Measuring and Modeling Russian Newspaper Coverage of Climate Change[☆]

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Abstract

As a significant emitter of greenhouse gases and a country rich in fossil fuels, Russia plays a crucial role in achieving a comprehensive solution to climate-related challenges. Yet, Russia's official position on climate change has varied considerably since the beginning of global negotiations, with the country playing everything from policy leader to laggard. While there are a number factors that shape domestic policy positions on climate change, this study offers a comprehensive investigation of newspaper coverage on climate change in Russia. How have Russian newspapers discussed the issue since the Yeltsin era? We approach this question by compiling the largest data set of Russian newspaper coverage to date, which includes 11,131 climate-related articles from 65 papers over a roughly 35 year period. After introducing a "computer assisted" approach to measure the core themes running through climate change coverage, we statistically evaluate the national- and newspaper-level factors associated with how coverage is framed, focusing attention on 23 high circulation papers over the period from 2000 to 2014. We find that national-level predictors—particularly economic conditions—are highly influential of whether climate change is covered and how the issue is framed, while paper-level factors such as the presence of energy interest and ownership structure also have notable effects. Overall, this study offers a rich data set and an array of methods to better understand the drivers of climate communication in Russia.

Keywords: climate change, newspaper coverage, Russia, text analysis

1. Introduction

As the world's fourth largest greenhouse gas (GHG) emitter, Russia remains a vital piece of any comprehensive and effective plan to mitigate the harmful effects of climate change (UNFCCC 2014). Although Russia played an ambiguous but, nevertheless, pivotal role in the Kyoto Protocol's acceptance (Afionis and Chatzopoulos 2010, Andonova 2008), its current commitment to reducing GHG

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emissions remains unclear. Recently, Russia announced its withdrawal from the second commitment period to the Kyoto Protocol (Bedritsky 2014), eliminated expenses on energy efficiency from the 2015 federal budget (Davydova 2015), and released a set of "intended nationally determined contributions" (INDCs) that could increase GHG emissions considerably above current levels by 2030 (Levin and Damassa 2015). It is thus an open question as to whether Russia will be a leader or laggard in the pursuit to negotiate and implement an effective solution to challenges posed by anthropogenic global warming.

Understanding Russia's position on climate change policy requires careful consideration of the international and domestic factors that promote or impede cooperation. While a diverse array of factors have been suggested in the literature, media coverage is seen to play a crucial role in various aspects of the climate debate. First, considering the agenda-setting function of mass media (McCombs and Shaw 1972) and its influence in shaping public opinion in Russia (White and Oates 2003), news coverage offers a useful means to discern domestic support for climate change action. Discerning public opinion is crucial, as only roughly 3 in 10 Russians believe that climate change is a serious problem and overall concern has decreased by roughly 10% since 2010 (Stokes et al. 2015). Second, mass media also play an important role in translating state views of climate change to national and international audiences, particularly in nations with limited press freedom (Bell 1994, Boyce and Lewis 2009, Boykoff 2012, Butler and Pidgeon 2009, Davidsen and Graham 2014, Dirikx and Gelders 2009, Doulton and Brown 2009, Grundmann and Scott 2012, Lockwood 2009, Lyytimäki 2011). Having a long history of close relations with the state, Russian media coverage often serves as a window into official government positions on climate policy and thus inform interested parties on how to understand Russia's position at future climate change negotiations (Poberezhskaya 2015).

Against this backdrop, we examine the evolution of Russian media discourse on global warming in the post-Soviet era. Although a number of studies examine climate change-related communication in Russia (Poberezhskaya 2014; Tynkkynen 2010; Wilson Rowe 2009; Yagodin 2010), past work is limited both in terms of time period under study and the number of media outlets examined. We contribute to the literature by 1) compiling the largest corpus of Russian newspaper coverage on the issue of climate change, collecting 11,131 relevant articles from 65 newspapers over the time period from May, 1980 to May, 2014; 2) introduce a computer *assisted* approach to content analysis appropriate for a large corpus of documents; and 3) offer a multi-level statistical framework for assessing the drivers of media coverage in Russia. To our knowledge, this study offers the first large-scale analysis of Russian print media coverage of climate change that statistically evaluates how both paper and national level characteristics shape climate discourse. Overall, the evidence suggests that economic conditions are more likely than political factors to explain climate coverage, while paper-specific characteristics—such as energy interests, ownership structure, and ideology—also play a role. Our study thus questions arguments on

the predominant influence of political personalities over climate discourse in the country and suggests a range of alternative explanations for the media approach to the problem.

2. Media Coverage of Climate Change in Russia: Theory and Hypotheses

The importance of mass media in communicating climate change risks has been stressed by a variety of scholars (Bell 1994; Boyce and Lewis 2009; Boykoff 2012; Butler and Pidgeon 2009; Carvalho and Burgess 2005; Davidsen and Graham 2014; Dirikx and Gelders 2009; Doulton and Brown 2009; Grundmann and Scott 2012; Lockwood 2009; Lyytimäki 2011; Olausson 2009). Often the first point of contact between public and climate science, the media is tasked with the crucial role of interpreting the somewhat abstract and difficult to comprehend scientific discourse (Beck 1992; Boykoff and Boykoff 2007; Carvalho 2007; Nelkin 1987 ; Rapley and De Meyer 2014). Olausson and Berglez (2014 p. 251) suggest that scholarly investigations of media coverage of climate change issues should expand inquiries of the power dynamics within national media discourses: "it is vital to examine who becomes the 'primary definer' of the climate issues." In other words, it is crucial to identify the role of mass media in "setting the agenda" (Newell 2006; Boykoff and Boykoff 2004; Carvalho and Burgess 2005) and "framing" the debate around the policy and science of global warming (Boykoff 2007a, Boykoff and Rajan 2007, Carvalho 2007).

