worth noting that these effects of rurality on voting behavior are more pronounced when considering the economic structures of rural counties (Scala and Johnson 2017). Increased unemployment and out-migration during the past decades often characterized the counties that gave a majority to the Republican presidential candidate in 2016 compared to previous presidential election years (Monnat and Brown 2017).

One possibility is that rural-urban value differences result from “relative deprivation,” the concept describing individuals’ feelings that they are deprived of things of value relative to their own past, other people or groups, or some other social category (Walker and Pettigrew 1984). Indeed, such perceptions have been shown to be intertwined with a class- and place-based social identity among rural residents in Wisconsin, who attribute perceived deprivation to urban political elites who they believe disregard and disrespect rural residents and rural lifestyles (Cramer 2016).

Cramer (2016) pointed out that rural consciousness is dominated by three kinds of beliefs: 1) rural areas are ignored by people in power; 2) rural areas do not have fair access to public resources; and 3) unique experiences and knowledge that rural residents possess are not understood or respected by political elites and urban residents. These belief sets raise the question as to what degree such divides in political attitudes and voting behavior can also apply to views toward other social actors such as scientists and, consequently, how they can affect attitudes toward science issues. The first belief set in rural consciousness touches on the feeling among rural residents of being abandoned by “people in power.” Scientists are professional people with expertise whose assets rural residents may find difficult to access in explicit ways. This can make rural residents feel as if their needs are being ignored.

Second, in addition to unequal access to knowledge and higher education (Pew Research Center 2018), risks and benefits resulting from science and technologies are unevenly distributed in society (Beck 1992). For example, the benefits of technologies such as nuclear power may be available to society as a whole, yet the risks of operating nuclear energy plants are often primarily the province of rural regions, with less population density and fewer alternate

industries. In this way, the second belief set about unequal access to public resources among people with a rural consciousness could be associated with the perception of unevenly distributed fruits of scientific findings, and with resulting negative sentiment toward scientists.

Lastly, the belief of rural residents that their knowledge and culture are not respected by "those who are in power" and by people who reside in urbanized areas can be extended to low trust and credibility toward scientists as well. Such a feeling was observed in a case study by Wynne (1992), which described the unfair power balance and conflicting values between farmers and scientists. This study exmined the response of Cumbrian sheep farmers to scientific advice on the restrictions imposed after the 1986 Chernobyl nuclear plant meltdown and resulting radioactive fallout. The farmers developed antipathy resulting from unfair power differentials between them and scientists and the feeling that scientists did not respect the unique experiences, knowledge, and practices of the farmers. After all, trust and credibility toward social actors including scientists are largely contingent upon the social relationships.

Also, the fact that scientists work for universities or companies and reside in college towns or cities where companies are located can make place-based social identity salient specifically among rural residents. The physical distance between lay people in rural areas and the scientific community limits social relationships and increases the psychological distance between them. Thereby, scientists can be perceived as an "outgroup" like the establishment and urbanities in the eyes of rural residents. Because of this, place-based identity may have widened the attitudinal gap toward scientists and science between the residents of urban and rural areas.

In sum, place-based identity may be closely associated with negative sentiment against science and scientists. The authority of scientific communities, inequalities in distributing the

benefits and risks associated with employing the technologies, and physical and psychological distance between scientists and lay audiences can all contribute to negative attitudes toward them, especially among the rural residents. Based on this premise, the concurrent rise of place-based identity, and the politicization of scientists and science make it possible that science has become enmeshed in more expansive social identities that lead individuals in urban areas to support science and scientists, while encouraging those living in more rural areas to become increasingly critical of science and scientific work.

Partisanship

Partisanship is one of the most powerful and salient social identities in U.S society today that promote strong dislike and even loathing of political opponents (Iyengar and Westwood 2015). Many political elites feel extreme stances appeal to their constituencies, and we know that polarized messages further reinforce partisanship among members of the public, leading to "party sorting" in which every issue is divided by party lines (Fiorina 2016). Consequently, most public issues, including scientific ones, have been influenced by partisanship.

Much research has found partisan divides in attitudes toward a variety of scientific issues and that increased political polarization is associated with the increased politicization of science (e.g., Suhay and Druckman 2015). Partisanship plays a major role in patterns of exposure to and processing of information (Hmielowski et al. 2014), risk and benefit perceptions, and attitudes toward scientific issues and scientists (Hmielowski et al. 2014; Hamilton et al. 2015). In particular, findings consistently show that, compared to Conservatives and Republicans, Liberals and Democrats tend to possess more positive attitudes toward scientists and show higher acceptance toward recommendations and findings provided by the scientific community (Blank

and Shaw 2015; Hamilton et al. 2015).

The strength of partisanship as a predictor can swamp the influence of other factors such as place-based identity. Relative to residents in urban and suburban areas, for example, rural residents in recent elections provided more support for Republican candidates (Oberhauser et al. 2019; Scala and Johnson 2017), who tend to be more skeptical of science. The apparently similar effects of the level of rurality and partisanship in predicting attitudes toward science make it important to disentangle them.

Attention to Political News

Attention to political news is another important factor in examining the politicization of science. Previous studies have found that political actors such as politicians and interest groups have played important roles in the scholarly conceptualization of politicization and in examining the politicized frames and norms (Bolsen et al. 2014; Chinn et al. 2020). As a result, attention to political news that covers these social actors can function as a catalyst for politicization at an individual level. This is because attention to political news can be considered as the extent to which individuals are exposed to and process information about various issues, including science, in relation to political actors. Higher levels of attention can reinforce social identities such as partisanship and place-based identity by placing them in the context of politics.

Additionally, attention to political news is guided by partisanship. Stroud (2011) demonstrated that exposure to and processing of information are significantly determined by partisanship, and it can further affect the attitudes toward scientists and scientific issues (Hmielowski et al. 2014). That is, Republicans are likely to consume conservative media while

Democrats are inclined to be exposed to liberal media. Because of repeatedly expressed skepticism toward science and the lack of consensus on scientific findings on climate change covered in conservative media, attention to conservative media use may serve to lower trust in scientists, while attention to more liberal media use may increase trust toward them (Hmielowski et al. 2014). Moreover, due to motivated reasoning, even when individuals view the same content, they process information contingent on their preexisting stances, including partisanship (Kraft et al. 2015; Taber and Lodge 2006).

In politically charged environment typified by the 2016 presidential election cycle, attention to political news should be higher than usual. Consequently, its role as a catalyst for politicization may be greatly strengthened by interactions with such social identities as partisanship and place-based identity. Attention to political news, thus, may moderate partisanship and place-based identity.

Research Question and Hypotheses

Although partisanship is a different social identity from place-based identity (Munis 2020), rurality has been significantly associated with support of Republican candidates in past elections (Oberhauser et al. 2019; Scala and Johnson 2017). Since identifying as Republican and/or Conservative is correlated with negative attitudes toward scientists and scientific issues (Hmielowski et al. 2014), H1 seeks to find out if rurality makes an independent contribution to attitudes.

Hypothesis1: Even after controlling for the effect of partisanship, people living in rural regions will express more negative attitudes toward scientists and funding for science than those

in urban regions.

By examining this hypothesis, we can test if there are rural-urban divides in the attitudes surrounding science as well as in the realm of voting behavior as a result of rural consciousness against scientists as "people in power" as academic elites. Due to such anti-sentiment and perceptions that their values are disrespected by out-group with power (scientists in this case) among rural residents can make their attitudes toward scientists and science more negative than residents in more urbanized areas.

Another actor in the production of negative attitudes among rural residents may be the politicization of science. As Hmielowski et al. (2014) demonstrated, conservative media use led to less trust in scientists that, in turn, was associated with decreased belief in global warming. Meanwhile, non-conservative media use was associated with increased trust in scientists, which further raised certainty about the reality of global warming. Also, conservative politicians including Trump expressed skepticism toward climate change during the 2016 presidential election (Goode 2016) and attacked the trustworthiness of scientists.

If rurality is indeed strongly linked to attitudes about scientists and the scientific enterprise, it is possible that such attitudes are being reinforced by attention to political news. However, as I reviewed previous studies, the association between rurality and attitude toward scientists and science has not been fully examined yet. The possible moderated effect of attention to political news on the correlation between these two variables remains unclear. Therefore, I explore the RQ as below.

RQ: Will the associations between residential patterns and attitudes towards scientists

and science be moderated by attention to news about politics? If so, how will this moderation function based on the level of rurality?

Methods

Data

This research relied on the 2016 American National Election Studies (ANES) data, which were collected during the 2016 presidential election cycle, tracking a representative sample of 5,680 respondents. Both the independent and dependent variables employed here were administered only in the post-wave survey; hence, the present study is a cross-sectional analysis.

Measurements

Dependent variables

Attitude toward scientists

I created this variable by using a question employing *the feeling thermometer toward scientists (How would you rate scientists?)*. Respondents were asked to enter a number between 0 and 100, with higher scores demonstrating more positive feelings toward scientists (M = 76.70, SD = 19.44).

Attitude toward federal funding on scientific research

This was assessed by asking "Should federal spending on science and technology be increased, decreased, or kept the same?" I treated this variable as an ordinal variable (1 =

"decreased" (7.52%), 2 = "kept the same" (34.13%), and 3 = "increased" (58.35%)).

Independent variables

Party Identification

Respondents identified their party orientation (1 = Democrat (35.84%), 2 = Republican (30.40%), and 3=Independent (33.76%)). In the following analyses, Independent was used as a reference category and respondents who chose the other categories including "Don't know" were excluded.

Attention to news about politics

Attention to news about politics (TV, radio, newspapers, and the internet) asked how closely respondents follow politics in the news and utilized a four-point scale (1 = "Not at all" to 4 = "Very closely", $M = 2.78$, $SD = 0.82$).

Rurality of each county

To calculate the level of rurality, I employed the 2013 National Center for Health Statistics (NCHS)'s Urban-Rural Classification Scheme for Counties (Ingram and Franco 2014) and combined the NCHS' codes provided for each county with the ANES 2016 survey dataset by matching the respondents' county of residence. This NCHS categorization is based on the 2013 Office of Management and Budget's (OMB) delineation of metropolitan statistical areas (MSA) and micropolitan statistical areas and is widely used, especially in the field of health research (Ingram and Franco 2014).

Based on population size and urbanized areas, OMB classifies individual counties into metropolitan counties ("urban") and non-metropolitan counties ("rural") (See Table 2.1 for the detailed description of the 2013 OMB classification and NCHS rural-urban scheme). Non-metropolitan counties are further subdivided into micropolitan and noncore counties, whereas the large metropolitan areas are further separated into two categories: large "central" metro (akin to inner cities) and large "fringe" metro (akin to suburbs) by the NCHS's scheme.

This delineation is useful for this study. People who reside in rural, suburban, and urban areas vary with respect to their values and political predispositions (Pew Research Center 2018), as well as with respect to access to and distribution of the public goods (Cramer 2016; Munis 2020). Place-based identity should be operationalized more finely than rural versus urban areas; the 2013 NCHS categorization allows the study to contrast patterns between rural and suburban areas and urban and suburban areas, as well as to differentiate between residents of inner cities and those of the suburbs of large metropolitan areas.

In order to capture these types of communities at an appropriately granular level, residents of the inner cities and suburbs of large metropolitan areas need to be differentiated. This helps to obtain an accurate characterization of communities across the full urban-rural spectrum with special attention to suburban areas (see Table 2.1 for values and description of the criteria for each residency).

Table 2.1. 2013 National Center for Health Statistics (NCHS) Rural-Urban Classification Scheme for Counties in the U.S.

Code	Description
Metro counties: Counties defined as Metropolitan Statistical Areas (MSAs), which have at least one urbanized area of 50,000 or more population, plus adjacent territory that has a high degree of social and economic integration with the core as measured by commuting ties.	
1	Large central metro areas: Counties in Metropolitan Statistical Areas (MSAs) defined by the Office of Management and Budget (OMB) of 1 million or more population that: 1. Contain the entire population of the largest principal city of the MSA, or 2. Have their entire population contained in the largest principal city of the MSA, or 3. Contain at least 250,000 inhabitants of any principal city of the MSA.
2	Large fringe metro areas: Counties in MSAs of 1 million or more population that did not qualify as large central metro counties.
3	Medium metro areas: Counties in MSAs of populations of 250,000 to 999,999.
4	Small metro areas: Counties in MSAs of populations less than 250,000
Nonmetro counties: Counties as outside of metropolitan areas and as one of two types	
5	Micropolitan areas: Counties in micropolitan statistical areas in OMB definition, have at least one urban cluster of at least 10,000 but less than 50,000 population, plus adjacent territory that has a high degree of social and economic integration with the core as measured by commuting ties.
6	Noncore areas: Nonmetropolitan counties that did not qualify as micropolitan

Demographics

The following variables were used for control purposes: *gender*, *age*, *educational attainment*, and *family income*. In our sample, the average age of respondents was 49.6 years (SD = 17.6), and there were slightly more women, 52.9 %, than men, 47.1 %. Measured categorically, median household income fell between $45,000 to $49,999. About 6.6 % of respondents had less than high school education, 19 % had a high school diploma, 21% attended some college, and 38.3 % earned a bachelor's degree or higher.

In addition, considering the finding of Gauchat (2012) that church attendance was a significant predictor of confidence in science, I also included *religiosity* as a control variable. In the 2016 ANES survey, respondents were asked whether religion was an important part of their lives (1 = important, and 2 = not important). Those who answered that religion was important further rated the extent to which religion provides guidance in their daily lives (1 = Some, 2 = Quite a bit, and 3 = A great deal). Those who answered religion as not important in the first question were coded as 0 in the variable for the second question, thereby creating the measure for religiosity which ranges from zero to three (M = 1.51, SD = 1.28)

Data Analyses

To test the aforementioned research questions and hypotheses, I used a series of Ordinary Least Squares (OLS) regression models to explore the associations between the independent

variables and attitudes toward scientists. I employed ordered logistic regression models to assess the linkages of these IVs with attitudes toward federal funding of science and technology. “Don’t know” and “Refused” responses were treated as missing values and those cases were dropped from the analyses.

First, the demographic variables were entered for control purposes. Then I added the independent variables--party identification, the level of rurality in the place of residence, and attention to political news--in the second block. Following that, I entered the main effects and two-way interaction effects of party identification, media attention to political news, and rurality. The final block consisted of statistical interactions that were created by multiplying the standardized values of the main effect variables.

Also, considering the criteria used in the 2013 NCHS’s codes to classify community types, I operationalized the level of rurality as an ordinal categorical variable rather than a continuous variable. The OMB’s scheme, which classifies counties into metropolitan and nonmetropolitan, uses multiple criteria including population size in a county, the type of land use, and adjacent territory that has a high degree of social and economic integration with the core as measured by commuting ties. The 2013 NCHS codes follow this scheme and have further subdivided metropolitan counties defined by the OMB into four categories by population size and inclusion of any principal city of the metropolitan areas.

Based on these classification schemes, it is difficult to assume a unidimensional approach to the 2013 NCHS codes. Consequently, I treated the level of rurality as an ordinal categorical variable in a way similar to the approach of Scala and Johnson (2017) and used the large central metro core areas as the reference category. The current study, therefore, looks for differences in

attitudes between the residents of the large central metro core areas and those who reside in areas of the other five categories shown in Table 2.1.

Results

First, as shown in Table 2.2 (next page), when predicting the attitude toward scientists, there were no statistically significant interaction effects of party identification and attention to political news (Democrat: b = 1.99, Republican: b = - 2.08). Similarly, in relation to RQ2, none of the interaction effects of the level of rurality and attention to political news was associated with attitudes toward scientists (Large fringe metro: b = - 0.70, Medium metro: b = - 0.81, Medium metro: b = 1.34, Small metro: b = 1.60, Noncore: b = 1.26).

In exploring H1, the main effects of both partisanship and the level of rurality were significantly correlated with attitudes toward scientists. That is, in line with previous studies, as compared to Independents, Democrats were likely to have more positive attitudes (b = 3.43, $p < .05$) while Republicans tended to express more negative attitudes (b = - 3.53, $p < .05$). Importantly, significant associations were found between the level of rurality and attitude toward scientists even after controlling for the effect of party identification. Specifically, compared to the residents of the central metro core areas, people who reside in small metro areas (b = - 2.82, $p < .05$), micropolitan areas, (b = - 4.19, $p < .05$), and non-core areas (b = - 5.52, $p < .05$) showed significantly less positive attitudes.

Analysis of predictors of attitudes toward funding of science and technology yielded similar patterns, as shown in Table 2.3. In relation to RQ2, no significant interaction terms were found between the level of rurality and attention to political news (Large fringe metro: b = 0.06, Medium metro: b = 0.01, Small metro: b = - 0.20, Micropolitan: b = 0.07, Noncore: b = - 0.05). The interaction effect of party identification (being Democrat compared to Independent) and attention to political news, on the other hand, was significantly correlated with more positive

attitudes toward the federal funding of science and technology research (b = 0.22, $p < .05$). The interaction effect of being Republican and attending to political news did not reach significance (b = - 0.05).

Table 2.2, Regressions Predicting the Attitude toward Scientists

	Model1	Model2	Model3	Model4
Predictors	Coef.	Coef.	Coef.	Coef.
Gender (1=Female)	-0.76 (0.84)	-0.72 (-0.84)	-0.25 (0.83)	-0.29 (0.82)
Age	0.15 (0.13)	0.17 (0.13)	0.06 (0.13)	0.07 (0.13)
Family Income	0.11 (0.06)	0.08 (0.06)	0.07 (0.06)	0.07(0.06)
Education	1.38* (0.29)	1.29* (0.29)	1.06* (0.30)	1.05* (0.30)
Religiosity	-1.98*(0.35)	-1.94* (0.35)	-2.00* (0.35)	-1.94* (0.35)
Partisanship				
Democrat (vs Independent)	4.35* (1.02)	4.15* (1.02)	3.59* (1.02)	3.43* (1.03)
Republican (vs Independent)	-3.61*(1.08)	-3.29* (1.08)	-3.57* (1.08)	-3.54* (1.08)
Rurality (Reference category; Large Central Metro)				
Large Fringe Metro		-0.85 (1.19)	-0.82 (1.18)	-0.69 (1.18)
Medium Metro		-1.59 (1.20)	-1.40 (1.20)	-1.63 (1.19)
Small Metro		-2.86*(1.42)	-2.77* (1.39)	-2.82* (1.36)
Micropolitan		-4.27*(1.55)	-4.13* (1.54)	-4.20* (1.56)
Noncore		-5.51*(2.25)	-5.61* (2.21)	-5.56* (2.21)
Attention to Political News			2.36 (0.48)	2.10 (1.22)
Party ID*Attention to Political News				
Democrat*Attention to Political News				2.00 (1.03)
Republican*Attention to Political News				-2.08 (1.17)
Rurality*Attention to Political News				
Large Fringe Metro*Attention to Political News				-0.71 (1.27)
Medium Metro*Attention to Political News				-0.81 (1.25)
Small Metro*Attention to Political News				1.34 (1.40)
Micropolitan*Attention to Political News				1.61 (1.60)
Noncore*Attention to Political News				1.32 (2.40)
Total R squared (%)	6.85%*	7.46%*	8.73%*	9.51%*
N	3,199	3,199	3,194	3,194

Note: * $p < 0.05$, coefficients are not standardized and SE is shown in the parenthesis.

Table 2.3. Regressions Predicting the Attitude toward Federal Funding of Science and Technology Research

	Model1	Model2	Model3	Model4
Predictors	Coef.	Coef.	Coef.	Coef.
Gender (1=Female)	-0.25* (0.09)	-0.25*(0.09)	-0.22* (0.09)	-0.22* (0.09)
Age	0.02 (0.01)	0.02 (0.01)	0.02 (0.01)	0.02 (0.01)
Family Income	0.01* (0.01)	0.01* (0.01)	0.01 (0.01)	0.01 (0.01)
Education	0.15* (0.03)	0.14* (0.03)	0.13* (0.03)	0.13* (0.03)
Religiosity	-0.08* (0.04)	-0.07* (0.04)	-0.08* (0.04)	-0.08* (0.04)
Partisanship				
Democrat (vs Independent)	0.18 (0.10)	0.15 (0.10)	0.10 (0.10)	0.12 (0.11)
Republican (vs Independent)	-0.45* (0.11)	-0.43* (0.11)	-0.46* (0.11)	-0.45* (0.11)
Rurality				
Large Fringe Metro		-0.13 (0.13)	-0.14 (0.13)	-0.13 (0.13)
Medium Metro		-0.28* (0.13)	-0.27* (0.13)	-0.28* (0.13)
Small Metro		-0.41* (0.16)	-0.41* (0.16)	-0.44* (0.16)
Micropolitan		-0.37* (0.16)	-0.36* (0.16)	-0.38* (0.16)
Noncore		-0.38 (0.22)	-0.39 (0.22)	-0.38 (0.22)
Attention to Political News			0.17* (0.05)	0.11 (0.12)
Party ID*Attention to Political News				
Democrat*Attention to Political News				0.22* (0.10)
Republican*Attention to Political News				-0.05 (0.12)
Rurality*Attention to Political Nnews				
Large Fringe Metro*Atention to Political News				0.06 (0.13)
Medium Metro*Attention to Political News				0.01 (0.14)
Small Metro*Attention to Political News				-0.20 (0.16)
Micropolitan*Attention to Political News				0.07 (0.16)
Noncore*Attention to Political News				-0.05 (0.24)
Total R squared (%)	2.54%*	2.84%*	3.21%*	3.47%*

N	3,216	3,216	3,211	3,211

Note: * p < 0.05, coefficients are not standardized and SE is shown in the parenthesis.

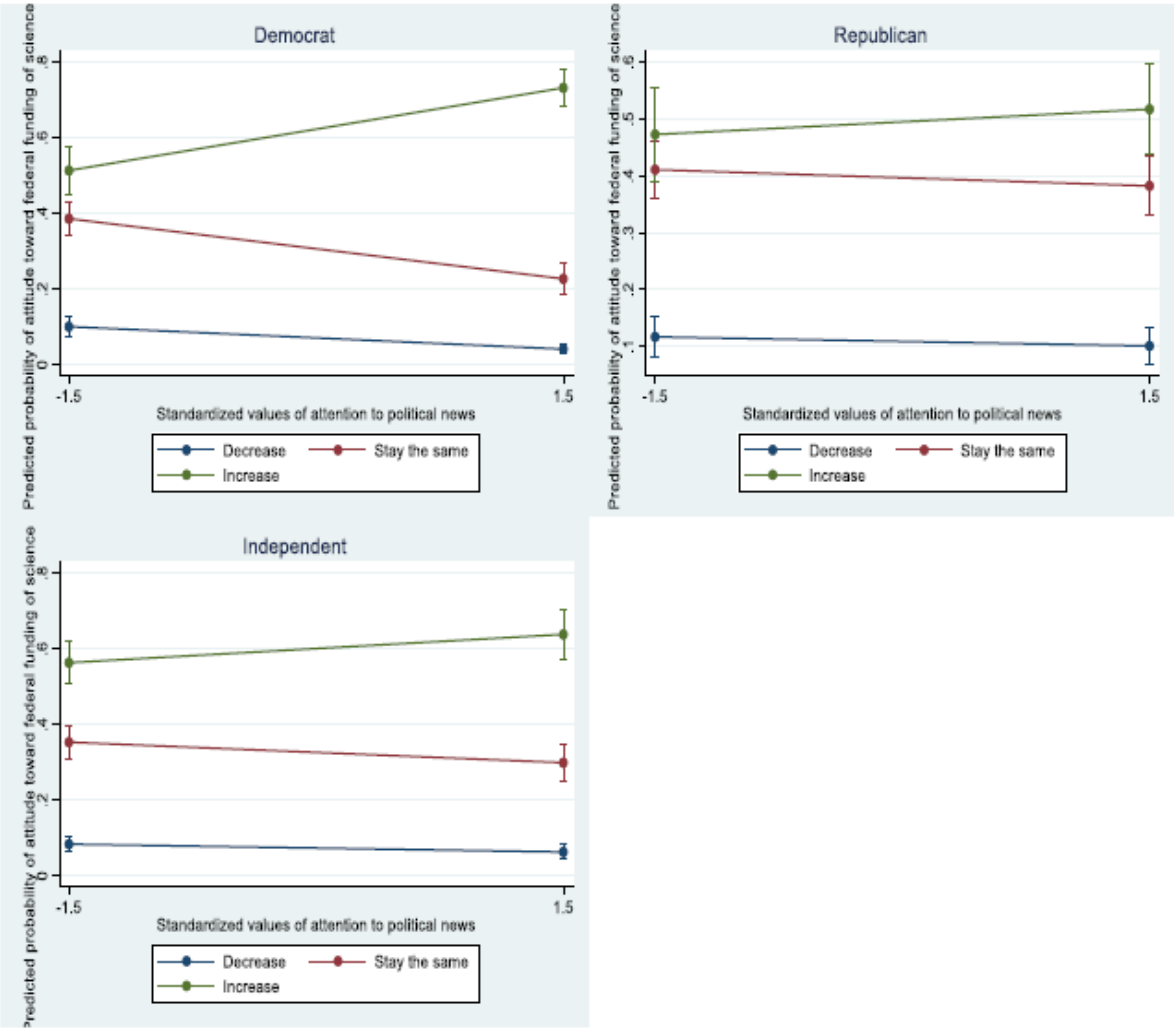

Figure 1. Predicted Probabilities of the Attitude toward Federal Funding of Science and Technology by Interactions of Party Identification and Attention to Political News

Figure 2.1 indicates the predicted probabilities of attitude toward federal funding on science and technology research by party identification and attention to political news, controlling for the other independent variables. The predicted probabilities are shown for

Democrats, Independents, and Republicans, respectively. Among people who identified as Democrats, the likelihood of supporting increased federal funding of science and technology research increased when they paid more attention to political news. However, the probabilities to judge that funding should "stay the same" and "decrease" declined and stayed low regardless of attention to political news. Independents and Republicans did not show such trends; the predicted probabilities of attitudes toward science for each category remain unchanged regardless of the level of attention paid to political news.

Also, in line with the results predicting the attitude toward scientists, in relation to H1, the main effects of rurality were significantly associated with attitudes toward funding science and technology. That is, relative to the residents of large central metro areas, those who reside in medium metro (b = - 0.28, $p < .05$), small metro (b = - 0.44, $p < .05$), and micropolitan (b = - 0.38, $p < .05$) areas expressed more negative attitudes toward such funding. This provides supporting evidence for H1. Also, in contrast to the results relevant to attitudes toward scientists, residing in noncore areas (most rural areas) was not significantly associated with such attitudes (b = - 0.38).

These results illuminated clear tendencies pointing to negative attitudes toward scientists and science among residents of smaller communities compared to residents of large central metro areas, even after controlling for the effect of partisanship and its interaction effects with attention to political news. Meanwhile, the associations between the level of rurality and attitudes toward scientists and science, queried in RQ2, were not significantly moderated by attention to political news.

On the other hand, the interaction effect of party identification and attention to political news was significant only in predicting attitudes toward funding science and technology,

suggesting that increased attention to political news was associated with higher probability of supporting increase in the federal funding on science and technology research among Democrats. Meanwhile, that moderation was not found in the associations between being Independents and Republicans and attitudes toward scientists and science. The main effects of being Democrat and Republican were observed in predicting both attitudinal variables.

Discussion

Based on Cramer (2016), this study explored how residential patterns, signifying the place- and class-based social identity of people, might determine attitudes toward scientists and toward science policy (federal funding in this case) independent of party identification and social economic status. Specifically, I investigated how the level of rurality in one's place of residence in the United States was associated with attitudes towards scientists and toward federal funding of science and technology, as well as how that relationship could be moderated by attention to political news in a highly politically-charged environment, the 2016 presidential election. During this election cycle, attention to political news, a catalyst of politicization was increased. Partisanship, the social identity which is formed based on the sense of belongingness to the party was also highlighted by the election campaigns. These conditions created a more stringent environment in which to test the role of place-based identity as distinct from partisanship.

The results showed significant links between the level of rurality and attitudes about scientists and federal funding, even after controlling for party identification. In particular, compared to those who reside in large central metro areas, people who live in less urbanized areas (i.e., small metro and micropolitan areas) showed significantly less positive attitudes toward scientists and the federal funding on science and technology research. Meanwhile, in

terms of statistical significance, the effect of level of rurality was less consistent for residents of medium metro and noncore areas, where data revealed significant correlations either with attitudes toward scientists or with funding for science, but not both. Also, the associations of the level of rurality with attitudes toward scientists and science were not significantly moderated by attention to news on politics across all levels of rurality.

In line with previous studies exploring the associations of political predispositions and trust towards scientists (Hmielowski et al. 2014) and scientific issues, partisanship was associated with attitudes toward scientists and science. A significant main effect of party identification, for both Democrats and Independents, was linked to more positive attitudes towards scientists than for Republicans. However, no significant interaction effect of party identification and attention to political news was found on attitude toward scientists.

In contrast, the correlation between partisanship and attitudes toward federal funding of science and technology research was significantly moderated by attention to political news among Democrats who expressed more support for science funding as their use of political news increased. Meanwhile, this significant pattern of interaction between party identification and attention to political news was not observed among Republicans and Independents. There was a significant main effect for Republicans: Identifying as a Republican was associated with less support for funding regardless of attention to political news, when compared to Independents.

Based on these outcomes, it is clear that the level of rurality is associated not only with voting behavior and policy preferences but also with attitudes about science. Compared to those who reside in large metro areas, residents of less urbanized areas tended to have more negative attitudes toward scientists and science. It is important to note that the underlying mechanisms of these less positive attitudes in more rural areas are still unclear and should be explored more in

future studies considering the dissimilar local media environments and other socio-economic factors.

Given that the influence of level of rurality was not moderated by individuals' attention to political news, it is possible that rurality, along with attention to political news, has not been directly connected with the increasing politicization of science, at least as of 2016. One reason may be the decline in the resources to cover science not only in media outlets at local levels but also at a national level. Science journalists have departed from even major news organizations as resources have become more scarce (Dunwoody 2014), as a result, it is likely that people are being exposed to less science news in relation to their own communities, regardless of the level of rurality. That is, due to scarcity of resources to cover scientific issues at local levels, news about scientific issues could be "nationalized" and covered mainly in the context of national politics. This can explain insignificant associations between the interaction effect of the level of rurality and individuals' attention to political news on the attitudes toward scientists and science. A lack of news about science within local contexts may also lead to unfamiliarity and less positive sentiments toward scientists and science, as we found significant associations between the level of rurality and attitudes toward them.

I conducted a post hoc explanatory analysis to better understand the significant correlation between rurality and the attitudes toward scientists and science from the perspective of anti-elitism. Rural consciousness is rooted in perceived unfairness and the feeling of being abandoned by the people in power and those living in urban areas (Cramer 2016). Therefore, we can hypothesize that level of rurality in the place of residence would work in a similar way as

does anti-elitism and populism (Wells et al. 2021), sentiments present at a global scale, even against science (Mede and Schäfer 2020).

Based on this hypothesis for the post hoc analysis, I added the distrust of the government to the models presented in Table 2.2, as one of the central belief sets of rural resentment to predict attitudes toward scientists and science. However, the results of this post hoc analysis implied that scientists and politicians may be perceived as different kind of elites. When distrust of the government was added to the models, it was not significantly associated with attitudes toward scientists and science. This suggests that scientists may be perceived as distinct from political elites. Nonetheless, the results reported here are based solely on data collected during the 2016 election cycle. Hence, we need to be alert to the impact of events on attitudes in real time. The conflicts between the Trump administration and scientific communities amid the coronavirus pandemic in 2020, for example, could change these associations substantially.

It is also important to note other limitations of this study, including the operationalization of rurality. As Scala and Johnson (2017) point out, multiple operationalizations of rurality exist despite their common focus on two dimensions: distance from a metro area and population size. Differences in operationalization can lead to movement of counties across categories, possibly affecting the results of analysis. This study relied on a widely used measure of rural-urban codes to minimize the subjectivity of analysis. Also, by treating the codes as the categorical variables, I intentionally avoided assuming the linearity of the level of rurality. By doing so, I highlighted the significant differences toward attitudes toward scientists and science, rural-urban divides in science exist only between the certain comparisons, not all.

These efforts shed a light not only on the significant associations between the level of rurality in the place of residence and the attitudes toward scientists and federal funding of

science, but also on the non-linear associations between them. Specifically, this study showed significant effects of rurality in some more or less urbanized areas, but not in all areas, compared to large central metro areas, with the consistent pattern that residents in less urbanized areas tended to have more negative attitudes toward scientists and science. Such outcomes indicate that attitudes surrounding sciences do not linearly become negative contingent on the level of rurality, because the largest divide in the attitudes surrounding sciences were not found between the most and least urbanized areas.

This pattern was consistent even when the level of rurality was operationalized using other criteria, such as Rural Urban Commuting Area codes (U.S. Department of Agriculture 2019), and the percentage of urbanized land use, significant differences in the attitudes towards scientists and science were observed between rural and urban residents. Hence, while acknowledging the modest levels of variance explained in the models, this study suggests that rurality matters when considering attitudes toward science and scientists. Since the beginning of 2020, fear of the pandemic and increasing conflicts between science and politics surrounding the reaction to COVID-19 may exacerbate rurality's impact on attitudes toward scientific evidence, leading to serious place-based inequalities in accepting the benefits and reducing risks.

Study 1-2, Underlying Mechanisms of Rural-Urban Divides in the Attitudes toward Scientists:Socio-Economic Relative Deprivation, Psychological Distance from Higher Education, and the Decline of Local News

As demonstrated in exploration of the aforementioned Hypothesis 1 and Research Question1in Study 1-1, this study found that rural-urban divides indeed exist in the attitudes toward scientists and federal funding on science and technology research. Such geographic divides in these attitudes were not moderated by attention to political news, suggesting that the politicization of science has not occurred in relation to the place-based identity based on rurality in the place of residence, at least in 2016 when the data collection was completed. These results construct another new question, however: What would be the underlying mechanisms or factors that can explain such rural divides in the attitudes surrounding science?

As discussed above, rural-urban divides in voting behavior has been investigated in relation to a variety forms of relative deprivation. For example, Scala and Johnson (2017) revealed that vote shares for Trump was significantly predicted not only by rurality but also the dominant industry at each county. Monnat and Brown (2017) also illuminated that the more out-migration counties had in the past years, the more votes were given for Trump in the 2016 presidential election. Similarly, by employing multi-level analysis, Suk et al. (2020) demonstrated such contextual factors interact with the individual level factors, and determine individuals' evaluations toward political candidates. That is, individuals' digital media use and talk with family and coworkers about politics all significantly reinforced the effect of partisanship in predicting attitudes toward politicians (Scott Walker and Barak Obama). Furthermore, the cross-class interactions of individual-level party identifications and the county-level socio-economic relative deprivation, represented by changes in unemployment rate, health

distress, and population size were significantly correlated with these variables, implying that the effect of partisanship tended to be strengthened among people living in counties with more affluent, less precarious conditions during 2009-2012 exhibited more polarized attitudes toward these political candidates.

Based on these previous findings, will we be able to explain the underlying mechanisms of rural-urban divides in attitudes surrounding science? In this study, I explore the effects of population change and unemployment change due to the findings of Suk et al. (2020) and Monnat and Brown (2017), as the measures of relative deprivation based on social and economic inequalities *between* the counties. In addition, I further examine the following county-level variables.

The Variables to be Considered as the Underlying Mechanisms of Rural-Urban Divides in Science

1, *Gini index:* Relative deprivation is a psychological state of feeling deprivation compared to other groups, time, and regions (Walker & Pettigrew, 1984). Given this conceptualization, it is also possible to fee relative deprivation based on comparison with others who reside in the same region. Hence, I aim to capture relative deprivation within the county using this Gini Index for each county.