The media's ability to define the issue of climate change does not take place in a vacuum—mass media both shapes and is shaped by social, political, and economic forces. Bailey et al. (2014 p. 199) note, in their comparative study of Spanish and American media coverage of climate change, that "media portrayals of climate (un)certainty are steeped in the historically contingent space of ideology, culture, and politics, where various actors and institutions battle to shape public understanding and engagement." When studying the Russian case, one observes a historical progression marked by an ambiguous relationship between the media, the state, and key economic actors. Towards the end of the 1980s and in the early 1990s, the media became an influential actor in the regime change process through its increasingly open criticism of the old regime and growing support of emerging political actors (Coyne and Leeson 2009, Mickiewicz 1999, Strovskiy 2011, Voltmer 2000). During the presidency of Boris Yeltsin, the mass media's political role swung from that of active support for the ruling elite to extreme criticism of some of its more questionable political decisions (for example, the war in Chechnya, see Grabel'nikov 2001). Furthermore, Yeltsin's presidency was marked by the growth in power of the so-called "oligarchs" and their expanding control over the media market (Lipman and McFaul 2001; Zassoursky 2001). The dawn of the Putin era in Russian politics further signified a move towards the centralisation of the media market and the re-establishment of state authority in the public discourse (Becker 2004; Zassoursky 2004). Moreover, when studying media coverage of climate change, it is important to consider

that "oligarchs" and the state have close connections to the Russian fossil fuel industry, with such "gas giants" as Gazprom owning a vast number of national media outlets (Toepfl 2013). As will be discussed below, the interests of such owners are expected to shape newspaper coverage of climate change.

2.1. Presidency and Kremlin loyalty

Richard Sakwa (2010: viii) argues that Russia is "a dual state" where "the legal-normative system based on constitutional order is challenged by shadowy arbitrary arrangements." For example, it can be argued that power in the country is disproportionately skewed towards the president or towards key political figures (for example, Putin's personal domination over Russian politics (Hanson 2010)). Regarding Russia's climate policy, it has been suggested that stagnation in its development can be explained by Putin's personal negative attitude towards this environmental problem (Henry and Sundstrom 2012). At the same time, the recent positive change in national climate affairs could be attributed to Medvedev's striving for a green economy and modernisation (Monaghan 2012). Therefore, we suggest that while pro-Kremlin newspapers are expected to closely follow the state's agenda on climate change, their coverage will adjust depending on whether Putin or Medvedev is in power. Where Putin's presidency would have a negative impact on the quantity of articles and qualitatively on their content, the discussion will steer away from the sensitive issues of domestic politics and emphasize the costs of climate action. Under Medvedev's leadership, we expect to see an increase in coverage with more discussions dedicated to energy efficiency, international cooperation, domestic politics as well as science.

2.2. Newspaper ownership, interests and ideology

As Andonova (2008) argues, we cannot oversimplify Russia's political process by narrowing it down to the changes at the executive level. Therefore, we need to consider a range of other societal and newspaper-level variables that may determine newspaper attention to climate change. By examining the UK quality press, (Carvalho 2007 p. 223) discusses how the media representation of climate change, "is strongly entangled with ideological standpoints." In Russia, the ideological orientation of the newspapers has to be treated with caution as the distinction between left, centre and right are often blurred and need to be treated in consideration with media ownership structures and their governmental links. That said, as demonstrated by previous research on the influence of the newspapers' political leanings on their approach to climate change coverage (Carvalho and Burgess 2005, Carvalho 2007, Poberezhskaya 2015), we can suggest that oppositional newspapers (far-right and far-left) owned by non-governmental political parties will be very vocal across various topics as they can use climate change as an opportunity to criticise the state. Similar expectations (but to a lesser degree) could be expected from the newspapers whose majority shareholders are journalists, especially those on the political left. At the same time, the media outlets belonging to the political right and centre should be

quite reserved in their climate coverage and likely eschew economically problematic areas (e.g. Russia's international obligations or fossil fuel industry). We expect that avoidance will also be intensified if a newspaper is owned by business interests or if it state-owned. At the same time, considering the nature of the climate change problem, we hypothesise that newspapers with energy interests will avoid discussing the problem in the context of fossil fuels or renewable energy development, and should also be less likely to discuss climate change overall. It should be noted that, throughout the studied years, the Russian newspapers' market has been dominated by the business led ownership structure with various degrees of their relations with the state (Lehtisaari 2015).

2.3. National economic performance

It has been argued that during economic recessions people tend to privilege financial stability over environmental security (e.g. Inglehart 1995, Scruggs and Benegal 2012, Shum 2012). For decades this has been the case for Russia where the environment has been persistently sacrificed to economic development (Henry 2010). Therefore, we can assume that economic crises (e.g. high inflation) should reduce newspaper attention to climate change, as the national economic well-being would take precedence. However, the state of the economy might also have an impact on what themes are focused on when climate change is indeed discussed. We posit that poor economic performance should be positively associated with discussion of climate change in the context of economic opportunities (e.g. Arctic development, international cooperation and energy efficiency).

2.4. Natural disasters

There is some (but limited) evidence in the literature linking the influence of extreme weather events to media coverage of climate change (Shanahan and Good 2000, Boykoff and Boykoff 2007, Boykoff 2007b, Schäfer et al. 2014). However, impacts of natural hazards on attention to global warming seem to also depend on various social, political, economic, and other country-specific factors. Current understanding suggests heterogeneous effects, with cross-national variation in the intensity of the negative consequences of climate change on public discourse (e.g. Schäfer et al. 2014, Schmidt et al. 2013). However, there is evidence which indicates that warm temperature anomalies might impact individual attitudes toward climate change (Li et al. 2011, Zaval et al. 2014). Considering Russia's growing climate vulnerability, we suggest that climate change related natural hazards should increase media attention to global warming. The 2010 Russian heatwave, which resulted in the deaths of over 55,000 people and an estimated economic loss of $15 billion (Barriopedro et al. 2011), was a catastrophic event that led to a strengthening of ecological groups in Russia (Yanitsky 2012). We therefore expect that when natural disasters occur, newspaper coverage of climate change should be more likely.

3. Measuring Russian Newspaper Coverage of Climate Change, 2000-2014

This study extends previous work on media coverage of climate change in Russia by incorporating an extensive list of Russian newspapers over a considerable period of time. To create the corpus, we retrieved newspaper articles which contained the terms "climate change", "global warming", or "greenhouse effect" from the Eastview Russian Central Newspapers database (UDB-COM). This resulted in the identification of 11,131 relevant articles from 65 newspapers. The temporal coverage of the corpus is large, ranging from 3 May 1980 to 7 May 2014. The full list of newspapers and article counts, along with an illustration of temporal variation in coverage for the entire period are presented in Appendix A.1. Most newspapers entered the Eastview database in the late 1990s and early 2000s. Estimates of attention to climate change by the Russian press are therefore reliable starting around 2000. It is for this reason that the analysis conducted in Section 4 relies on 6,527 articles from the 23 most circulated newspapers over the period Q1/2000-Q2/2014. Specifically, we focus the study on a sample of papers with moderate to high circulation counts, ranging from 85,000 (the social-political weekly magazine *Itogi*) to a maximum observed count of 2,985,000 (the national popular weekly *Argumenty i fakty*). We expect that newspapers with very large circulation figures are influential due to massive exposure and that newspapers with average circulations are likely to have more narrow audiences. However, these somewhat smaller papers (e.g. *Kommersant*) are also likely to be influential since they are more likely to target "elites" and opinion leaders.

It is also important to note the potential limitations associated with focusing on newspapers to measure media coverage. As in many other countries around the world, the majority of Russians get their news from television, with over 90% of Russians tuning in each week (Broadcasting Board of Governors 2014, Deloitte CIS Research Centre 2016). Moreover, consistent with international trends in media consumption, the importance of online news has increased steadily over-time, particularly among younger individuals and those living in urban areas (Ibid). At the same time, print media remains an important source of news in general and political news in particular, with over 50% turing to newspapers and magazines for their news each week (Deloitte CIS Research Centre 2016).

Figure 1 displays quarterly counts of climate change related articles for the 23 most circulated Russian newspapers. Several features of aggregate media coverage based on the corpus are worth noting. Coverage of climate change in the Russian press maintained a steady increase until 2007, when we can observe a significant spike in attention. This finding is somewhat unexpected, as existing literature on Russian media coverage of climate change focuses on the period around 2009; prior years such as 2007 have been relatively ignored. Following a brief drop in coverage after 2007, there is a renewed spike in attention over the 2009-2010 period (Copenhagen meeting and 2010 Russian heat wave), which is then followed by a steady decrease in coverage. This attention pattern, more or

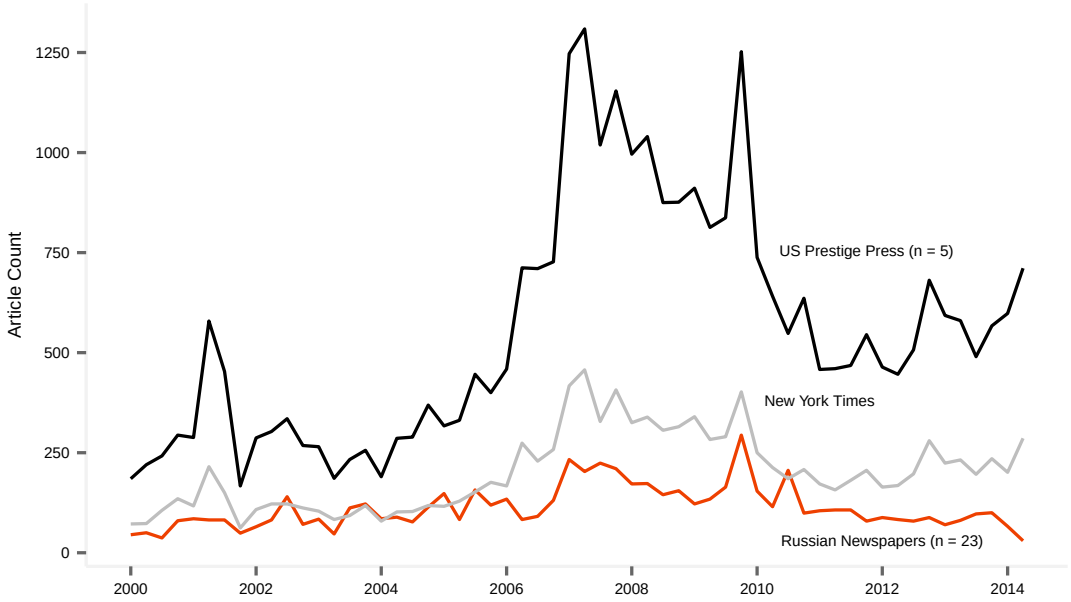

Figure 1: *The number of newspaper articles that mention climate change over time.* Displays quarterly counts of climate change related articles for the US "prestige press" (*Washington Post, Wall Street Journal, New York Times, USA Today and Los Angeles Times*) [black], the *New York Times* [grey], and the 23 most prominent Russian newspapers based on circulation [orange]. US newspaper data are derived from Boykoff et al. (2015). See Appendix C.1 for a detailed list of the most prominent Russian newspapers.

less, maps well with coverage rates from major American newspapers (Boykoff et al. 2015). However, as is clear from the plot, in terms of absolute coverage, Russian newspapers have devoted strikingly low attention to the issue when compared to the American press. Notably, the *New York Times* has published more climate change related articles than all prominent Russian papers combined for most of the 2000-2014 period.