2, *The percentage of bachelor's degree holders for each county:* It should be noted that psychological and physical distance from "people in power" and those with professional

occupations who reside in city areas were one of the central foundations of belief sets among rural residents that abandoned and disrespected by urban residents (Cramer, 2016). In addition, considering a recent argument (Sandel, 2020) and empirical finding (Wells et al., 2021) that rural-urban divides are a form of anti-elitism, the psychological and physical distance from higher education should be explored as the potential significant factors predicting the attitude toward scientists (as scholarly elites) and scientific research (as intellectual products by scientists).

Hence, to quantify the psychological distance to higher educations, I examine *the percentage of bachelor's degree holders.* The higher percentage of bachelor's degree holders in a region can indicate a county-level feasibility of obtaining higher education, and therefore is expected function as a measure of psychological distance to higher education.

4, The availability of local newspapers at each county:

Rural-urban divides have been mainly explored in terms of rurality as well as economic, health, and social distress using county statistics in each region (i.e., median income, unemployment rate, and population size). In contrast, both in science and political communication, there are few articles investigating rural-urban divides from the perspectives of the information environment and exposure to media. As a result, it is still unclear as to what roles individual-level factors and the information environment play in filling the link between such societal level factors (economic, health, and social distress in each region) in rural areas and rural residents' values in determining attitudes toward scientists and scientific issues as well as their voting behavior (as one of a few exceptions, see Suk et al. (2020).

A potential candidate to fill this research gap is the literature available about the influence of a decline in the number of local newspapers (Darr et al., 2018) and adoption of high-speed internet that facilitates access to national news (Trussler, 2020) on political polarization and nationalization. According to Das, Sinclair, Webster & Yan (2018), nationalization is conventionally conceptualized as (1) individuals' consistent voting preference of political candidates based on their evaluations of the national parties (i.e., partisanship) whether or not election is at national or local level, and (2) the phenomena that state and local elections are fought over national issues rather than local issues. Also, Das et al. (2018) point out that this nationalization can occur especially when we witness changes in local media markets that prioritize national over local news (Hopkins, 2018; Martin and McCRAIN, 2019).

Here, we can find an interesting link between nationalization and rural-urban divides, both of which are affected by a similar information environment. It is, nationalization is likely to occur in rural regions where local media is declining due to a lack of economic sustainability, which we often observe in rural areas. In fact, the 'Expanding News Desert' project led by the Center for Innovation and Sustainability in Local Media at the University of North Carolina, pointed out as follows:

> "The residents of America's emerging news deserts are often its most vulnerable citizens. They are generally poorer, older and less educated than the average American. They are much more likely to live in rural areas of the country. Eighteen percent of residents are living in poverty compared with the national average of 13 percent"
>
> (The Expanding News Desert, 2018).

In other words, although the decrease in the number of local newspapers in each region does not necessarily correlate with rurality, rural residents are most likely to have been experiencing an information environment without the media that cover their own communities and the news representing their voices. Coupled with the availability of national news and other online information resources, people living in the 'local news deserts' may be forced to expose themselves to information mainly about national news via both offline (Darr et al. 2018) and online media (Hindman, 2011; Trussler 2020). Consequently, there is a possibility that rural residents are exposed more to information about the central government rather than the local government in their communities, as well as to the voices and opinions of stakeholders at the national level relative to the ones from the representatives of their regions. Rural consciousness, a class- and place-based social identity (Cramer, 2016) and a form of relative deprivation, can be developed in this way as a product of lack of local media that can cover information about rural residents' needs and the voices representing them.

Also, this tendency might be strengthened by the availability of national news and other news resources, which mainly cover political and economic issues at country level and social actors relating to the U.S central government. Following this, we can hypothesize that rural-urban divides in voting behavior can be explained as the outcomes of nationalization and decline of the number of local newspapers. That is, as Darr et al. (2018) imply, the decline of the number of local newspapers is associated with polarized voting behavior possibly because exposure to national news can strengthen people's reliance on cheap party cues rather than other information to be considered such as candidates' career and past accomplishments. Similarly, Hopkins (2018)

suggests that increased choices of media at national level can lead to the other two problematic phenomena in democracy in local politics such as: 1) decreased knowledge about local politics and 2) lower level of political engagement at the local level. All of these outcomes suggested by Hopkins (2018) are confirmed by the empirical studies (decreased knowledge about local politics and representatives: Hayes and Lawless, 2015; Peterson, 2019), less engagement in local politics (Hayes and Lawless, 2018).

Drawing parallels with the findings of nationalization, we can hypothesize that similar phenomena are occurring in the attitudes toward scientists and scientific issues too. That is, we can postulate that 1) the decline of and/or lack of local news motivated individuals go online to seek news and expose themselves to national news which often includes party cues and is influenced by the polarized political environment, 2) and as a result, compared to those who are living in urban areas, among the residents who reside in rural areas, their attitudes toward social actors, not only political candidates but also scientists, can be more polarized based on their party identification. (i.e., attitudes toward scientists and science can be nationalized and influenced by party identification in the same way as voting behavior).

Based on these previous findings, I explore if *the availability of local newspaper for each county* is correlated with the attitudes toward scientists and political elites.

Research Question and Hypothesis

As discussed above, there are multiple potential factors to be explored as underlying mechanisms of significant rural-urban divides in the attitudes toward scientists and science: 1)

socio-economic relative deprivations (i.e., change in unemployment rate, population size which were shown to be the significant predictors of the evaluations toward political elites in Suk et al., (2020), and change in Gini index), 2) psychological distance from higher education (i.e., the percentage of bachelor's degree holders), and 3) the availability of local newspapers, as a driving force of nationalization and its undesirable outcomes in local politics and voting behavior (Hopkins, 2018). In Study 2, therefore, I investigate the effects of these county-level variables as below.

RQ1: Will we find significant mediations between rurality and the attitudes toward scientists via socio-economic relative deprivations, psychological distance from higher education, and the availability of local newspapers as the underlying mechanisms of rural-urban divides?

In addition, based on Suk et al. (2020)'s finding and Hopkins (2018), individual-level party identification can moderate these mediating processes of the county-level variables. The effect of party identification on the evaluation toward politicians were significantly moderated based on socio-economic relative deprivations in Suk et al. (2020). Given their potential mediating effects between rurality and the attitude toward scientists, the moderation effect of partisanship are also worth exploring. Hence, the RQ2 set as follows.

RQ2: Will partisanship moderate the mediating processes of the aforementioned socio-economic relative deprivations, psychological distance from higher education, and the availability of local newspapers?

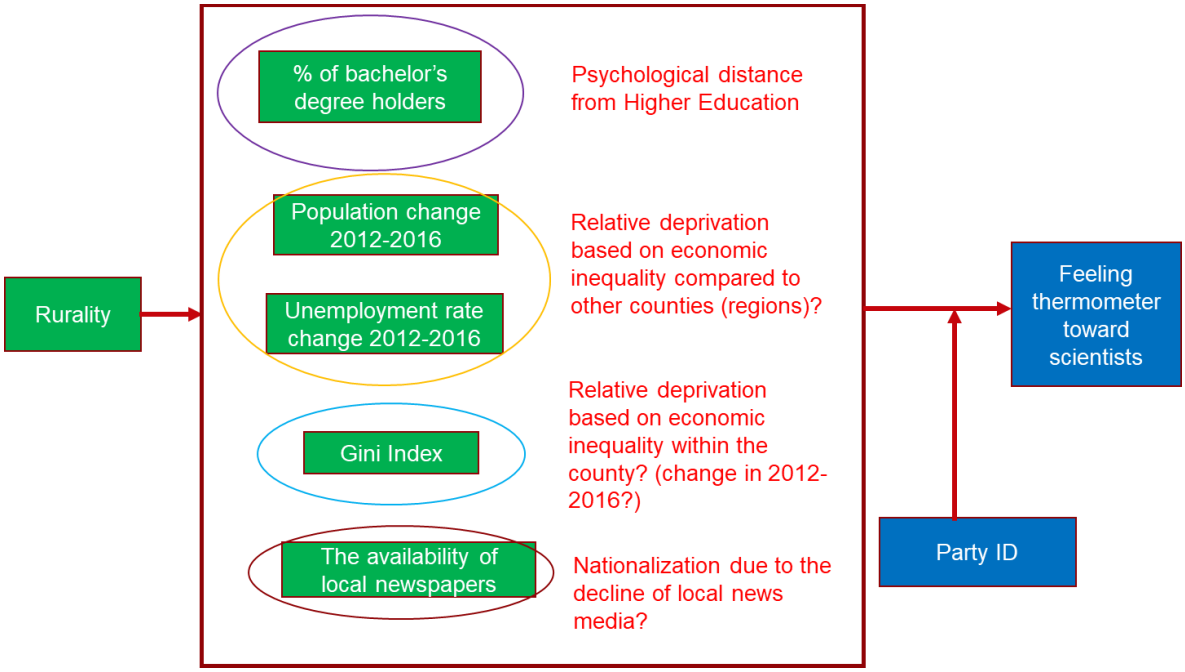

Figure 2.2, Explored Underlying Mechanisms of Rural-Urban Divides in the Attitudes toward Scientists in Study1- 2

Methods

Data

Similar to Study 1, I relied on the 2016 American National Election Studies (ANES) data, which were collected during the 2016 presidential election cycle, tracking a representative sample of 5,680 respondents. All the variables employed here were administered only in the post-wave survey; hence, the present study is a cross-sectional analysis.

Measurements

Dependent variables

Attitude toward scientists: I created these variables by using the questions about *the feeling thermometer toward scientists*

Independent Variables

Individual Level Variable

Demographics: Following Study 1, the following variables were used for control purposes: *gender*, *age*, *educational attainment*, *family income*, and religiosity (Please refer to the Study 1 for the descriptive statistics for these variables).

Partisanship: Unlike Study 1, in order to conduct multi-level moderated mediation analyses, I used a seven-point scale of partisanship and treated it as a continuous variable. If partisanship is operationalized as an ordinal categorical variable, the models this study need to explore become too complicated to fit by using the existing statistical software programming and packages such as R and Stata. Respondents identified their party identification ranging from 1 (Strong Democrat) to 7 (Strong Republican) and 4 (Independent) was located as the midpoint of this

scale (*M* = 3.86, *SD* = 2.15). In the following analyses, those who chose the other categories including "Don't know" and "Refused" were excluded (N = 23, 0.54 %).

Attention to political news: Similar to Study 1, I included attention to political news to controll its potential moderating effects on predicting the attitudes toward scientists by interacting with partisanship.

Contextual Variables

Rurality: Similar to Study 1, I used the 2013 National Center for Health Statistics (NCHS)'s Urban-Rural Classification Scheme for Counties (Ingram and Franco, 2014) to quantify the level of rurality in the place of residence for each county. This NCHS categorization is based on the 2013 Office of Management and Budget's (OMB) delineation of metropolitan statistical areas (MSA) and micropolitan statistical areas, and have detailed categories useful to classify metro areas into large "central" metro (akin to inner cities) and large "fringe" metro (akin to suburbs) (Please see Table 2.1 for the details about this classification scheme).

However, to make the following multi-level Structural Equation Modeling (SEM) simple, I created a categorical variable with the three categories (1= Urban, 2 = Suburban, and 3 = Rural areas) for this study. There were 51.98 %(urban), 34.04 % (suburban), and 13.98 % (rural) respondents residing in regions of each of these categories. As demonstrated in Figure 2.2, rurality serves as the independent variable (X) in the hypothesized model in this study. Consequently, keeping all the six categories of the 2013 NCHS code had to be avoided for the model's simplicity and computability.

Social and economic inequalities between and within the counties: Following the finding in Suk et al.(2020), this study assessed the social and economic inequalities as an index of relative deprivation *between* counties by *Population change* (*M* = 5706.43, *SD* = 51075.2) and *Unemployment rate change (Mean* = 2.60 , *SD* = 1.81*)* in 2012- 2016 for each county. In addition, I also included *the Change of Gini Index* in 2012 to 2016 for each county (*M* = 0.009, *SD* = 0.025), aiming to illuminate the effect of perceived relative deprivation compared to those reside *within* the same county. These statistics were derived from the estimations made by the 2012 and 2016 American Community Survey.

Proportion of Bachelor's degree holders was employed to capture psychological distance from higher education and elites in general: the feasibility to obtain and access to higher educations. This variable was measured by the percentage of population whose age is 25 and over 25 holding bachelor's degree in each county (*M*= 20.34, *SD* = 9.08).

The availability of local newspapers: To measure this variable, I relied on the data provided by the News Desert Project led by to create this variable for each county in the year of 2016. Specifically, I used the amount of circulation of the local newspapers observed in 2016 per the estimated number of households for 2016 at the county-level. As described in the News Desert Project (2018), there are some limitations to track the market reach of local newspapers completely. Consequently, it is hard to measure the availability of local newspapers at the county-level (defined as the amount of circulation of the local newspapers divided by the number of households for each county), especially when the market reach of the local newspapers split into multiple counties. In such cases, I measure the availability of local newspapers by dividing

the sum of the total circulation of local newspapers by the sum of the number of households of the counties where these local newspapers were listed.

In the year of 2016, the total number of local newspapers listed by the News Desert Project is 6736. In terms of county-wise descriptive statistics, there are 157 counties with zero local newspapers circulated, and 59 respondents who provided their answers to the 2016 ANES survey resided in such counties. In general, the distributions of the number of available local newspapers for each county was heavily right-skewed, so did the percentage of the total circulation of local newspapers per households (*Mean* = 9.73, *SD* = 12.55, *Median* = 5.89, *Min* = 0, *Max* = 786.00).

Analytic Strategy for Testing Moderated Mediation Models with Multi-Level Analysis

To explore the RQs of Study 1-2, I employed a multi-level analysis to compute the Intraclass Correlation Coefficients (ICC) (discussed below) and a multi-level Structural Equation Modeling (SEM) by predicting the final dependent variables (the attitudes toward scientists) by all the control and independent variables as well as the hypothesized mediating and moderating variables (see Figure 2.2 for the models explored in this Study 1-2). By doing so, this study explored which county-level variables and cross-level interactions of them with individual level variables can significantly mediate the associations between rurality and the attitudes toward scientists.

In the first multi-level analysis, the Intraclass Correlation Coefficients (ICC), the degree of association among observations within the same county, of the attitudes toward scientists and was 0.134. About 13.4 % of scientists, the evaluation were attributable to county-level

differences. ICC for the state-level for the model predicting the attitude toward scientists were 0.012, 1.2% were attributable to the state-level differences. Considering these outcomes and the RQs of Study 1-2, I estimated multi-level random intercept models as our baseline models, starting from a simple random intercept model with only fixed effects, more complex models with the random effects and cross-level interactions followed.

These exploratory data analyses as well as the results of model fit comparisons showed that a random intercept at county-level model was appropriate for the models predicting the attitudes toward scientists. This suggests that the attitudes toward scientists for each county have variant intercepts (mean) at county level with invariant slopes (rate). Meanwhile, because of the poor model fits, I did not include such random effect in estimating the associations between rurality (X) and the county-level mediating variables (M) in the multi-level SEM (in which Y was predicted by X and all the possible Ms together simultaneously, please see Figure 2.2 for the models explored in this Study 1-2 and the variables used for X, M, and Y, respectively).

Also, due to the concern for multi-collinearity, I tested bivariate correlations of the aforementioned county-level variables and VIF by regressing one of these county-level variables by the rest of the county-level variables. As we can see below, there were relatively moderate correlations between these county-level variables. However, the values of VIF were low enough (less than 2.0) to justify including all of these county-level variables as the mediating variables explaining the link between rurality and the attitude toward scientists. Hence, the multi-level SEM analysis I demonstrate below included these county-level variables as the potential mediators.

Table 2.4 Pair-Wise Correlations between the County-Level Variables of Study 1-2

	Share of bachelor's degree holders	Availability of local newspapers	Unemployment rate change
Share of bachelor's degree holders		-0.38	-0.1
Availability of local newspapers	-0.38		-0.15
Unemployment rates change	-0.1	-0.15	
Population size change	0.41	-0.46	0.11
Gini index change	-0.07	-0.04	0.17
	Population size change	Gini index change	
Share of bachelor's degree holders	0.41	-0.07	
Availability of local newspapers	-0.46	-0.04	
Unemployment rates change	0.11	0.17	
Population size change		-0.09	
Gini index change	-0.09		

Table 2.5, VIF of the County-Level Variables of Study 1-2 (When One of These Variable was Predicted by the Rest of County-Level Variables)

	Share of bachelor's degree holders	Availability of local newspapers	Unemployment rates change
Share of bachelor's degree holders		1.046379	1.11569
Availability of local newspapers	1.081751		1.162148
Unemployment rates change	1.029423	1.037227	
Population size change	1.073048	1.036881	1.078484
Gini index change	1.019365	1.017817	1.011752
	Population size change	Gini index change	
Share of bachelor's degree holders	1.133606	1.140438	
Availability of local newspapers	1.132426	1.177199	
Unemployment rates change	1.051252	1.044398	
Population size change		1.080972	
Gini index change	1.020741		

Table 2.6, Multi-level SEM Predicting the Attitudes toward Scientists

Multi-Level SEM Predictig the Attitude toward Scientists (X -> M paths)

	Population change
Rurality (1=Suburban vs Urban)	-0.74*
Rurality (1=Rural vs Urban)	-0.90*
	% bachelor's degree holders
Rurality (1=Suburban)	-0.75*
Rurality (1=Rural)	-1.60*
	Change in Gini index
Rurality (1=Suburban)	-0.09
Rurality (1=Rural)	-0.06
	Unemployment rate change
Rurality (1=Suburban)	-0.28*
Rurality (1=Rural)	-0.55*
	Availability of local newspapers
Rurality (1=Suburban)	0.36*
Rurality (1=Rural)	1.30*

Multi-Level SEM Predictig the Attitude toward Scientists (X & Ms -> Y paths)

X & Ms -> Y	Scientists
Individual-level variables	
Gender (1= female)	-0.19
Age	0.003
Family income	0.10
Education	0.65*
Religiosity	-2.07*
Party ID (7 = strong Republican)	-1.33*
Attention to political news	2.88*
Party ID*attention to political news	1.05*
County-level variables	
Rurality (1=Suburban vs Uban)	-0.58
Rurality (1=Rural vs Urbam)	-1.85

% bachelor's degree holders	1.64*
Population change	1.05*
Unemployment rate change	0.30
Gini index change	0.13
The availability of local newspapers	-0.66
Cross-level interactions	
Party ID*	
% of bachelor's degree holders	-0.003
Population change	0.06
Unemployment rate change	0.07
Gini index change	-0.46
The availability of local newspapers	0.47
N	3,649

Note: * $p < 0.05$, coefficients are not standardized. (the county-level mediating variables are standardized)

Results

In Table 2.6, I demonstrate the results of the multi-level SEM analysis predicting the attitudes toward scientists. In particular, the first part of the results in Table 2.6 describes the estimated coefficients of all the X (i.e., rurality) to M paths (i.e., explored county-level variables as the potential factor explaining the underlying mechanisms of rural-urban divides in the attitudes toward these social actors). The second part of Table 2.6 indicates the estimated coefficients for the paths from all the Ms to the final predicting variable, the attitude toward scientists. In addition to these paths, the cross-level interaction effects of the mediating variables with partisanship and the individual-level control variables were included in this part of the model. We should note that these two parts of the model were estimated simultaneously by fitting the multi-level SEM model by including the X to Ms paths, the X and Ms to Y paths, and

the control variables altogether. The model can thereby test mediation processes based on the method recommended in Preacher, Zyphur, & Zhang (2010).