3.1. Measuring climate-related themes: computer "assisted" content analysis

While aggregate trends offer some insight into climate-related coverage, the obvious next question centers on what themes are prevalent in Russian newspapers. Past content analyses of climate change coverage rely almost exclusively on traditional methods based on human coders (Antilla 2008, Bailey et al. 2014, Olausson 2009, Shrestha et al. 2014, Taylor and Nathan 2002). These methods are, however, extremely costly—in terms of both time and effort—and thus researchers are often forced to make important trade-offs, either constraining

temporal coverage (c.f., Nissani 1999, Painter and Ashe 2012) or focusing on thoroughly reading a smaller, more manageable set of documents (c.f., Elsasser and Dunlap (2013), Dunlap and Jacques (2013)).

Yet, if traditional content analytic methods do not scale to meet the needs of scholars of climate communication, it is essential to identify approaches that do. More recently, scholars have examined the "promise and pitfalls" of automated classification methods across a range of common tasks in the social sciences (Grimmer and Stewart 2013), and for classifying news story content in particular (Ali et al. 2010, Young and Soroka 2012). The promise of computational methods is clear: they offer a reliable means to classify the primary topics or themes for large corpora of text (Mikhaylov et al. 2012). The drawback of computational methods, however, is that considerable effort must go into ensuring model validity (Quinn et al. 2010). In short, important trade-offs must be considered irrespective of whether an analyst chooses to employ traditional or automated forms of content analysis.

We argue that much may be gained by combining aspects of both methodologies. Consistent with recent literature on the use of text analytic models in the social sciences, our approach views computational methods as *assisting*, not replacing, traditional techniques (Grimmer and King 2011). Grimmer and Stewart (2013 p. 2) summarize this position quite well:

> "the complexity of language implies that automated content analysis methods will never replace careful and close reading of texts. Rather, the methods that we profile here are best thought of as *amplifying* and *augmenting* careful reading and thoughtful analysis." (emphasis in original)

As such, we analyze key themes in climate-related articles using an approach that strikes a balance between traditional methods based on human coding and recent advances in the field of natural language processing. Specifically, we employ the following three-step procedure:

1. we first "augment" the corpus using an *unsupervised* algorithm to identify meaningful topics (or clusters) in Russian newspapers and utilize the estimated topics to identify a small subset of documents that require a "careful and close reading;"
2. use the results of step 1 and traditional inductive content analytic methods to code a sample of documents into a set of valid, reliable, and substantively meaningful themes;
3. combine the results from steps 1 and 2 to develop a computational procedure for classifying the primary themes in the corpus, validating the model using common classification performance metrics (i.e., accuracy, precision, and recall).

The remainder of this section briefly outlines our approach—a fuller description of all of the methods described in this section is available in the online appendix.

3.1.1. Reducing dimensionality via unsupervised learning

We begin with the observation that while reading 11,131 articles is practically infeasible, carefully assessing 100 key "topics" is much more attainable. As a first step, then, we need a method to reduce our overall corpus to a core set of topics or themes. To achieve this objective, we utilize the well-known latent Dirichlet allocation (LDA) model originally proposed in Blei et al. (2003). Viewing each document as a finite mixture of "topics" (i.e. meaningful clusters of words), the LDA models the random process responsible for "generating" a particular text (see the supplemental appendix for technical details). While the Bayesian methods used to produce "topics" are a bit involved (see the appendix for details), the important point is that the LDA has been shown to preform well in a wide range of areas, from population biology to information retrieval, and thus provides a suitable method our data reduction task (Blei 2012 see).

The results from estimating a 100 topic model are available in the appendix (see Table B.4). Analyzing all 100 topics, however, is unwieldy and many topics deal with similar overarching themes. As such, there are substantive and practical benefits from further coding the topics into higher order themes that conform with key aspects of climate change coverage. To do this, we first categorize topics into topic families or "meta-topics" using the topic keywords and, more importantly, the descriptive labels derived from a careful read of the top 5 to 10 most probable documents. This procedure yielded a total of 23 substantive meta-topics which cover themes related to science, energy, economics, international and domestic politics, and society. A full list of these meta-topics are displayed in Table 1 along with the labels and identification numbers of each meta-topic's underlying topics, a measure of how often the meta-topic is sampled from the corpus (prevalence), and two classification accuracy scores which are discussed in detail in Section 3.1.2.

3.1.2. Model validation

A critical—if not *the* critical—step in any computer-assisted approach to content classification is model validation. If the specified model is working well, then the predicted primary topic or topics should correspond to the categories assigned by human coders. To construct a manually annotated set of documents to use for purposes of validation, we relied on the standard operating procedure of "inductive" content analysis: we use a small (randomly selected) set of documents, classified the primary topic of each document using the 23 codes outlined in Table 1, discussed disagreements, and modified accordingly. More specifically, we repeated this inductive process until reliability was sufficiently high (Krippendorff's $\alpha \geq 0.80$). After ensuring sufficient reliability, each individual coder classified the primary topic of 225 documents, leaving a total of 450 manually annotated for validation purposes.

With a human-coded test set in hand, the next question is what criteria should be used to judge model validity. One approach is to draw on procedures commonly used to assess supervised learning problems, which include measuring some combination of classification accuracy, reliability, and precision. We rely on

Meta-Topic Label	Prevalence	F1 Score		Underlying Topic Label [ID]
		Top	*Top 2*	
Activism	0.01	0.73	0.76	Activism (Protests) [26], Earth Hour [30]
Agriculture	0.01	0.59	0.74	Food security [42]
Arctic politics	0.01	0.82	0.87	Arctic geopolitics [4]
Climate impacts	0.08	0.54	0.76	Water resources [27], Sea level rise [31], Archeology [35], Housing [36], Wild life [41], Sea life [69], Climate impacts (Mountains and glaciers) [73], Climate consequences (Scientific forecast) [90]
Climate science	0.08	0.53	0.76	Space (Celestial bodies) [19], Carbon emissions [22], Meteorology (Roshydromet) [24], Space science (Sun) [49], Climate science (Ocean and climate) [62], Climate change (General) [84], Science (Atmosphere) [93]
Comparative politics	0.04	0.63	0.68	Politics (Germany) [5], Politics (USA) [20], Politics (UK) [33], Politics (South America) [54], Politics (Elections) [68], IR (China) [95]
Disasters/Extreme weather	0.07	0.72	0.83	Nature disaster (Forest fires) [0], Weather abnormalities [39], Catastrophe (Futuristic predictions) [45], Nature disaster (Hurricanes and floods) [58], Catastrophe (Response/MCHS) [60], Winter abnormalities [66]
Economy/Business	0.08	0.47	0.67	Budgeting climate risk [1], Business [6], Economy general [29], Corporate responsibility [59], Economy (Sustainable development) [86]
Education	0.01	0.36	0.67	Education [23], Education (University competition) [52]
Non-renewable energy	0.02	0.61	0.81	Energy (nuclear) [48], Energy (gas) [99]
Renewable energy	0.01	0.50	0.78	Energy (Sustainable sources) [8]
Energy efficiency	0.02	0.43	0.67	Transport (Mostly aviation) [15], Transport (Cars) [17], Energy (Efficiency, Emission reduction) [82]
Health	0.01	0.86	1.00	Health [47]
Information technology	0.004	0.50	0.80	IT [78]
Int'l climate agreements	0.03	0.84	0.91	Climate research (Russian-Belarusian) [10], Climate politics (COPs) [28], Climate politics (Kyoto Protocol) [61]
International politics	0.05	0.53	0.71	UN (and Russia) [21], IR (ASIA-APEC) [34], Politics (EU) [53], IR (Summits) [64], IR (Bilateral relations) [83]
International security	0.05	0.5	0.71	Russian national security [50], IR (Power politics) [55], Military [65], Russian national security policy [67], IR (Security-conflicts) [94], Russian foreign policy [98]
Polar science	0.01	0.75	0.89	Antarctic [12], Arctic (Science) [89]
Pollution	0.01	0.29	0.46	Env. protection (General pollution) [57], Env. protection (Air pollution) [87]
Russian cities	0.01	0.25	0.33	Moscow [79]
Domestic climate politics	0.04	0.49	0.74	Russian legislation [2], Medvedev's politics (Russian politics) [9], Politics (Russian officials meet) [13], Russian mitigation legislature [40], Russian diplomacy [51], Russian Politics (Ministries/docs) [91]
Science (other)	0.02	0.67	0.73	Russian Science [71], Scientific discoveries (Genetics) [96]
Society and culture	0.10	0.44	0.70	Historical mysteries [3], Justice (crime) [7], Art (Film/music industry) [11], Nobel Prize [88], Sport [97], Art (Music) [25], Philosophy [43], Population growth [46], Fashion [63], USSR [70], Religion [74], Literature [75], Politics and Society [76]

Table 1: *Meta-topics and underlying topics within the newspaper corpus.* This table provides the meta-topics determined using the methodological approach outlined in Section 3.1.1. "Prevalence" offers a rough measure of the importance of a meta-topic to the corpus and is measured using the proportion of words assigned by the LDA to a particular meta-topic over the sample period. The table presents two measures of predictive accuracy using the F1 score (see Section 3.1.2 for a full description). Lastly, we present the topic labels that underlie each meta-topic.

this approach here. Table 1 examines classification accuracy using the harmonic mean of precision and recall—i.e., the well-known and often used "F1 score". First, we compare the primary (or "top") topic suggested by the model to the

primary topic identified by human coders. As demonstrated in Table 1, there is considerable variation in classification accuracy across the 23 categories, with the F1 score ranging from 0.84 (*Health*) to only 0.25 (*Russian Cities*). For the set of issues salient for the literature on Russian coverage of the climate issue, meta-topics such as *International Climate Agreements* (0.84) and *Arctic Politics* (0.82) are classified accurately, while other themes such as *Domestic Climate Politics* (0.49) do not perform well.

Yet judging an LDA model based only on the primary topic alone offers a conservative assessment of model accuracy. Even a cursory glance at articles in the Russian media corpus suggests that a single story will often discuss multiple climate-related themes, and it is not always easy for either human or computer to decide on what topic is "primary." To offer a less conservative assessment of predictive accuracy, we examine whether the model classifies the human-coded primary topic as either the first or the second most probable topic for each document in the sample. When doing so, the F1 scores improve considerably for several important climate-related themes (see Table 1). For instance, we observe a sizeable increase in the F1 scores for energy-related themes, with both *Non-renewable* and *Renewable Energy* registering values near 0.80. Similarly, we observe a considerable increase in the F1 scores for the *Climate Science* and *Climate Impacts* themes, as well as a dramatic improvement for *Domestic climate politics* and *International security*. Overall, while this analysis demonstrates a range of validity across the 23 meta-topics, we find reasonable predictive accuracy for key climate-related themes.