In the first part of this multi-level SEM, except for Gini index change (Suburban: b = -0.09 (n.s.), Rural: b = -0.06, (n.s.)), rurality has significant correlations with all the explored mediating variables in this study. Population size change (Suburban: b = -0.74, Rural: b = -0.90), the share of bachelor's degree holders (Suburban: b = -0.75, Rural: b = -1.60), and unemployment rate change (Suburban: b = -0.28, Rural: b = -0.55) were all negatively and significantly associated with rurality. The availability of local newspapers (Suburban: b = 0.36, Rural: b = 1.30) had a significant positive correlation with rurality.

In the second part of the multi-level SEM predicting the attitude toward scientists, rurality (Suburban: b =-0.58, Rural:b = -1.85) became insignificant, showing the lack of significant direct effect of rurality on this predicted variable. Also, among the mediating variables found to be significant in the first part of the SEM (X to M paths), only two variables reached the 5% significant level: population size change (b = 1.05) and the share of bachelor's degree holders (b = 1.64). None of the cross-level interaction terms between the county-level mediating variables with partisanship was significant.

Based on these outcomes in the multi-level SEM analysis, I conducted a formal assessment of mediation for all the county-level mediating variables except for the Gini index change using Hayes (2013)'s bootstrap technique, because of the insignificant assocaiton of the Gini index change and rurality (i.e., X->M path failed for this variable). By doing so, this study produced confidence intervals (CI) for the indirect effect based on the distributions obtained from the dataset. As shown in Table 2.7, the result obtained by the bootstrapping method

indicated the significant mediation process in the relationship between rurality and the change in population size (Suburban: b = - 0.7836801, SE = 0.3672418, CI[-1.503461, -0.0638995], Rural: b = -0.9439777, SE = 0.4197124, CI[-1.766599, -0.1213566]). In addition, a significant indirect effect was found between rurality and the share of bachelor's degree holders (Suburban: b = -1.229528, SE = 0.3417381, CI[-1.899323, -0.5597341], Rural: b = -2.625638, SE = 0.7269775, CI[-4.050487, -1.200788]). Meanwhile, the rest of the county-level mediating variables tested in this study did not have a significant indirect effect (Please see Table 2.7 for these assessments of indirect effects).

Table 2.7, Mediation Analyses using Bootstrap Technique

	Population change
Rurality (1=Suburban vs Urban)	- 0.783680* (0.3672418), CI[-1.503461, -0.0638995]
Rurality (1=Rural vs Urban)	-0.9439777* (0.4197124), CI[-1.766599, -0.1213566]
	% bachelor's degree holders
Rurality (1=Suburban)	-1.229528* (0.3417381), CI[-1.899323, -0.5597341]
Rurality (1=Rural)	-2.625638* (0.7269775), CI[-4.050487, -1.200788]
	Unemployment rate change
Rurality (1=Suburban)	-0.0850849 (0.1108636), CI[-0.3023735, 0.1322038]
Rurality (1=Rural)	-0.1677773 (0.2030065), CI[-0.5656627, 0.230108]
	Availability of local newspapers
Rurality (1=Suburban)	-0.241985 (0.1626521), CI[-0.5607773, 0.0768074]
Rurality (1=Rural)	-0.8646295(0.5579008), CI[-1.958095, 0.228836]

Note: * $p < 0.05$, coefficients are not standardized.

In sum, the percentage of bachelor's degree holders and the change in population size for each county were positively associated with a more positive attitude toward scientists. As the underlying mechanism of rural-urban divides in such an attitude, the lower share of bachelor's degree holders and decreased population size in 2012-2016 in suburban and rural areas compared

to urban areas mediate the link between rurality and the attitude toward scientists completely. In addition to these tested mediation effects, some individual-level control variables included in the models were shown significant at 5 % level in predicting the attitude toward scientists (education: b = 0.65, religiosity: b = -2.07, party identification: b = -1.33, attention to political news: b = 2.88, party identification*attention to political news: b =1.05).

Discussion

Based on the results of Study 1-1, this Study 1-2 explores the effects of county-level variables as the potential underlying mechanisms of rural-urban divides in the attitude surrounding scientists and science. In particular, following previous findings such as Suk et al. (2020) and Monnat and Brown (2017), this study examines the mediation effects of 1) population change, and 2) unemployment rate change as the indexes of relative deprivation based on socio-economic disparities between counties. In addition to these variables, I further tested mediation processes through the other county-level variables, including 1) Gini index change (as the index of relative deprivation based on socio-economic disparities within the counties, 2) the availability of local newspapers (as the cause of nationalization in information environment), and 3) the percentage of bachelor's degree holders as the measure of psychological distance from higher education. Among these variables, the percentage of bachelor's degree holders and change in population size at the county-level significantly and completely mediates the link between rurality and the attitude toward scientists.

The complete mediating processes via the percentage of bachelor's degree holders suggest one possibility. The accessibility to obtaining higher education and the potential to

interact with those possessing degrees in higher education can promote shared pro-science values: scientific research and its products are not monopolized by scientific elites but accessible to lay audiences. It is likely that in the eyes of individuals who reside in counties where are rural and receiving higher education is not that widely common, scientists are perceived as the social actors who do not share values with them. Based on such interpretation, we need to be aware of the possibility that such a community-based gap in obtaining higher education may result in the trust gap toward scientists.

Moreover, the significant mediation between rurality and the attitude toward scientists via the change in population size implies that the attitude toward scientists was immune from the effect of socio-economic disparities. We need to consider the significant mediating effects of the share of bachelor's degree holders and change in population size altogether. Rural-urban divides in the attitudes surrounding science and scientists are likely attributable to the dissimilar level of dependence on higher education in the dominant industries in urban, suburban, and rural areas. The rise of the internet and technology (IT) industry in the past decades has created high demand for jobs requiring higher education. Such industry tends to flourish in large cities and attract more and more people with degrees in higher education to urbanized areas. Consequently, our society as a whole may have been sorted by skills and education level, making values toward science diverged between urban, suburban, and rural residents.

We need further studies to investigate if such an interpretation is valid. However, these community-level educational and socio-economic disparities would be challenging to fix in the current knowledge society. Hence, for all social actors who try to communicate about science, it

is crucial to keep in mind that these community-level disparities can be significantly reflected in disparities of the effectiveness of science communication.

Despite these findings, it is worth mentioning a few shortcomings of Study 1-2. First, due to the limited function of statistical software used to conduct multi-level SEM analysis, the results I reported did not disentangle between and within county effects when estimating the mediation processes between rurality and the attitude toward scientists. To better understand the underlying mechanisms of rural-urban divides in the attitude toward scientists, it is necessary to conduct a more accurate assessment of mediating effects. Second, the data used for this study was obtained via a cross-sectional survey, allowing us to test correlation but not causality between the variables in the hypothesized model in this study. Future studies should consider using longitudinal data to evaluate the underlying mechanisms of rural-urban divides more rigorously.

Amid the COVID-19 pandemic, the visibility of scientists in media coverage, including political news, has escalated dramatically. The Unemployment rate and infection rate of the virus have also increased unevenly in tandem with a noticeable change in the visibility of scientists in media coverage. Therefore, it is exceptionally crucial to track the associations between the variables explored in this study and the attitudes toward scientists. Study 1-1 and Study 1-2 both imply some potential perils of the politicization of science under the pandemic. Due to the inevitably increased visibility of scientists who are making decisions in political and economic issues, the community-based gaps in education and socioeconomic disparities may interact with party identification and increasingly can affect the attitude toward scientists like the one toward political elites, as suggested in Suk et al. (2020).This peril will be especially true if scientists are

perceived as the elites who do not share essential values with people who reside in these areas and if their communities suffer from increasing socio-economic disparities. In addition to individual-level variables, attention to community-based variables explored in this study is needed than ever before to communicate about scientific issues, such as vaccination and the pandemic.

Chapter 3: Study 2, Will Social Media Narrow or Enlarge Rural-Urban Divides in the Public Discourse on Scientific Issues?: A Case of Climate Change Amid the COVID-19 Crisis

Current society is characterized by the ubiquitous presence of social media, in which anyone with an internet connection can read and share online news via social media platforms regardless of the credibility of information sources and news itself. Users can also post their own opinions with little skill, effort, or time. Because of these advantages, social media can potentially play a key role in society by functioning as a supplementary or even main information source in the regions experiencing a decline in local news. In other words, social media might to some extent be able to fill information gaps especially in relation to the local news environment, and thereby could mitigate possible negative outcomes of the decline of local newspapers, including nationalization (Hopkins, 2018) and political polarization (Darr et al., 2018).

That is, as Darr et al. (2018) imply, the decline of the number of local newspapers is associated with polarized voting behavior, possibly because exposure to national news can strengthen people's reliance on cheap party cues rather than other information to be considered such as candidates' careers and past accomplishments. Similarly, Hopkins (2018) suggests that increased choices of media at the national level lead to two other problematic phenomena in democracy in local politics: 1) decreased knowledge about local politics and 2) lower level of political engagement at the local level. All of these outcomes suggested by Hopkins (2018) are confirmed by empirical studies on decreased knowledge about local politics and representatives, as well as less engagement in local politics (Hayes and Lawless, 2015).

To be sure, it is necessary to consider the quality of news circulated on social media as a

potential candidate of supplementary media for declining local traditional media. In particular, given that some previous studies pointed out that social media is the main platform where misinformation is circulated, because of mechanisms that can promote echo chambers and homophily (Altay et al., 2020), in terms of quality, we should not await the gatekeeping role in social media to the same extent as traditional media do.

On the other hand, we cannot pretermit possible detrimental consequences of the decline of local media, such as a lower level of participation and knowledge in local politics (Hayes and Lawless, 2015). Although local media use depends on both individuals' media preferences and the local news environment, exposure to local news was associated with local ownership and engagement with the community, and thereby can cultivate an affinity relationship. National media usage, however, moved the focus of individuals out of their community and "constituted opting out of the place" even in rural areas where interviews were conducted (Metzler, 2021).

Based on these studies on the alarming effects of the decline of the local news media environment, it is essential to explore how social media is functioning as a platform to obtain and share information with local contexts, in relation to the level of rurality and the availability of local news. This study therefore aims to serve as one of the early attempts in this line of exploration. By doing so, this study explores what topics were used to discuss climate change, and how individual and contextual level factors, (i.e., the level of rurality in the place of residence and the availability of local newspapers) interact each other, and ultimately can affect the associations between these factors and topical frames in the public discourse on climate change.

Specifically, I relied on Twitter data posted about climate change from January 31 to

April 30 of 2020, during the early stage of the COVID-19 pandemic. On January 31, 2020, the World Health Organization (WHO) declared coronavirus a public health emergency, and the U.S. government ordered all American citizens returning from the Wuhan, China, region to be quarantined for two weeks. In addition, the U.S. Centers for Disease Control and Prevention (CDC) also updated its interim guidance for health care professionals on this date, expanding the criteria for identifying patients under investigation for novel coronavirus (Jernigan, 2020). Following this, on March 11, WHO declared COVID-19 a pandemic and the Trump administration also declared COVID-19 a "national emergency." On March 19, California became the first state to issue a stay-at-home order, mandating all residents to stay at home except to go to an essential job or shop for essential needs (The American Journal of Managed Care (AJMC), 2021).

To date (July 3, 2021), the issue of the COVID-19 pandemic has not only been politicized and polarized even in the early stage of its development (Hart et al., 2020), this worldwide peril has limited geographical mobility to an unprecedented extent. The pandemic has greatly increased online communication as well, because of the stringent restrictions on in-person social interactions posed by "stay-at-home orders" and fears of getting infected by the virus that causes COVID-19. As a result, unfortunately yet interestingly, the COVID-19 pandemic has raised the importance of all the following factors: the effects of partisanship, the awareness of the local community in the place of residence, and online communication, including social media. Considering that many companies and schools moved their operations online, and some decided to allow their employees to work remotely for more than a year, satisfying all the conditions above might represent a "new normal" in the near future.

Hence, with the Twitter dataset generated during the aforementioned period, we can not only examine but also predict how social media is functioning (or will function) as a platform to obtain and share information with local contexts, but how we should design social media platforms to build meaningful and healthy discussion about universal issues such as climate change.

The Limited Role of Online Media in Local News Environments

Although previous studies warn of detrimental effects on local communities and politics resulting from the decline of local news environment (Hayes and Lawless, 2015; Hayes and Lawless, 2018; Darr et al., 2018), not much scholarly work has explored the possibility of the online media, including social media, to supplement the deficit of local news and mitigate these undesirable outcomes. Furthermore, this strand of studies prohibits us from having an optimistic view on the supplementary role of online media in the local news environment. For example, by tracking individuals' web browsing records, Hindman (2011) revealed that the reach of online local news media (websites of local news TV and radio stations, newspapers as well as local online news sites) was generally very low. Also, the content of these local online news was found to be very similar with the news covered in traditional news media operating those online news websites in this study.

The low cost of editing and spreading news in the online media platform did not contribute to adding local contexts and diversifying the content based on communities' needs. In other words, it is too optimistic to expect that the internet will increase web-based local news

outlets and therefore can expand the voices of local news, which can subsequently fill gaps in the shrinking traditional local news coverage.

Along with Hindman (2011)'s finding, Trussler (2020) demonstrated that the higher adoption rate of broadband internet has a significant correlation with increased nationalization. Stated simply, it implies that not only does online media not provide alternative sources of local news which can draw sufficient viewership, but it exacerbates the decline of interest in and knowledge of the local community in the regions experiencing a decline of local news.

Social Media as a Potential Platform for Promoting the Public Discourse and Information Sharing with the Local Contexts

Similar to studies about online media in the context of the local news environment, ample knowledge has not accumulated yet for the role of social media as a platform to obtain and share information about news *with local contexts*. As one of the initial efforts, Das et al. (2018) examines how local politicians (mayors and governors) employ the social media platform Twitter to express their opinions and thereby reach out to their constituencies, and how geographical factors such as population size can affect the content they post. As a result, Das et al. (2018) found a nationalized discourse only in gubernatorial rhetoric and not mayoral rhetoric. The gubernatorial rhetoric in tweets closely matches that of members of Congress, which include rhetoric with a national context, whereas the emphasis of mayoral speech was on local issues. In this regard, Twitter is functioning to spread information about local communities.

Also, in the public discourse about Brexit, physical distances between users did not necessarily correlate with increased interactions among them on the Twitter platform (Bastos,

Mercea, and Baronchelli, 2018). Alternatively, frequent retweets and mentions were observed either between and within large cities or within smaller towns. Although the focus of this study is the patterns of retweets and the shared contents via retweets, its finding also suggests that Twitter has a potential to serve as an information infrastructure to obtain and share news with local contexts, especially in smaller towns.

In addition, in social media, individuals can sometimes lead the agenda and topical frame setting in some issues such as natural disasters, followed by traditional media (Neuman, Guggenheim, Jang, and Bae, 2014). Similarly, Guggenheim et al. (2015) imply that frame setting can be reciprocal rather than one-directed between mass media and audiences, in which frames used by the public can affect the frames used by traditional media coverage. In other words, the direction of traditional agenda-setting and framing from mass media to the public is changing in a more interactive way in the age of digital media. Even when local news is not covered by traditional media due to its declining resources, people can still obtain and share important information about local communities, which may be further picked up and reported by traditional media.

Potential Rural-Urban Divides in Science Communication and Social Media

With the aforementioned potential of social media in the local information environment in mind, it is worth exploring if and to what extent lay audiences, journalists, politicians, and scientific experts are trying to fill the gap in the need of information about science in relation to local contexts by employing social media. In science communication, however, how online media including social media relates to local media as well as news with local contexts is even more complicated and not fully uncovered.

According to Dunwoody (2014), along with the decline of science journalism as a specialty, fewer resources have been allocated to cover sciences in the past decades even in the national legacy media such as the *New York Times*. Such a trend can be more emphasized in local media including local newspapers which have less human and financial resources for reporting about sciences, leading to a smaller amount of coverage about sciences with local contexts. To this point, regardless of national or local media, traditional media can be less influential as the supplier of science information specifically in local contexts due to the decline of resources available to science journalism.

Meanwhile, in tandem with the decline in resources to cover sciences even in the national legacy media, news reports about science and technology have become based more on online sources such as online news releases from universities and scientific journals (Schäfer, 2017). Also, in the demand side of science communication, we witness the shift to the online media environment. Now that audiences turn more and more to blogs and other non-traditional online media sources to seek information about specific sciences (National Science Board, 2012), this trend would have been even reinforced in the recent years due to the generational shift.