4. Explaining coverage: the correlates of climate change reporting

We now turn to examining the correlates of climate change coverage. What societal- and newspaper-level factors explain variation in coverage on key climate-related issues in Russia? To examine this question, we focus on 23 newspapers for which sufficient data was available over the 2000 to 2014. These papers represent a substantial percentage of the overall circulation in Russia and include a representative cross-section of papers based on ownership structure, political ideology, and ties to the Russian central government (see appendix table A.2). The remainder of this section outlines our variables of interest, statistical methodology, and presents our main empirical findings.

4.1. Outcome variables

The 23 meta-topics in Table 1 offer a detailed set of themes for measuring the intensity of climate coverage. Yet, to keep the analysis manageable, we focus our attention on three sets of meta-topics that 1) cover salient themes that are important in the Russian climate change literature (Poberezhskaya 2014; Tynkkynen 2010; Wilson Rowe 2009; Yagodin 2010) and 2) exhibit reasonable levels of predictive accuracy (*F1 top 2* > 0.70). First, we examine the intensity of coverage for two key aspects of climate change by combining *climate science* and *climate impacts* (see Table 1) into *climate science & impacts*. This variable

represents a core aspect of climate literacy and provides a useful means to gauge coverage of climate change fundamentals. Second, we combine *international security* and *arctic politics* into *geopolitics*, which centers on discussions of climate change in the context of international relations. Further, we seek to explain variation in how Russian newspapers have reported on climate change negotiations by investigating the *international climate agreements* meta-topic. Lastly, we investigate the variation in newspaper attention on energy-related themes within the context of climate change by combining *non-renewable energy*, *renewable energy*, and *energy efficiency* into *energy issues*. Time-series plots of these outcome variables over the period Q1/2000-Q2/2014 are illustrated in Figure C.5, which can be found in Appendix C.2 of the supplemental appendix.

The obvious next step involves determining an operational definition for the selected themes. As described in Boussalis and Coan (2016), there is no agreed upon "best" strategy for generating measures from underlying topic data and the appropriateness of a particular strategy is contingent on the research question of interest. Given the literature on Russian climate communication, our primary interest is in determining how papers frame the climate issue and whether the framing changes according to national- and newspaper-level factors. In particular, we examine how different papers make trade-offs when discussing different climate-related themes, focusing on the proportion of all words devoted to a particular meta-topic in Table 1 for each paper-quarter. As such, this measure allows us to examine under what context a particular paper discusses the issue of climate change.

4.2. National and newspaper-level covariates

We also focus on national and newspaper-level covariates considered important in the communications literature. Classifying Russian newspapers' ownership, ideology and their relations with the state has proven to be a difficult task for researchers, and as Koltsova (2006) notes due to the rapid and constant changes in the Russian media market, these variables often remain a mystery even to market actors. In order to eliminate as many coding inaccuracies as possible, we have consulted a range of sources including: web-pages of the studied newspapers, publicly available databases (e.g. media-atlas.ru, mediageo.ru) and relevant literature sources (e.g. Nenashev 2010, Strovskiy 2011, Zassoursky 2004). To account for national level variables which may influence newspaper coverage of climate change, we control for consumer prices and the occurrence of extreme temperature, drought and storm events. A list of the variables along with their levels and descriptions are presented in Table 2.

4.3. Statistical methods

The next challenge is finding a suitable statistical model to examine variation in climate coverage as a function of key covariates. We assume that decisions regarding climate coverage result from a mixture of two random processes: newspapers first decide whether to discuss the issue of climate change at a given point in time and next decide how much coverage to devote to a particular theme.

Variable Label	Levels	Description
Ownership structure	Business	Ownership structure is dominated by the business organisations with interests outside of the media market
	State	Predominately state-owned newspapers
	Journalist collective	Predominately owned by people with main interests in the media market
	Political party	Owned by oppositional political parties
Energy	Yes	Owners have interests in energy sector
	No	No obvious connection with energy sector
Political spectrum	Left	Supports or advocates socialist/communist ideas
	Centre	Supports or advocates ideas of political and economic stability, and traditional values
	Right	Supports or advocates ideas of capitalism and liberalism
Kremlin affiliation	Pro-Kremlin	Non-state owned paper supports government in power
	Independent	No obvious support for the government in power from non-state owned paper
Inflation	*Mean* = 11.78	Average quarterly consumer prices (all items),
	SD = 5.04	percentage change on the same period of the previous year (OECD 2016).
Disasters	*Mean* = 0.67	Quarterly counts of extreme temperature,
	SD = 1.00	drought and storm events (Guha-Sapir et al. 2015).

Table 2: *National and newspaper-level variables and descriptions.* Note: The identification of the Russian political spectrum is a complex task, as notions of the political "right", "centre" and "left" have been altered and even swapped over time (see more in Simonsen 2001). In this article we have adopted the most common interpretation of the concepts. Summary statistics and descriptions are also presented for *Inflation* and *Disasters*.

More specifically, we model climate coverage using a mixture of a Bernoulli distribution for the decision to cover the issue *at all* and a beta distribution to represent coverage *intensity* (see the appendix for technical details). While a Bernoulli-beta mixture model offers a flexible approach to examining the skewed and zero-inflated proportions that are typical in our data, the standard setup ignores the clustering produced by examining a cross-section of newspapers over time. We thus extend the standard model to include random effects for both the newspaper ($n = 23$ papers) and time ($t = 58$ quarters). All of the models presented below are estimated using a fully Bayesian approach (see the appendix for additional details).

4.4. Results

We begin with the first step in the data generating process by examining the factors that influence whether or not a paper covers climate change at all in a particular quarter. Figure 2 provides estimates from a logistic regression for the decision to cover the climate issue, where the outcome is equal to 1 if a paper mentions climate change in a given quarter and zero otherwise. The figure plots the estimated coefficients (log odds) for each variable of interest based on the median posterior value, while also providing 90% credible intervals. To ease the interpretation, we set the baseline category to the group expected, *a priori*, to have the most overall coverage of climate change based on the past scholarship:

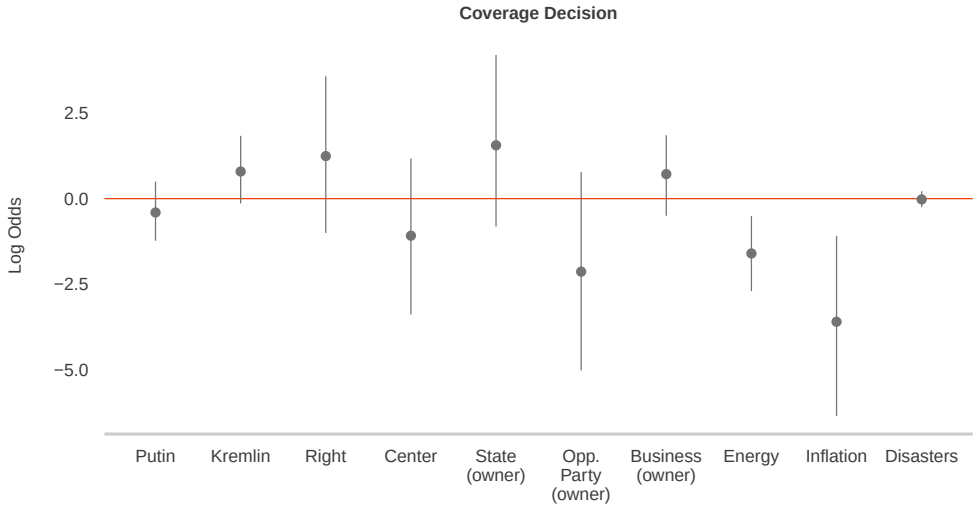

Figure 2: *Explaining variation of any mention of climate change.* Dots represent parameter estimates based on the posterior median; lines provide the 90% highest density intervals. The baseline represents the newspaper profile expected to cover climate change most frequently: left leaning, journalist-owned newspapers, with no direct energy interest, and not affiliated with the Kremlin. The estimated coefficient for the intercept (not shown) is 5.7 (HDI = [2.8, 8.5]).

left-leaning papers, owned by journalists, without a direct energy interest, and not beholden to the Kremlin (Poberezhskaya 2015). The results generally fit with expectations. The overall state of the economy—as measured by inflation—has the largest overall influence on the probability of covering the climate issue. Not surprisingly, when times are tough economically, climate change is less likely to appear in the news agenda: moving inflation from its minimum to maximum value—while fixing all other variables at constant values—leads to a 0.10 decline in the probability of covering climate change. This level of change, however, represents a considerable swing in economic conditions and, for more moderate changes (e.g., from the 1^{st} to the 3^{rd} quartile of inflation), inflation leads to a roughly 1% decline in discussing climate-related issues. Energy ownership also reduces the propensity of a newspaper to report on climate-related issues, with the likelihood of covering climate change again falling by roughly 1% for papers owned by an energy company. Lastly, opposition party papers are approximately 2% less likely to mention climate change at all—though, this estimate is quite uncertain. We do not find a significant difference in the likelihood of climate change coverage between Putin or Medvedev presidential periods. Further, we do not find a significant conditional relationship between presidential period

and state-owned or Kremlin-loyal papers on the probability of covering climate change (not shown).

Examining mentions alone, however, offers little insight into *how* climate change is being covered in the Russian press. That is, if a paper decides to cover the climate issue, in what context do they do so? To examine this question, we use the relative measure of coverage intensity introduced in Section 4.1 and the mixed effects zero-inflated beta model outlined in Section 4.3. We begin with two central features of climate change communication—reporting on *climate science & impacts*. As demonstrated in Figure 3, we find support for the impact of national-level variables on coverage of climate science in the Russian press. Specifically, we find that if a paper covers climate change during times of high inflation, the discussion is less likely to be framed around climate science (log-odds = -1.03, CI = [-1.96, -0.26]). Moving inflation from one standard deviation above to one standard deviation below the mean leads to around an 8% decline in the likelihood of emphasizing climate science and impacts. Conversely, during periods with high instances of natural disaster, coverage is more likely to emphasize scientific discussion (log-odds = 0.07, CI = [0.02, 0.13]). Here, moving from no extreme weather events to 4 extreme weather events (i.e., the maximum), increases the likelihood of framing discussion in terms of climate science and impacts by roughly 7%. There does not seem to be a substantive presidential effect on how newspapers discuss *climate science & impacts*. Further, by and large, there is little evidence for newspaper-level effects. There are, however, several exceptions: right-leaning (log-odds = -0.22, CI = [-0.64, 0.18]) and opposition party papers (log-odds = -0.40, CI = [-0.93, 0.11]) are generally less likely to emphasize science, while state-owned newspapers are more likely to focus on science-related issues (log-odds = 0.30, CI = [-0.10, 0.72])—though, again, uncertainty remains relatively high for these estimates.