As a result, what people find and encounter in online media environments has become increasingly crucial in communicating about scientific issues because of the needs in both the supply and demand sides in science communication. In the current highly polarized U.S. society, however, science is not immune to the influence of political and ideological divides, and the impacts of politicization and polarization of science are observed in social media in sharing of information (Brady et al., 2017; Jang and Hart, 2015). Considering the rise of place-based identity (Munis, 2020), otherwise known as rural-urban divides in the 2016 and 2020 elections,

geographic factors warrant more exploration as another important axis of divides in the values, information sharing, and the public discourse on social media.

Research Questions

The literature discussed above raises several questions. Specifically, in relation to the findings about the decline of local news media (Darr et al., 2018) and resulting increase in exposure to (nationalized) news via online media (Trussler, 2020), will we see the impacts of nationalization in the public discourse about scientific issues in local news deserts? Or, given that science journalism has been suffering in the national legacy media (Dunwoody, 2014) and local media, information about sciences in social media may have been already "nationalized" much earlier than political issues. If this is the case, will we see a nationalized public discourse about scientific issues, regardless of the availability of local news and the level of rurality in social media?

These are all the essential questions to be explored to have a good understanding of potential unequal access to science information based on geographic factors, and further to promote participation in "civic science" regardless of physical locations. Nevertheless, again**,** only a small number of studies exist which examine the associations between geographic factors, including rurality and local information environment, and the public discourse and information sharing about science in local contexts**.** Following such a need, I set the following research questions.

RQ1: Will we find differences in the share of tweets and the kinds of discussed topics in the public discourse about scientific issues in social media (i.e., Twitter) on the basis of geographic factors (i.e., rurality and the availability of local newspapers)?

RQ2: How will the contextual factors we explore in RQ1 interact with each other, and relate to individual-level factors such as political ideology to predict the kinds of discussed topics on Twitter?

Methods

Data

Despite the limited availability of geographical information of users, based on the RQs of this study, Twitter is about the only social media platform where we can access information about users' residential information, the contents of posts, and the estimated political ideology based on the follower relationships (Barberá et al., 2015). Also, unlike other social media platforms such as Facebook, Twitter is a great platform from which to collect a massive amount of data about public discourse, thereby enabling the researcher to observe a variety of expressed opinions as well as the process of information dissemination among users. Thus, I collected tweets posted in the U.S. about climate change, one of the most polarized and politicized scientific issues, from January 31 to April 30, 2020.

In particular, I collected Twitter data about climate change posted by American users via the platform provided by a private company, Synthesio. I collected the Twitter data on a daily

basis. Synthesio puts a 50,000-post limit on every data scraping, and because of this, the data we obtained through this method is limited to either a full sample for the days when the number of tweets about climate change did not exceed the 50,000 limit or the random samples of the tweets I intended to collect for the days when the number of daily tweets hit this cap. As a result, after removing the tweets posted by users whose location information was not accessible due to their privacy settings, 1,108,750 tweets (including retweets) were included in the initial stage of the following data analysis.

Data Analysis 1, Structural Topic Modeling (STM)

To explore the aforementioned RQs, I conducted structural topic modeling (STM) (Roberts et al., 2014). By doing so, this study investigated the topics used in tweets to discuss climate change, which was further employed in the following multi-level data analyses to examine how the proportions of these topics associated with individual and contextual factors of this study. After completing the standard data-cleaning process and fitting the models by including the date when tweets were posted as a predictor of the prevalence of topics, I compared models with a broad range of k (i.e., the number of topics) (10-100) to find the most optimal and interpretable model.

For this model selection process, I used a random sample of 10% of the obtained data due to the constraints of computing power. The model selection (determining the number of topics, k) was made in terms of held-out, residuals, coherence, and exclusivity (Figure 3.1). Among several criteria, this study prioritizes coherence and exclusivity, because these measures are essentially a trade-off (i.e., high coherence can be easily attained by having a few topics dominated by very

common words), and therefore serve as the informative criteria to determine the optimal number of topics (Roberts et al., 2014). In Figure 3.2, I plotted coherence against exclusivity for the models with k = 2 to 20 topics and qualitatively assess several candidates that generate the most semantically coherent and interpretable topics.

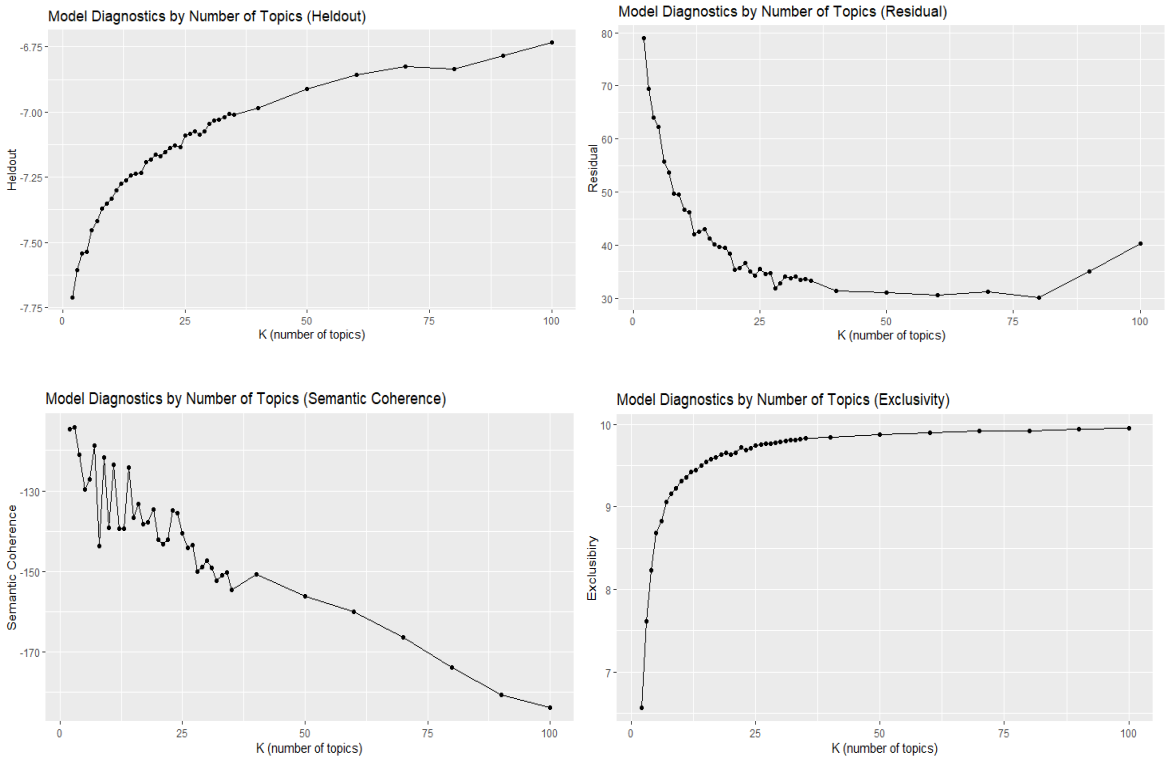

Figure 3.1, Diagnosic Values for Selecting the Optiomal Number of Topics in STM

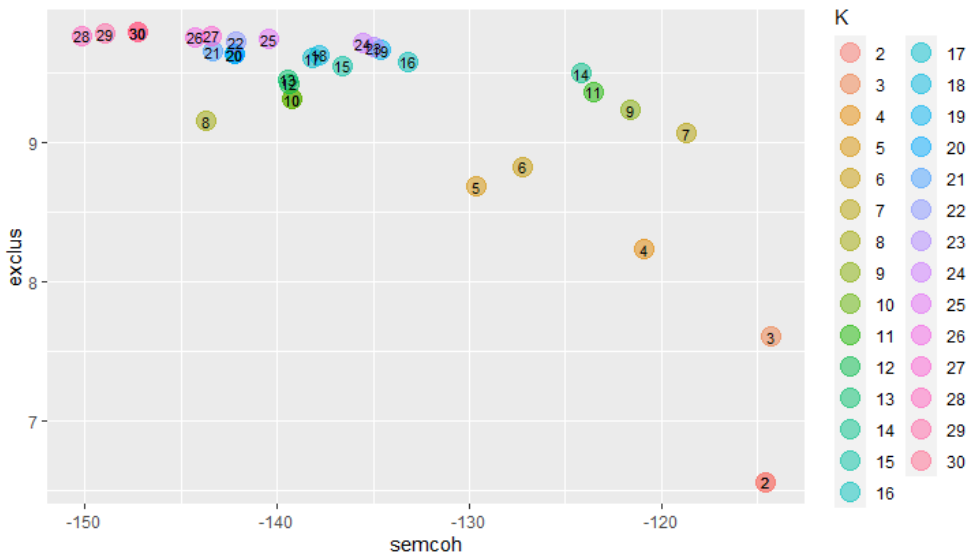

Figure 3.2, Comparison between Exclusivity and Semantic Coherence for the fitted STM with k = 2 to 30.

Data Analysis 2, Exploration of the Associations between the Topical Prevalence and the Individual and Contextual Factors using HLM.

By employing the topic prevalence computed in the STM, this study explores how individual and contextual factors can interact with each other, and ultimately affect the topics discussed in the public discourse about climate change. In particular, to avoid endogeneity, after extracting the topics based on the date when the tweets were posted, I associate the prevalence of these topics with each tweet. By doing so, this study integrates the outcomes (topical proportions) from STM with the information about users, such as their Twitter user names and location information obtained from their profile information.

Additionally, I scraped the followee information of users who posted tweets or retweets about climate change by relying on Twitter's RESTAPI. This followee information was used to estimate users' political ideology by employing the "tweetscores" package (Barberá et al., 2015).

The estimated political ideology using "tweetscores" was then linked with the tweets I scraped via Synthesio by users' account names. Therefore, in the final dataset I used in the following HLM, each tweet was integrated with the estimated political ideology score for the user who posted the tweet and their (stated) place of residence. By using this location data of users, I further looked up contextual variables, including the level of rurality.

Individual Level Variable

Political Ideology

Based on the concept of homophily in the literature of social networks, Barberá et al. (2015) assumes that Twitter users prefer to follow the social media accounts of elected officials and media outlets whose political views are ideologically similar to their own. Following this assumption, with information of the following Twitter accounts of users, "tweetscores" generates the estimated ideological positions for each user. I relied on this method to estimate political ideology, because this is one of the most widely used methods to assess political ideology for Twitter users (e.g., Sterling, Jost, and Hardin, 2019), and therefore make this study comparable with other previous studies. Also, the accuracy of this estimated political ideology was validated as acceptable by employing the records in offline settings such as officials' party affiliations and ordinary users' voting registration records (Barberá et al., 2015).

The resulting estimated political ideology is designed to be a continuous variable which follows a standard normal distribution (i.e., with a mean of zero and standard deviation of one). A score of zero is the midpoint ideological position, and less than zero is given for conservative-leaning ideological positions while scores larger than zero imply liberal-leaning ideological

positions (Barberá et al., 2015). It is also important to note a critical limitation of the estimates generated by this "tweetscores." The estimates of ideological positions were simulated using the Twitter account users follow, such as the ones of political elites, media outlets, governmental and research institutions, which are famous and visible enough to assess political ideology of these "elites." As a result, Barberá et al. (2015)'s method not only does not allow us to estimate users' political ideology who do not follow any of these "elites" (in this case, "tweetscores" will simply give NA value for the user), but also tends to make unstable estimations if the users follow only a small number of elites.

Moreover, some Twitter users did not make their followee information publicly accessible. As a result, this study was unable to generate an estimate of political ideology for these users. As mentioned above, this study also limits the scope of data analyses to the tweets which were posted by users who allowed access their location information. Among users whose location information was accessible, the authors of 190,441 (17.18%) tweets were not able to be estimated by using "tweetscores" either because the restriction to access their followee information, or no accounts of "elites" were followed by the users who posted these tweets. The resulting distribution of users' estimated political ideology was relatively skewed to the right, including more conservative users than moderate and liberal users (*Min* = -2.54, *Max* = 2.48, *Median* = -1.18, *Mean* = -0.70, *SD* = 1.33).

I further created a three-categorical ordinal variable using this estimated political ideology. In particular, users whose tweetscores located within less than and equal to 1 SD above and below zero were classified as "Moderate," and those whose estimated political ideology were greater than 0.5 SD below zero were labeled as "Conservative." Likewise, users whose

tweetscores exceeded 0.5 SD above zero were categorized as “Liberal.” Consequently, similar to the original continuous variable of estimated political ideology, it was revealed that most of the users have conservative-leaning political ideology (1 = Conservative (63.54 %), 2 = Moderate (16.58 %) and 3 = Liberal (19.88 %)).

Contextual Variables

Place-level variables

As mentioned earlier, the Twitter data I obtained via Synthesio has location information of some users about “State” and “City” contingent on their privacy setting. This study looked up the county-level statistics based on this location information, by matching up “State” and “City” names (e.g., California, San Francisco) with “State” and “Census Designated Place” (CDP) names simultaneously. CDP is a concentration of population defined by the United States Census Bureau, and includes self-governing cities, towns, and villages, for the purposes of gathering and correlating statistical data (Census Bureau, 2018). In this sense, CDP does not always match with the (stated) “City” name in the obtained Twitter data. However, CDP is the smallest and most compatible unit to “City” that can be used to look up the county in which “City” belongs to, and thereby can be used to find the county-level statistical data such as population size and number of households, collected by the 2010 Census and American Community Survey, as the smallest geographical unit. This study therefore uses the CDP to look up the county-level statistics in the “City” where each user was located to measure the following variables: the level of rurality and the availability of local newspapers.

Nonetheless, due to the complexity of geography in the U.S, this approach generated missing values for some tweets. Among the tweets that have location information of users,

1.73% of tweets' "City" were not matched with CDP, and therefore treated as missing cases in the following analyses. Also, even when "City" in the Twitter data matched with a place in the CDP, some places split into multiple counties (22.76% of all the tweets with location information were posted by the users in such places). To deal with such cases, I calculated the mean values for the following variables to obtain the CDP (place)-level statistics, because the variables of interest in this research provided only at the county-level. It is crucial to emphasize this point that the following variables were originally provided as the county-level statistics by the third party, the Office of Management and Budget's (OMB) and the News Desert Project led by the University of North Carolina. However, I employed these county-level statistics and computed the mean to generate the place-based statistics for these variables.

Rurality (Place-level)

I used the 2013 National Center for Health Statistics (NCHS)'s Urban-Rural Classification Scheme for Counties (Ingram and Franco, 2014) to quantify the level of rurality in the place of residence for each county. This NCHS categorization is based on the 2013 Office of Management and Budget's (OMB) delineation of metropolitan statistical areas (MSA) and micropolitan statistical areas, with detailed categories useful to classify metro areas into large "central" metro (akin to inner cities) and large "fringe" metro (akin to suburbs). Because of the complicated geographical structure, again, 22.76% of the all the tweets with location information of users were computed to the mean for this rurality measure. After taking the mean of the level of rurality of the counties which matched by a place, 11.47% of tweets were assigned different values for this measure from the original 2013 NCHS codes. (Median = 1.00, Mean = 1.88, SD = 1.23).

The availability of local newspapers (Place-level)

To measure this variable, I relied on data provided by the News Desert Project led by the University of North Carolina to create this variable for each county in the year of 2020. Specifically, I used the total amount of circulation of the local newspapers observed in 2020 per the estimated number of households for 2019 at the county-level. As described in the News Desert Project (2018), there are some limitations to track the complete market reach of local newspapers. Consequently, it is hard to measure the availability of local newspapers at the county-level (defined as the amount of circulation of the local newspapers divided by the number of households for each county), especially when the market reach of the local newspapers split into multiple counties. In such cases, I measure the availability of local newspapers by dividing the sum of the total circulation of local newspapers by the sum of the number of households of the counties where these local newspapers were listed.

In the year of 2020, the total number of local newspapers listed by the News Desert Project is 6,736. There are 157 counties with zero local newspapers circulated ("News Desert"), and 1,511 counties with only one local newspaper. Again, some tweets were posted from a CDP which split into multiple counties. I calculated the mean of the percentage of the total circulation per households for these cases, to measure the availability of local newspapers at the county level. Because of this heavily right-skewed distribution of the number of available local newspapers for each county, the percentage of the total circulation of local newspapers per households computed for each CDP also showed very skewed distribution (*Mean* = 9.73, *SD* = 12.55, *Median* = 5.89, *Min* = 0, *Max* = 786.00).

Popular Vote Outcomes for the 2016 Presidential Election (Place-Level)

Based on Jang and Hart (2015), the state-level vote shares were significantly associated with the frames of topic and stance in the public discourse about climate change in the Twitter-sphere. However, as described more in detail in the following section ("Analytic Strategy for HLM"), the intraclass correlation coefficients (ICC), the degree of association among observations within the same clusters for the state-level ranges from 0 to 0.006 (Table 3.1). These low values of ICC indicate that there is not much variance explained at the state level. Therefore, this study did not include random intercept, slope, and IVs at the state level in the following HLMs to explore the aforementioned RQs. Based on this decision, instead of the state-level popular vote outcomes for the presidential election, this study adopted the place-level popular vote outcomes.

Similar to the other place-level variables in this study, the place-level popular vote share (Democrat) was created by computing the mean of the county-level popular vote share given for the Democrat presidential candidate in the 2016 election. The county-level vote share was not available for most counties in Alaska (1160 tweets) and Bedford City in Virginia (46 tweets). As a result, the tweets posted by the users who resided in these areas (n = 1206, approximately 0.11 % of all the tweets) were excluded from the following multi-level analyses. After removing these tweets, the place-level Democrat popular vote share ranges from 3.61% to 90.86 % (*Mean* = 61.40, *SD* = 19.27).

Dependent variable

Topical prevalence

Topical prevalence refers to how much of a document is associated with a topic (Roberts et al., 2014), which is set to follow a normal distribution. As the results of STM, this study

identified 11 topics, which were further grouped into the two upper topics (clusters) and the rest of the six topics. To avoid the problem of endogeneity, I included only one variable in extracting topics in STM, the date when the tweets were posted only in predicting this topical prevalence variable. Hence, as the next step, I predict this topical prevalence for all the extracted topics in STM by the aforementioned individual and contextual factors below. Also, as described in results of STM, it is reasonable to group the topic 1 and 3, and topic 2, 7, and 11, as the upper topics. I therefore took the mean of these topical prevalence to measure the upper topic scores.

Analytic Strategy for HLM

Based on the results of STM and descriptive statistics of the distribution of tweets about climate change, I constructed and tested a series of multi-level models predicting the topical proportions for each topic and the two upper topics. In these models, the data was nested in multiple levels, the uppermost level was the state-level, then followed by the place-level and the individual-level. In addition to these levels, each tweet was nested within each user. Therefore, although not many users posted more than one tweet during the data collection period, this study tested the four-level multi-level models as below to compute the intraclass correlation coefficients (ICC).

Table 3.1, The Intraclass Correlation Coefficients (ICC) for Each Level

Level	Topic 1 & 3 Scientific Fact-based Topic	Topic 2, 7, & 11 Presidential election	Topic 4 Primary election	Topic 5 Skepticism toward the government & establishment	Topic 6 Sustainability of the society	Topic 8 Skepticism toward the climate change	Topic 9 Behavioral change in relation to COVID-19 & climate change	Topic 10 Energy & economy

User	0.352	0.236	0.268	0.634	0.254	0.447	0.574	0.241
Place	0.023	0.002	0.003	0.005	0.002	0.003	0.001	0.010
State	0.006	0	0.0002	0.0009	0	0.0003	0	0.0002

The intraclass correlation coefficients (ICC), the degree of association among observations within the same clusters in each level, was computed for these levels (Table 3.1) based on the outcome of the null models predicting the eight topical prevalence I describe in detail in the results of STM. The ICCs provided supporting evidence to use a multilevel model rather than a model with a single level, especially for exploring the effects of variables at the place-level in addition to the user-level. Also, the low values of ICCs at the state level (ranging from 0 to 0.006) indicate that only very small proportions of variances were explained at the state level. Therefore, according to such results, this study constructed multi-level models not using state-level variables (state-level vote share) and random components (i.e., random intercept and random slope). Instead, for the sake of simplicity, the following multi-level models were created as the three-level models.

Exploratory data analysis, as well as the result of model fit comparisons, showed that a random intercept model with the three-way interaction effects of the estimated political ideology, the level of rurality and the availability of local newspapers for each CDP, and the place-level vote shares for Clinton were most optimal for all the predicted variables to examine the RQs of this study. In other words, all the models I discuss in more detail below suggest that the proportions of the topics for each user and place have variant intercepts (mean) with invariant slopes (rate).

Results

Results 1, Structural Topic Modeling (STM)

Based on the criteria I mentioned above, the STM with 11 topics are shown to be the most optimal and interpretable. Following Roberts et al. (2014), the generated topics were interpreted and labeled based on three types of information: each topic's top words (highest probability to be included in the topic), top FREX words (top exclusive words for each topic), and representative texts (articles with the highest theta scores) (see Figure 3.3 l for the label given for each topic, the expected topical proportion, and the representative words in terms of top words and top FREX words). I conducted manual validation of the top 50 words and texts sampled for each topic when interpreting the topics. Furthermore, some of these topics (topics 1 and 3, and topics 2,7, and 11) are clustered into broader themes based on their occurrence within documents, which was measured using the cosine dissimilarity distance. In particular, I employed cluster analysis with Wald as a clustering algorithm (Figure 3.4).

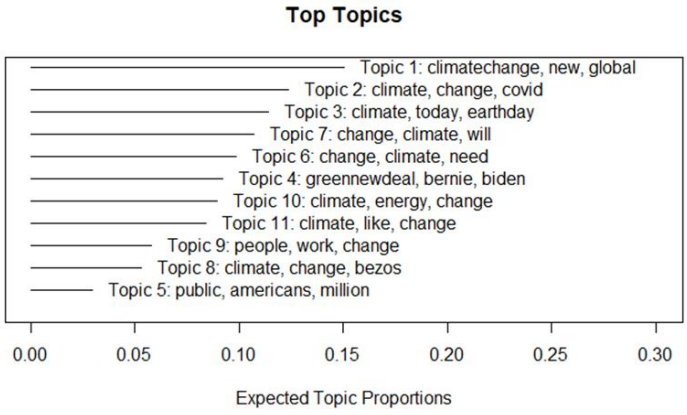

Figure 3.3, Expected Topic Proportions and Top Words (Words with Highest Probability to be Included in the Topics)

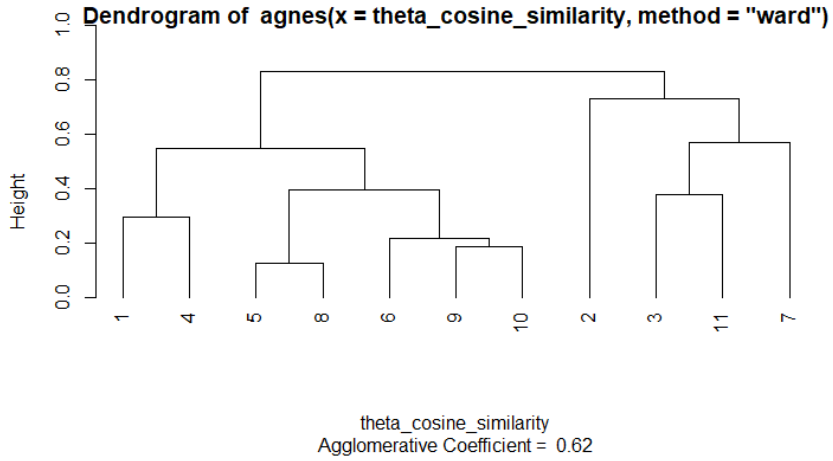

Figure 3.4, Results of Cluster Analysis (Wald) using Cosine Dissimilarity as the Distance between the Topics

As we can see in Figure 3.4, the results of cluster analysis suggest that topics 1 and 3, and topics 2, 7, and 11 are clustered in the same groups, respectively, whereas the other topics were not closely connected each other. This pattern of clustering is consistent with the interpretation given for each topic. That is, topics 1 and 3 are labeled as the scientific facts-based public discourse and resulting calls for action to combat the climate change, while in relation to the topics 2, 7, and 11, climate change is discussed not as the focus of the discourse, but rather as one of the presidential election and political issues (topic 2), and policy debates (topic 11) in the 2020 election cycle. Also, in topic 7, the focal point includes climate change, however, it is served as the issue to evaluate the public figures including Donald Trump, Barack Obama, and Bill Gates. In this sense, all these topics (2, 7, and 11) can be considered as representing the politicization of climate change (Chinn et al., 2020) in the context of 2020 presidential election.

Meanwhile, the rest of the topics (4, 5, 6, 8, 9, and 10) were relatively distinct from the two grouped topics and each other, in terms of the outcomes of the cluster analysis, topical

correlations, and the labels given based on their representative words and texts. Therefore, I keep these topics as independent topics and did not group with the other topics. Based on these analyses, this study labels and groups the topics as shown in Table 3.2. All in all, most of the topics detected by STM are closely associated with politics, policy debates, and other issues such as COVID-19 and health care, or distrust toward the establishment and fear about the future, implying that climate change tends to be discussed as a nationalized political issue, rather than a science-based discussion or local issue (expect for the topic 1 and 3). Although topics 1 and 3 occupy the highest topical proportions, it should be worth considering that in most of the topics, climate change is mentioned just as one of the problems existing in our society.

Table 3.2, Labels for Each Topics and Upper Themes.

Topic 1 & 3 Scientific Fact-based Topic Topic1: Rising temperature and its outcomes Topic 3: Calling for actions and promoting information about climate change	Topic 2, 7, & 11 Presidential Election Topic 2: National Elections, climate change, and COVID-19 as agenda Topic 7: Evaluations toward the public figures (politicians and Bill Gates) Topic 11: Policies in relation to the 2020 election	Topic 4 Primary election	Topic 5 Skepticism toward the government & establishment	Topic 6 Sustainability of the society	Topic 8 Skepticism toward the climate change	Topic 9 Behavioral change in relation to COVID-19 & climate change	Topic 10 Energy and economy

Results 2, Mapping Tweets about Climate Change in the U.S by Place (CDP)

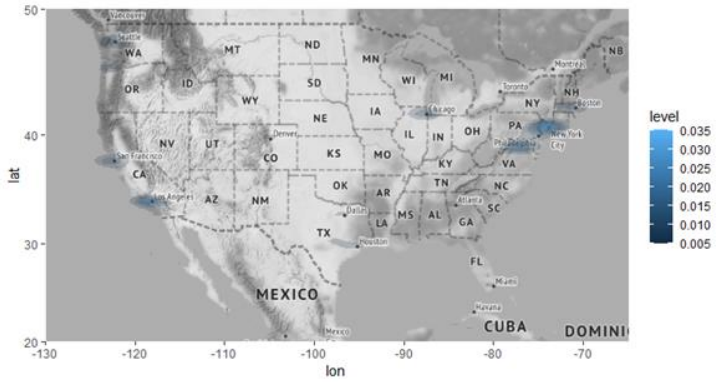

Figure 3.5, The Distribution of the Tweets about Climate Change by Place, per 10,000 Population

Next, in order to have a holistic view of the tweets about climate change and how they are distributed in the U.S., using the full sample of the collected tweets, I plot the number of tweets by place per population (the number of tweets per 10,000 population size) in Figure 3.5. As we can see in Figure 3.5 at a first glance, it is clear that tweets about climate change were not evenly distributed in the U.S., even after considering population size. Specifically, the shares of tweets about climate change shown in the density map reveal that large and liberal cities, such as New York, Washington D.C., Los Angeles, and San Francisco serve as the center of tweets about climate change. Meanwhile, large cities located in red states, including Atlanta and Houston, did not stand out compared to those large liberal cities in this map. In sum, even from such a simple visualization on the map, we can see a clear pattern that the state-level political orientation and the rurality of places are associated with the tweet shares about climate change.

Results 3, Examples of Tweets From Urban, Suburban, and Rural Areas

Before describing a series of multi-level analyses, or Hierarchical Linear Modeling (HLM), this study shows some examples of tweets posted by the users who (satated that) reside in urban, suburban, and rural areas as follows. By doing this, I aim to provide readers with clearer ideas about how representative tweets can differ based on rurality. Due to the limited computing power, the following analyses, including exploration of representative tweets and a series of multi-level analyses, employed a 10% random sample of tweets. Among the random 10% of all tweets collected for this study (N= 83470), 64392 (77.14%) of them are either retweets or quoted tweets. I did not explore retweets and quoted tweets in 3-1 to 3-3 as examples of representative tweets. These tweets should be considered an endorsement rather than own opinions expressed by the users who made these retweets and quoted tweets. Also, in the following sections, which provided examples of tweets from urban, suburban, and rural areas, the thirty "representative tweets" were selected randomly for each level of rurality.

3-1, Representative Tweets from Rural Areas

4415 (5.29 %) tweets were posted from rural areas, whose 2013 NCHS Rural-Urban Classification codes are equal to and more than 5. Among them, there are 931 (21.09 %) original tweets and 3484 (78.91 %) retweets.

3-1-1, Examples of Original Tweets from RuralAreas

The clearest tendency found in representative tweets from the users in rural areas is that most of them are blaming certain social actors such as politicians (e.g., Joe Biden, Barnie

Sanders, Donald Trump, scientists), social/political organizations (e.g., National Rifle Association and Green Peace). The examples for such blaming tweets include:

1, “ABSOLUTE MUST READ/SHARE VERY WIDELY: THIS IS HOW BIDEN APPROACHES THE BIGGEST AND MOST IMMINENT CHALLENGE FACING HUMANITY! TOTAL LACK OF COMMON SENSE: Joe Biden wants to head to the 'middle ground' on climate change https://www.businessinsider.com/joe-biden-wants-to-head-to-the-middle-ground-on-climate-change- ...” by a conservative user in Clearlake, California

2, “@SouthernersYang @DwayneHarveyJr @katiecannon2 @BernieSanders 350 dot org and Center for Biological Diversity are scientific groups that focus on the environment and Climate Change. Greenpeace and UnFrak are just activist groups. But the point is that environmental proponents always pick Bernie first.” (by a conservative user in Alexandria, Minnesota)

3, “@AOC apparently you don’t know a lick about how nature really works. You are not saving the planet you are arrogantly controlling how nature really works. We do not change the climate climate change is a natural process or are you too arrogant to figure that out? You too @algore.” (by a liberal user in Rexburg, Idaho).

4, “@EWErickson That is almost as dumb as the 97% of scientists agree on global warming.” (by a liberal user in Owatonna, Minnesota).

Among the randomly selected representative examples from tweets posted by the users in rural areas, the estimated political ideology was almost equally distributed (Liberal: 10, Moderate; 9, Conservative; 11), although a closer look at the user’s profile showed such estimated political ideology seems not that accurate for some users (e.g., the user who posted the

fourth example tweet above, he stated that he is an Iraq war veteran, former GOP activist, and #NeverTrump). It is worth considering that even after accounting for such somewhat inconsistent estimated political ideology, the targets blamed in the tweets posted from rural areas were mostly Democrat politicians and liberal policies. While scientists were also attacked in the tweet mentioned above, conservative and Republican politicians were not mentioned as the target to blame climate change.

Unlike representative tweets posted the users in urban and suburban areas, only six out of the randomly selected 30 tweets aimed to introduce scientific findings and news or information sources (e.g., Washington Post and ABC News) about climate change. Another striking difference from the representative tweets from suburban areas is that only one tweet called for action about climate change (i.e., "Please vote today. It is imperative that we all participate if we want to remove the putrid excuse for a human being from the White House. Our society, democracy, and humanity cannot survive 4 more years of this epic failure. @realDonaldTrump #democracy #ClimateChangeIsReal", a conservative user in Basalt, Colorado).

Meanwhile, although more than a half of the selected tweets' stances were believing in climate change, the proportion of tweets clearly stating their stance of a denier of climate change is much larger than suburban and urban areas. These tweets were characterized by their strong words and anger against Democrat politicians and liberal policies, denial of science, and faith in God, not citing any information or comments made by third parties/people as below.

1, "@theblaze The Climate hoax is actually a denial of God & His omniscience & His omnipotence. God alone created the universe & He alone will bring our planet to an end. It is arrogant of any human to believe we have that kind of power!!" (a liberal user in Lindsay,

Oklahoma)

2, “The MSM continues to bash President Trump for a non-traditional STOU message. That's why we elected him; The MSM supported Hillary who sold access to the highest bidder foreign & domestic! The MSM drooled over Obama's bad deals; Paris Accord; Billions to Iran & Poor Economy!”, (a liberal user in Port Lavaca, Texas).

It is not consistent with our expectation that the users with (estimated) liberal political ideology attack science and Democrat politicians in this way, warranting more consideration about the link between partisanship, (estimated) political ideology, and faith in God, as well as skepticism toward science. In general, tweets denying the existence of climate change and human-made climate change showed strong links with a religious or political ideology without cited information.

3-2, Representative Tweets from Suburban Areas

18101 tweets (21.69 %) of tweets were posted by the users who (stated that they) resided in suburban areas, whose rurality code is 3 to 4 in the 2013 NCHS Rural-Urban Classification codes. Among these tweets, there are 3695 (20.41%) original tweets and 14406 (79.59 %) retweets.

3-2-1, Examples of Original Tweets from Suburban Areas

Interestingly, this study found that the users who reside in areas categorized as “suburban” and posted their tweets about climate change tended to live in college towns, such as Ann Arbor, Michigan, Madison, Wisconsin, Boulder, Colorado, and State College, Pennsylvania.

Although the estimated political ideology for these users is well balanced, including an approximately equal number of Liberals, Conservatives, and Moderates, all the investigated original tweets from these suburban areas show the stance of pro-climate change except for only one tweet posted from Syracuse, New York. This exceptional tweet is characterized by skepticism toward the former Democrat president, Obama, and the current Canadian prime minister, Trudeau, along with the issue of climate change. ("@RaheemKassam @WarRoom2020 @DavidWohl @DavidJHarrisJr @Qanon76 The next political smoking gun! Research #repealPlan2014 & help expose Obama/Trudeau corruption blaming #climatechange while intentionally flooding ALL of the Great Lakes! Homes/businesses/shorelines gone FOREVER!", a liberal user, Syracuse, New York).

The other randomly selected 29 tweets as the example tweets from suburban areas mainly aim to 1) introduce scientific findings. (e.g., "Scientists propose a framework to mitigate mining is impact on climate change https://www.mining.com/scientists-propose-framework-to-mitigate-minings-impact-on-climate-change/ #MINING.COM", from a liberal user in Columbia, Missouri), and 2) call for action to mitigate climate change and environmental protection. (e.g., "Sign and send the petition: Urge your governor and state legislators to urge state pension fund divestment from fossil fuels. We cannot continue to fund climate change!. Write one here: https://actionnetwork.org/letters/sign-and-send-the-petition-urge-your-governor-and-state-legislators-to-urge-state-pension-fund-divestment-from-fossil-fuels-we-cannot-continue-to-fund-climate

Also, it is worth noting that the three tweets of the selected 30 tweets endorsed bipartisan/liberal politicians and elections for their effort to mitigate climate change. (e.g.,

@marcorubio , thank you for joining the bipartisan Senate #ClimateSolutionsCaucus. I appreciate your leadership on climate change, and I'm glad to see Senators working across the aisle on this important issue! https://citizensclimatelobby.org/climate-solutions-caucus/, from a conservative user in Kennebunk, Maine). Meanwhile, there is one tweet criticizing conservative politicians (i.e., "@KnuteBuehler ...climate change denial, fear mongering of immigrants and giving tax breaks to the mega rich. If these are the conservative polices you so desire than no thanks, Knute.", From a conservative user in Bend, Oregon).

All in all, those who reside in "suburban" areas and posted original tweets about climate change are from towns with large universities and showed trust in climate change. Probably because of relatively close distance from scientists and science in general in these areas, the investigated tweets mentioned scientific findings most frequently, followed by environmental protection. Some tweets also endorsed liberal/bipartisan politicians about their efforts for climate change; such political tweets did not belong to the majority. Such results may be attributable to the users who posted their own ideas (original tweets). They are highly interested in the issue of climate change as the "issue publics" and that these people residing in suburban areas are likely to be pro-science people living in college towns.

3-3, Representative Tweets from Urban Areas

Among the random 10% of all tweets collected for this study (N= 83470), 60691 (72.71 %) of tweets were posted from urbanized areas (i.e., places whose mean of the 2013 NCHS Rural-Urban Classification codes are 1 to 2). Such tweets are further divided into 46304 (76.29 %) original tweets and 14387 (23.71 %) retweets. I extracted random 50 original tweets

and retweets from such areas.

3-3-1, Examples of Original Tweets from Urban Areas

In terms of the distribution of the estimated political ideology for each user, unexpectedly, this study found the highest proportion of conservatives in the randomly chosen 30 tweets from urbanized areas. (Conservatives: 17, Moderates: 8, and Liberals 5). Nonetheless, such skewed distribution of the estimated political ideology was not associated with the stance of tweets toward the issue of climate change. There is only one tweet clearly stating its stance of the denier of climate change (i.e., "@MichaelEWebber Now, only climate change is a Chinese hoax." by a liberal user in Austin, Texas).

Also, similar to the representative tweets from suburban areas, most of the randomly selected tweets from urbanized areas aim to introduce scientific findings or news from mainstream and liberal online media (e.g., "Today in climate change headlines, via @wsj: https://www.wsj.com/articles/are-floating-hotels-office-buildings-the-answer-to-rising-sea-levels-11582027201?cx_testId=3&cx_testVariant=cx_2&cx_artPos=5#cxrecs_s", by a moderate user in Philadelphia, Pennsylvania). Some of such kind tweets also include a criticism toward the former president Trump (e.g., "Ugh -- via @latimes : Trump rolls back biggest U.S. effort to combat climate change https://www.latimes.com/politics/story/2020-03-31/trump-rolls-back-fuel-economy-standards", by a moderate user in Washington, District of Columbia, and "Ugh -- via @latimes : Trump rolls back biggest U.S. effort to combat climate change https://www.latimes.com/politics/story/2020-03-31/trump-rolls-back-fuel-economy-standards", by a conservative user in Boston, Massachusetts). Criticizing a particular social actor (mainly the former president Trump) along with some citations is more distinct in the tweets

from urbanized areas, unlike suburban areas whose tweets mostly included citations only, but not criticisms. It should be noted that such criticisms were made in a sarcastic and implicit way rather than expressing intense anger.

The second primary topic found in representative suburban tweets, calling for action to mitigate climate change, was less frequent in the representative tweets from urbanized areas. Also, the contents of required actions were more general rather than local in tweets posted from urbanized areas. (e.g., "@lindsaycrouse It is a once in a 100 yr chance to put bike lanes on every major street it will get people off dangerously crowded subways, give frontline workers a safe/free way to get to work. It is also the key to addressing climate change we *must* lower VMT & bikes in cities is the only way", a moderate user in Los Angels, California).

Lastly, there are a few very unique tweets in the representative tweets from urban areas only. The focus of these tweets is the link between gender equality and climate change as follows: "@smonteze Plz read: The Link Between #DomesticViolence & #ClimateChange Exploitation of ecosystems and exploitation of female bodies go hand in hand. https://www.damemagazine.com/2020/04/16/the-link-between-domestic-violence-and-climate-change via @damemagazine Plz support @JeanneGeigerCtr to end #DomesticAbuse #EarthDay2020", by a conservative user in Newburyport, Massachusetts. "Gender equality plays a vital role in #climatechange. Learn more from Earth Day Network: https://www.earthday.org/womens-empowerment-is-key-to-reducing-climate-change/ #earthday", a moderate user in Pittsburgh, Pennsylvania.

Generally, regardless of the level of rurality, climate change was mentioned as one of the social and political issues to tackle in the 2020 election cycle with other issues such as

sustainability of society (student loan and distribution of wealth), Black Lives Matter, and environmental problems. However, linking climate change and gender equality in such an explicit way was found only in the representative tweets in urbanized areas, requiring more attention to the narratives about them.

Results 4, Exploration of the Associations Between the Topical Prevalence and the Individual and Contextual Factors of This Study Using HLM.

RQs of this study explore how individual-level variables, including the estimated political ideology by followee information, as well as the contextual variables (i.e., the level of rurality in the place of residence and the availability of local newspapers) would be associated with the prevalence of each topic. As demonstrated in the models below, I found that individuals' estimated political ideology was the most influential factor predicting the topical proportions. It showed significant associations with the prevalence of all of the detected topics. Also, it suggested that the patterns of significant associations between the predicting variables and each topical prevalence vary based on the characteristics of the topics.

First, as shown in Table 3.4, among the topics mentioning sustainability of the society, skepticism toward climate change, behavioral change in relation to climate change and COVID-19, and energy and economy, significant associations were found only in the main effects, but not in the cross-level interactions. (Sustainability of the society: b = - 0.06 (liberal), b = - 0.03 (moderate), b = - 0.003 (rurality), and b = - 0.0003 (Democrat vote share); Skepticism toward climate change: b = 0.02 (liberal), b = 0.01 (moderate), b = - 0.003 (rurality), and b = - 0.0002 (Democrat vote share); Behavioral change: b = - 0.01 (liberal), and b = - 0.003 (rurality); Energy

& economy: b = - 0.01 (liberal)). It is important to emphasize that STM does not allow us to interpret the stance of the tweets about each topic. It rather enables us to examine the topics mentioned by people in relation to the individual and contextual factors of this study.

Table 3.3, Multi-Level Models Predicting the Topical Proportions about Climate Change

		Scientific facts	Presidential election	Primary election	Skepticism (gov& establishment)
	Fixed Effects				
	Intercept	0.11*	0.25*	0.10*	0.03*
M1	**Level 2 (User-Level) Predictors**				
	Political Ideology (Liberal)	-0.001	0.07*	-0.02*	-0.01*
	Political Ideology (Moderate)	0.03*	-0.01*	-0.04*	0.01*
	Level 3 (Place-Level) Predictors				
	Rurality	0.006*	0.0004	-0.002	-0.002*
	Availability of Local Newspapers	-0.00004	-0.0000002	-0.0001	0.0001
	Vote Share for Clinton	0.0006*	-0.000054	-0.0003*	0.000003
	AIC	-118777	-38884	-71233	-113379
	Cross-Level Interactions				
M2	Rurality				
	*Liberal	-0.003*	0.0004	0.0003	0.003
	*Moderate	0.0008	0.002	0.001	-0.001
	AIC	-118791	-38887	-71230	-113379
M3	Availability of Local Newspapers				
	* Liberal	-0.00001	-0.0002	0.0003*	-0.00001
	*Moderate	0.00004	0.0001	0.0001	-0.0002
	AIC	-118788	-38893	-71235	-113381
M4	Clinton Vote Share				
	*Liberal	0.0001	-0.0004*	0.0001	-0.00001
	*Moderate	0.0004*	0.000005	0.0001	0.0004*
	*Rurality	0.00003	-0.0001	-0.00002	0.00004
	*Availability of Local Newspapers	0.000002	0.00001	-0.000004	0.0000003
	AIC	-118794	-38905	-71231	-113384

M5	Clinton Vote Share				
	*Liberal*Rurality	0.00002	0.0001	0.00003	-0.00003
	*Moderate*Rurality	0.00004	-0.0001	0.00002	-0.00004
	*Liberal*Local Newspapers	-0.000006	-0.000003	0.00001	-0.000001
	*Moderate*Local Newspapers	0.000004	-0.000001	0.000001	-0.000002
	AIC	-118792	-38900	-71224	-113376

*$p < .05$. Note: N_{sample} = 83366, N_{users} = 50858, N_{Place} =4703, For M2–M5, level 1, 2 predictors were also included but its presentation was omitted to keep the presentation of results clear.

Because of this, these outcomes should be interpreted as follows: public discourse about these topics (sustainability of the society, skepticism toward climate change, behavioral change, and energy and the economy) were led mainly and significantly by the individual-level political ideology as well as rurality and the place-level political leaning (for the sustainability of the society and skepticism toward climate change) in terms of the topical proportion. These significant associations of the place-level variables and the topical proportions also indicated the importance of considering contextual factors and individual-level factors simultaneously in exploring determinants of topical frames used in the public discourse.

Table 3.4, Multi-Level Models Predicting the Topical Proportions about Climate Change

		Sustainability	Skepticism (climate change)	Behavioral change	Energy & economy
	Fixed Effects				
	Intercept	0.12*	0.05*	0.07*	0.09 *
M1	**Level 2 (User-Level) Predictors**				
	Political Ideology (Liberal)	-0.06*	0.02*	-0.01*	-0.01*
	Political Ideology (Moderate)	-0.03*	0.01*	0.002	-0.001
	Level 3 (Place-Level) Predictors				
	Rurality	-0.003*	-0.003*	-0.003*	-0.0004
	Availability of Local Newspapers	0.0001	0.000005	0.0001	-0.0001
	Vote Share for Clinton	-0.0003*	-0.0002*	-0.0001	-0.0001
	AIC	-51505	-74341	-98274	-62596
	Cross-Level Interactions				
M2	Rurality				
	*Liberal	0.001	-0.0003	0.002	0.002
	*Moderate	-0.0004	-0.004	0.001	-0.0003
	AIC	-51505	-74339	-98271	-62593
M3	Availability of Local Newspapers				
	* Liberal	-0.00002	0.00003	-0.0001	-0.00004
	*Moderate	0.0001	0.00004	-0.0001	-0.0001
	AIC	-51502	-74335	-98269	-62590
M4	Clinton Vote Share				
	*Liberal	0.0003	-0.0001	-0.00001	-0.00004
	*Moderate	0.0001	-0.0003	-0.0001	-0.0001
	*Rurality	0.0001	-0.00005	0.00003	-0.00001
	*Availability of Local Newspapers	-0.000003	-0.00000002	-0.000001	-0.000001
	AIC	-51508	-74337	-98263	-62583
M5	Clinton Vote Share				

*Liberal*Rurality	-0.0001	0.0001	-0.00004	-0.00005
*Moderate*Rurality	0.00003	0.0001	0.00002	-0.0002
*Liberal*Local Newspapers	0.00001	0.000003	0.000002	-0.000002
*Moderate*Local Newspapers	-0.00001	-0.000002	-0.000004	0.000002
AIC	-51508	-74328	-98256	-62576

*$p < .05$. Note: N_{sample} = 83366, N_{users} = 50858, N_{Place} =4703, For M2–M5, level 1, 2 predictors were also included but its presentation was omitted to keep the presentation of results clear.

Next, the other topics found in STM (shown in Table 3.3) demonstrated significant cross-level interactions, implying that exploring the place-level factors is crucial, as expected in the RQs of this study. No three-way interaction effects were significant in predicting all the topical prevalence. However, all the place-level variables in this study (rurality, availability of local newspapers, and political leaning (i.e., Democrat vote share in the 2016 presidential election) demonstrated the significant cross-level interactions with the individual-level political ideology below.

First, as demonstrated in Table 3.3, the cross-level interactions of the individual-level estimated political ideology and the place-level political leaning (Democrat vote share) were significant in predicting the following topics. (scientific facts, Moderate*Democrat vote share: b = 0.0004, the 2020 presidential election, Liberal*Democrat vote share: b = - 0.0004, and skepticism toward the government and establishment, Moderate*Democrat vote share: b = 0.0004). Figure 3.6 (below) indicates the predicted values for these interaction terms for each topic.

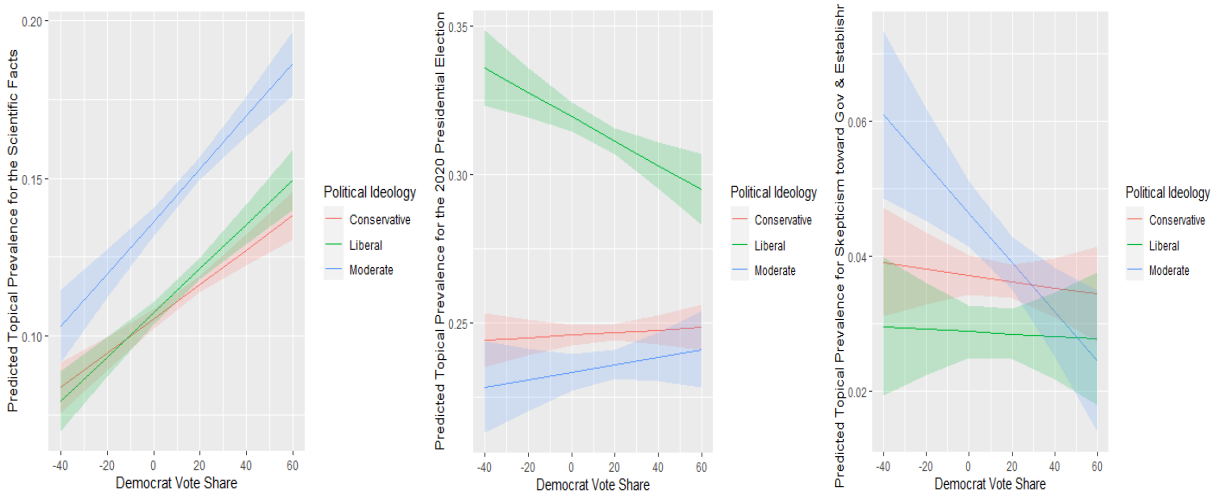

Figure 3.6, Predicted Values for the Topic Prevalence about 1) Scientific Facts, 2) the 2020 Presidential (General) Election in Relation to Climate Change, and 3) Skepticism toward the Government and Establishment as a Product of Political Ideology*Democrat Vote Share

The left figure shows that the higher Democrat vote share was associated with the increased predicted value of topical prevalence for the scientific facts for all political ideology groups (liberals, moderates, and conservatives). Such an increase in the likelihood of mentioning the topic of scientific facts was largest among those with moderate political ideology. These results imply that the place-level political leaning is influential in using the topical frame of scientific facts for all the political ideology groups, but specifically for moderates.

Next, the middle of Figure 3.6 indicates the predicted value of topical prevalence for the topic of the 2020 presidential (general) election. Only among liberals, the higher place-level Democrat vote share was associated with a lower likelihood of using this topic. Meanwhile, although the change was not as steep as the one among liberals, there were some changes among

conservatives and moderates in the predicted value of this interaction term, as Democrat vote share at the place-level increased. Among them, the higher Democrat vote share was associated with the higher predicted topical prevalence of the topic about the 2020 presidential election.

Lastly, the predicted value for the topical prevalence of skepticism toward the government and establishment is shown in the right of Figure 3.6. This right figure indicates that for all the political ideology groups, the higher Democrat vote share at the place-level was associated with the lower likelihood of using the topic of skepticism toward the government and establishment in relation to climate change. Such tendency was strongest among the liberal users, while the decrease in the likelihood of mentioning this topic was more subtle and showed a similar pattern among conservative and moderate users.

In addition to these cross-level interactions, there was another significant two-way interaction term in predicting the topical prevalence of scientific facts (Liebral*Rurality: b = -0.003). Figure 3.7 demonstrates the predicted topical prevalence for this cross-level interaction effect. There was a tendency that the higher level of rurality was associated with the higher topical proportion of scientific facts for all the political ideology groups; however, such increase was the smallest among liberal users.

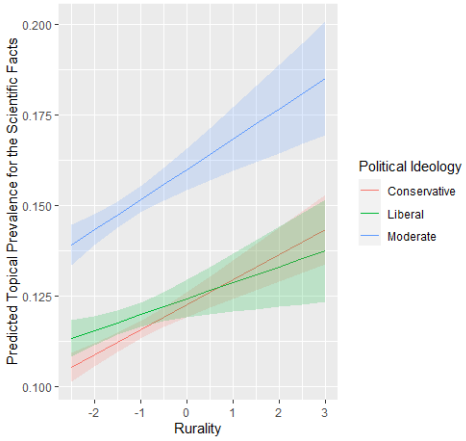

Figure 3.7, Predicted Values for the Topic Prevalence about Scientific Facts as a Product of Political Ideology*Rurality

Moreover, some main effects were found significant in predicting the topics in which I found the aforementioned significant cross-level interaction effects. In particular, for the topic about scientific facts, being moderate (compared to conservative, b = 0.03), rurality (b = 0.006), and Democrat vote share (b = 0.0006) were significant. In predicting the topical prevalence of the 2020 presidential election, being liberal (b = 0.07) and moderate (b = -0.01) compared to conservative were significant, respectively. Similarly, being liberal (b = -0.01) and moderate (b = 0.01) compared to conservative and rurality (b = -0.002) showed as the significant predictors in predicting the topical proportion of skepticism toward the government and establishment.

This significance of the main effect of rurality for the topical prevalence of skepticism toward establishment is worth mentioning. This main effect is a pure effect of rurality after controlling the other main effects and interaction terms of variables explored in this study. Similar to the topics of sustainability of the society, skepticism toward climate change, and

behavioral change, rurality was significantly correlated with decreased topical proportion for the topic of skepticism toward the government and establishment by itself, not by interacting with other variables.

Next, only when predicting the topical prevalence of primary election, the place-level availability of local newspapers showed a significant interaction effect with being liberal compared to conservative (b = 0.0003). As shown in Figure 3.8, depending on the estimated political ideology, as the availability of local newspapers increased, the likelihood of mentioning the topic about the 2020 primary election diverged. Regardless of the availability of local newspapers, the prevalence of this topic remained almost the same among moderates. Meanwhile, the increased availavility of local newspapers led the higher likelihood of using the topic of primary election among liberals, whereas such likelihood decreased among conservatives.

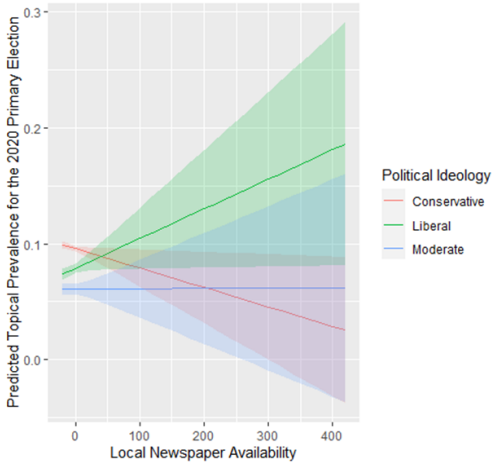

Figure 3.8, Predicted Values for the Topic Prevalence of Primary Election as a Product of Political Ideology*Availability of Local Newspapers

Additionally, there were some significant main effects in predicting the topical prevalence of primary election: being liberal (b = - 0.02) and moderate (b = -0.04) relative to conservative, and Democrat vote share (b = -0.0003). This negative association of being liberal compared to conservative and Democrat vote share with the predicting variable, the proportion of topic about primary election, implies that this topic is colored by partisanship both at the individual and place level.

Discussion

This study explores how the number and kinds of topics discussed in the public discourse about scientific issues can differ based on the geographic factors such as the availability of local newspapers, level of rurality, and the place-level political orientation in relation to the individual-level political ideology. By doing so, it intends to illuminate if Twitter can fill the information gap resulting from a declining traditional local news media, which can lead to nationalization and political polarization (Darr et al., 2018).

However, mapping of the shares of tweets about climate change clearly demonstrated that a majority of tweets were posted from a small number of big cities in liberal states, even after controlling for population size. Consistent with these findings, detailed qualitative analysis of the randomly selected representative tweets from urban, suburban, and rural areas suggest that the focal topics and the contents of tweets vary contingent on the level of rurality. The representative tweets from rural areas are characterized by blaming liberal politicians and policies with anger. Climate change denial tended to be made without citing any third-party information; it was rather

based on extreme religious or political ideology.

The representative tweets from urban and suburban areas were more similar than rural areas, and most of them were posted from college towns. Probably because of these tweets from college towns, the most striking characteristic of tweets from suburban regions is the frequent citation of scientific findings and news articles from liberal or mainstream media. Relatively many tweets included some callings for actions to mitigate climate change at the local level. These liberal and somewhat academic tendencies of tweets from suburban areas can be explained that those who posted tweets about climate change from suburban areas tended to be the "issue publics."

Such calls were also found among the representative tweets from urban areas, but their narratives tended to be framed more generally. Linking climate change and gender equality is one of the good examples of such general tweets, and such association was only found in the representative tweets from urban areas. This unique tendency of the representative urban tweets may result from the younger population in urbanized areas, warranting more attention to the future trends in the narratives of public discourse about climate change.

Meanwhile, the quantitative approach of text analysis, STM revealed that most of the topical frames detected in the public discourse about climate change were closely associated with the national-level political and social issues (e.g., general and primary presidential elections and the sustainability of the society, etc.) The only topic related to scientific facts included information about climate change with local contexts, such as calling environmentally friendly actions at local communities. Consistent with these outcomes obtained by STM, HLM predicting the topical prevalence also demonstrated that the individual-level variances are largest for all the

topics. In contrast, the place-level variances are much lower. The individual-level political ideology was the only variable that had significant correlations with all detected topics.

In this regard, these results generally suggest that the public discourse about climate change on Twitter is significantly associated with geographic contextual factors such as rurality, the availability of local newspapers, and the place-level political orientation. However, the topics discussed were directed more by individuals' political ideologies. In particular, the topic of energy and economy was significantly associated only with political ideology. Given that most of the detected topics did not relate to local contexts (except for the topic calling for actions, which were incorporated into the topic about scientific facts), it implies that Twitter is not filling the gap resulting from a decline of local newspapers as a platform to discuss scientific issues. It can also be considered that the public discourse about the scientific issues is already highly nationalized for climate change, which is a highly politicized and polarized issue.

Nonetheless, the contextual factors matter significantly. Specifically, in predicting the prevalence of non-political topics (i.e., skepticism toward the government and establishment, sustainability of the society, skepticism toward climate change, and behavioral change), the main effect of rurality showed negative and significant correlations. Sustainability of society and behavioral change are the topics that tend to be discussed with the stance believing climate change and environmental protection. The negative associations of the prevalence of these topics with rurality imply that such topics tended to be used less in rural areas. However, at the same time, the prevalence of topics closely related to rural resentment, including skepticism toward the government and establishment and skepticism toward climate change, was also negatively associated with rurality. These significant negative associations suggest that these topics were

also less employed among rural users.

These outcomes imply the multifaceted effect of rurality, its place-based social identity (Munis, 2020), the measures closely associated with its economic structures and dominant industries (Scala and Johnson, 2017), and other potential socioeconomic inequalities. Liberal-leaning topics related to environmental protection (e.g., sustainability of the society and behavioral change) may not be crucial for rural users compared to users residing in more urbanized areas. As Cramer (2016) observed, rural residents tend to have skepticism toward the redistribution of public goods and other liberal policies, including funding on scientific research (As supported in Study 1). It is possible that rural residents perceived that policies promoting environmentally friendly behaviors and sustainability were a form of unfair redistribution. Consequently, the public discourse using these topics did not resonate with resentment as a hot-button issue; however, they also did not become a salient topic among rural users, unlike urban and suburban users.

On the other hand, the negative main effect of rurality predicting the topical prevalence of skepticism toward climate change is somewhat inconsistent with the qualitative analysis of the representative tweets, requiring more detailed exploration about the stances expressed toward climate change. Again, STM enables us to detect the discussed topics, not stances. Compared to being conservative, liberal and moderate compared to conservative was positively associated with the likelihood of using the topic of skepticism toward climate change. The lower prevalence of this topic does not necessarily imply that rural users were less skeptical toward climate change.

In a similar vein, the topical prevalence for skepticism toward the government and

establishment also showed unexpected results. In addition to rurality, the less topical prevalence of skepticism toward the government and establishment was also associated with being liberal compared to conservative, not vice-versa. This unexpected negative main effect of rurality can be explained by place-based identity among rural residents. They may have felt "abandoned" by elites with who they were not politically affiliated (i.e., liberal politicians), but not by the government at the time of data collection (i.e., Trump administration and Republican/conservative politicians). Rurality was significantly associated with the higher vote shares of Trump in the 2016 election (Scala & Johnson, 2017).

Meanwhile, we need to consider that 1) being conservative (relative to liberal) and 2) the interaction of being politically moderate (compared to conservative) and increased Democrat vote share also showed a significant correlation with less prevalence of this skepticism toward the government and establishment. "The government and establishment" is a broad concept that can vary based on political ideology. It can be a business tycoon such as Bill Gates and Jeff Bezos, international or national government(s), or liberal or conservative politicians with established careers. Depending on users' ideologies in political and economic issues, their attitudes toward these various social actors can be substantially different. As a result, their interpretations toward which/how these social actors contribute to climate change will dramatically differ. Similar to skepticism toward climate change, this topic needs more detailed analyses related to stances toward the issue of climate change itself and these social actors.

Next, along with the topical prevalence of skepticism toward the government and establishment, the prevalence of the topic of scientific facts was significantly associated with rurality for its interaction effect with political ideology (being liberal compared to conservative).

It also correlated with the cross-level interaction of Democrat vote share and political ideology, like the topical prevalence of skepticism toward the government and establishment, and the political topic, the presidential election. In this regard, there are some similarities in the significant factors found in the topical prevalence of scientific facts and skepticism toward the government and establishment. Such similarities can be attributable to the fact that they are not political topics but are closely related to politics and colored by partisanship. However, interestingly, the increase in rurality and Democrat vote share led to the higher likelihood of mentioning this topic of scientific facts for all the political ideology groups. Rurality tends to be associated with farming and thereby may be related to the increased topical prevalence of scientific facts about climate change among conservatives. Scientific facts are the only topic in which

In the prevalence of topics related to politics (i.e., the 2020 presidential election and the primary election), rurality was not significant. However, the availability of local newspapers was found significant for its interaction effect with political ideology only in predicting the topical proportion of the primary election. The higher availability of local newspapers led to the decreased likelihood of using this topic among liberals and increased among conservatives. This outcome suggests that the increased availability of local newspapers diversified the choice of information sources. Consequently, liberals obtained more information about climate change in the context of the primary election used it more frequently. In contrast, conservatives were less exposed to such information and mentioned less when residing in counties with more Democrat vote shares. All in all, the availability of local newspapers did not contribute to providing information about climate change with local contexts, whether it is political or scientific facts.

There are some limitations to be pondered, however, mainly in terms of 1) operationalization of "place" and the estimated political ideology, 2) spatial correlations which were not able to be adjusted for in the analyses. I used the stated profile information in Twitter to identify the place of residence, however, this study had to limit the sample to users who made this information available to the public. Similarly, those who did not have followee information available and those who did not follow any elites whose political orientations were identifiable, were removed from the analyses of this study. In this sense, the sample of this study was limited to individuals who tend to have a high level of political awareness. Also, "stated" place of residence can be reported wrongly and is not stable for some users. In fact, this study found a small number of users changed their place during the four months of data collection.

Although such cases are very limited and will not affect the analyses presented in this study, it is worth considering what "place" of residence means for each person. Its meaning may greatly differ based on mobilities each individual has because of their socio-economic status, family, and jobs, however, the available information from Twitter did not allow exploration of these possibilities in detail. Lastly, due to limited computing power, potential spatial correlations were not controlled in the analyses. The HLM models demonstrated in this study adjusted the variances for the unit of place. However, spatial correlations were not removed beyond this unit and thereby affect results of analyses when the cities located were within a close distance. Analyzing more tweets was a priority rather than controlling for spatial correlation in order to explore potential rural-urban divides in public discourse on Twitter by including as many samples as possible. However, additional studies need to consider the spatial correlations for more accurate analyses. Even with the smaller sample size, it will decrease the possibility of causing a type I error by reducing the residual variances.

Despite these limitations, this study can serve as one of the initial attempts at exploring the possibility of social media (Twitter) as a supplementary media to fill the gap resulting from the decline of local news media. By examining the multi-level factors (the individual and place) simultaneously, this study also disentangled how these factors are associated with each other, and ultimately can determine the topics discussed in social media. In general, the analyses revealed both the potential and limits of social media to discuss politicized scientific issues within local contexts.

Based on these findings, more studies are needed to ponder how we should use and improve the design of social media to expand the use of social media with more local information but less politicization and polarization. Individual-level political ideology was consistently significant in predicting all the prevalence of topics in climate change. Emphasizing local contexts may not be a panacea for these issues, given that the place-level Democrat vote share decreased the likelihood of using the topic of sustainability of the society. This place-level vote share also caused divergence between liberals, moderates, and conservatives in mentioning the presidential election topic. The place-level availability of local newspapers functioned in a similar way in predicting the prevalence of the primary election.

However, rurality increased the probability of mentioning scientific facts for all the political ideology groups, including conservatives who showed a more skeptical attitude toward science than liberals and moderates (Hmielowski et al., 2014). Hence, our ideal goal is to find a way to appeal to individuals' attachment to their place of residence by discussing local industries or any non-partisan ways while avoiding the hot-button issues of relative deprivation and related place-based identity. If we can realize this goal, social media can promote scientific-fact-based

healthy discussion rather than politically-charged and ideologically divided arguments.

Chapter 4: Conclusion

Responding to the recent increased attention to rural-urban divides in voting behavior (Scala &Johnson) and values toward elites (Cramer, 2016; Wells et al., 2021), my dissertation explores rural-urban divides in the context of science communication. This dissertation relied on various datasets as follows to explore such geographical divides.

- A nationally representative survey data (i.e., the 2016 ANES survey data)
- The county-level administrative data (e.g., the shares of bachelor's degree holders, change in population size, and change in unemployment rates)
- The data of the availability of local newspapers
- Twitter data (i.e., tweets about climate change, location information of users who posted these tweets obtained via their profile information, and political ideology estimated using followee of these users).

By incorporating different kinds of data in this way, this dissertation illuminated the existence of rural-urban divides surrounding science in the attitudes toward scientists measured by the survey, as well as in the share and the contents of the randomly selected representative tweets about climate change from urban, suburban, and rural areas. In general, this study found less positive attitudes toward scientists and science in the results analyzing both survey and Twitter data. To be sure, the population of the nationally-representative survey and Twitter users in the U.S. would significantly differ. Twitter users who posted tweets about climate change should be considered "issue publics" who are highly interested and involved in this issue, rather than the general population in the U.S. It should be noted that rural-urban divides were found in

analyzing these significantly different datasets about their populations. Despite these differences in the survey and Twitter datasets, Rural-urban divides surrounding science are consistent and vivid enough to be detected.

Also, Study 1-2 demonstrated that disparities in obtaining higher education (the shares of bachelor's degree holders) and socioeconomic growth (the change in population size) at the county level are likely to be the underlying mechanisms of rural-urban divides in science. Considering difficulties solving these educational and socioeconomic disparities, rural-urban divides surrounding science are deeply-rooted complex issues in American society.

In addition, by employing an unsupervised machine learning text analysis, Structural Topic Modeling, this study showed that most of the topical frames used in public discourse about climate change on Twitter were more or less politicized. There were topics related to the 2020 election cycle and skepticism toward the government and establishment. However, even after controlling the individual-level estimated political ideology and the place-level political leaning (i.e., place-level Democrat vote share), rurality showed significant negative associations with the prevalence of the non-election related topics and the economy and energy topic.

These include the topics related to environmental protection, such as sustainability of the society and behavioral change concerning climate change amid the COVID-19 pandemic. Less prevalence of these topics among rural Twitter users than in more urbanized areas is consistent with less positive attitudes toward scientists and science.

Meanwhile, the association between the interaction of rurality and individuals' political ideology with the prevalence of the scientific-facts-based topic implied the complexity of rurality. The likelihood of using this scientific-facts-based topic increased among all the political ideology groups, although its increase was modest among conservative users. Such outcomes

may be explained by dominant industries in rural areas, including the farming and dairy industry. Based on these results, there is a possibility that scientific-facts-based healthy discussion may be feasible if we can frame an issue with local contexts while avoiding the hot-button issues of relative deprivation and related place-based social identity.

In sum, my dissertation highlighted the importance of the role of geography-based contextual factors in the contexts of rural-urban divides in communication studies. Previous studies such as Suk et al. (2020) and Wells et al. (2021) have explored this direction already, especially in the realm of political communication. However, such a framework has not been fully investigated in science communication. Similarly, studies about framing have not examined rural-urban divides sufficiently yet despite the consistent and significant effects of rurality on the topical frames about climate change on the Twitter-sphere in this study.

Hence, my dissertation serves as one of the early attempts to explore the role of place-based identity and contextual socioeconomic factors based on the place of residence in communication studies. By analyzing both the nationally representative survey and Twitter datasets, which were further incorporated with administrative data and the availability of local newspaper data, this dissertation sheds light on the critical role of rurality and its multifaceted characteristics. Rurality is a complicated concept and measure related to educational and socioeconomic disparities possibly resulting from the structures of local dominant industries.

On the other hand, the limitations of this dissertation, are resulted from such complex nature of rurality. In Study 1-1, 1-2, and 2, this dissertation operated the rurality variable differently, as a categorical variable with the six categories for Study 1-1 and the three categories for Study 1-2. Rurality was operationalized as the place-level continuous variable in Study 2. Such inconsistent operationalization is not ideal. However, to simplify models, this study had to

operate the rurality variable differently to explore its mediation effects via county-level variables (in Study 1-2) and moderation effects with individuals' political ideology (in Study 2).

Also, in Study 2, some cities appeared in the Twitter dataset split into multiple counties. As a result, this study had to take the mean of rurality of these multiple counties to create a rurality measure. In this way, inconsistent operationalization of rurality was inevitable, however, future studies should explore the non-linear association between rurality and attitudes and topical frames. Some insignificant differences were found between large central metro and rural areas in Study 1-1. Suk et al.(2020) and Wells et al. (2021) also found significantly different attitudes among suburban residents toward politicians compared to urban and rural residents. Hence, there can be the starkest difference between urban and suburban areas, not between urban and rural areas.

To classify regions in a meaningful way, detailed quantitative analysis using only one state may be useful, like Suk et al. (2020) and Wells et al. (2021). Likewise, qualitative research is valuable to explore the public discourse and attitudes among urban and suburban residents for further comparison with Cramer (2016) 's work on the rural-urban divide.
Especially *within* urban areas, both of the attitudes toward scientists and science and tweets about climate change indicated substantive variances. The in-depth interview can vividly illustrate diverse voices from urban residents.

In addition, to improve the generalizability, future studies should examine the association of rurality and the usage of topical frames in the different scientific issues. Air or water pollution and local vaccine and mask mandate can be good candidates because these issues tend to be discussed with local contexts more frequently. Climate change has been placed in the front line of the arena of national politics for more than decades. By investigating the role of rurality in

these more localized issues, we may find a possibility of social media to fill the gap of the decline of local newspapers. Lower interests among rural residents to be involved in pro-science and environmentally-friendly public discourse may be improved to some extent.

Lastly, this dissertation emphasizes the vital role of rurality and educational and socioeconomic disparities as the contextual factors to design effective communication strategies about science. Ignoring the role of rurality is a crucial issue not only for communication scholars but also for political and health campaign practitioners, especially amid the COVID-19 pandemic. Dissimilar acceptance toward recommendations by scientific experts at the community level can result in disparities in the risks damaging the health and even lives of residents in each community. Also, we should pay attention to the perils that rural-urban divides become as salient as partisan divides. We need efforts to seek solutions to mitigate such geographical divides.

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