Next, we move beyond science to issues associated with the political economy of climate change in Russia. Figure 3 provides estimates for our aggregate measure of *geopolitics*. As shown in the figure, both paper-level and national-level factors seem to play a role in the level of climate-related discussion devoted to geopolitical issues. Considering paper-level variables, energy ownership influences discussion of *geopolitics*, yet papers with energy interests are only less than 1% more likely to cover climate change in the context of international relations. Oppositional party papers are also more likely to frame climate coverage in the context of security concerns and international competition over the Arctic region (log-odds = 0.52, CI = [0.07, 0.97]). To a lesser extent, right-leaning and state-owned papers are more likely to cover climate change in the context of *geopolitics*—though, there is still a fair level of uncertainty associated with both estimates. And we continue to find evidence for the influence of economic conditions; when inflation is high, papers are more likely to frame the climate change debate in terms of geopolitical competition. Further, when disaggregating *geopolitics* into *international security* and *arctic politics* (not shown), we find that security is largely responsible for driving geopolitical frames. That is, the effects of energy and opposition party ownership as well as inflation are stronger

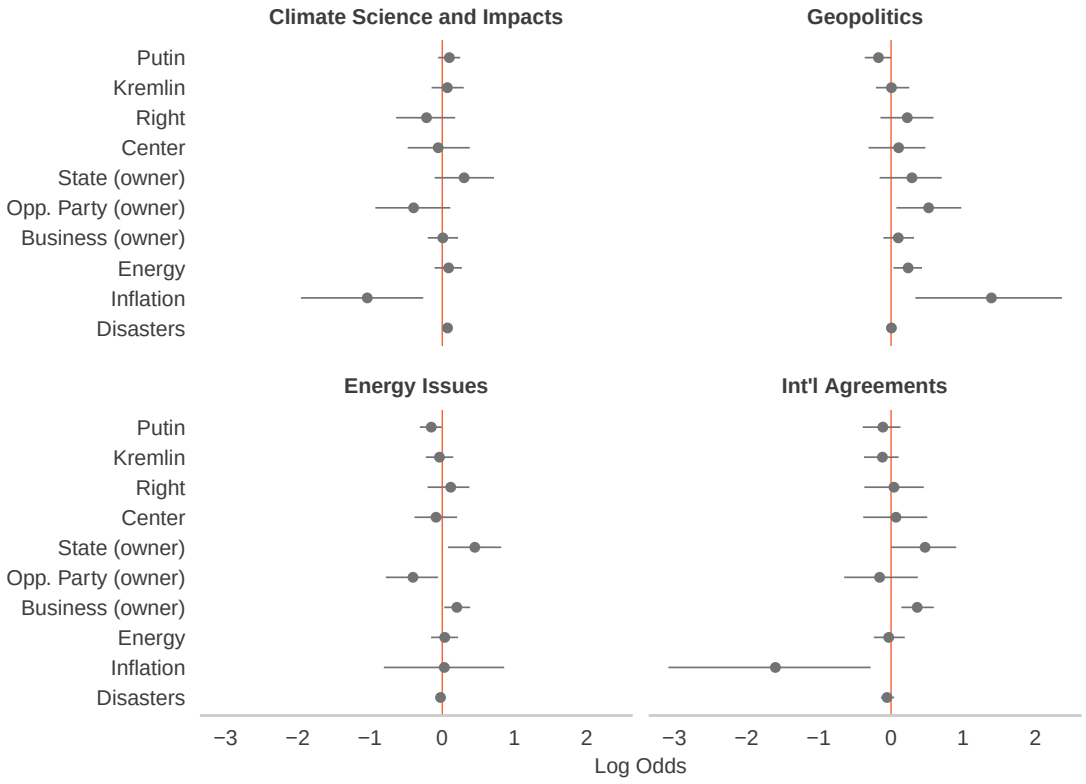

Figure 3: *Coverage of specific climate-related issues.* Dots represent the parameter estimates (posterior medians) from the zero-inflated beta regression model described in Section 4.3, and the lines once again represent the 90% HDI. We employ the same baseline as Figure 2 above and thus compare to a "high frequency" newspaper profile. The estimated intercepts (not shown) are as follows: climate science and impacts (-0.59, [-1.55, 0.32]), geopolitics (-4.55, [-5.68, -3.48]), energy issues (-3.46, [-4.42, -2.60]), and international agreements (-2.22, [-3.74, -0.74]).

when focusing on *international security* alone. There does seem to be a marginal presidential effect. Specifically, we find that during a Putin presidency, papers are less likely (log-odds = -0.15, CI = [-0.31, -0.01]) to discuss climate change in the context of *geopolitics*, however the effect is quite small: newspapers under a Putin presidency are only 0.4% less likely to frame global warming in terms of geopolitical concerns.

The analysis next shifts to climate change discussions in the context of *international climate agreements*. Again, economic hardship, as measured by inflation, has a negative impact on newspaper attention to climate change nego-

tiations (log-odds = -1.60, CI = [-3.08, -0.28]). For instance, moving inflation from one standard deviation below its mean to one standard deviation above, decreases discussion on global warming negotiations by roughly 4%. With respect to newspaper-level variables, the results suggest that state- (log-odds = 0.47, CI = [0.0001, 0.90]) and business-owned newspapers (log-odds = 0.36, CI = [0.14, 0.59]) are more likely to frame global warming along the lines of climate diplomacy. Substantively, government ownership is associated with an approximate 5% increase in discussion, while business group ownership leads to a roughly 4% increase.

Lastly, we examine the extent to which newspapers frame climate coverage in terms of *energy issues*. Not surprisingly, business-owned newspapers are more likely to emphasize climate change in the context of energy issues (log-odds = 0.20, CI = [0.03, 0.39]). Yet, the strongest newspaper-level effects are observed for state-owned (log-odds = 0.45, CI = [0.08, 0.82]) and opposition party papers (log-odds = -0.40, CI = [-0.78, -0.06]). State-owned papers are approximately 2% more likely to highlight energy issues when covering global warming, while opposition party papers are 2% less likely to do so. When digging a bit deeper into these estimates, we find that attention devoted to *renewable energy* and *energy efficiency* play a particularly influential role. While we observe weak differences across papers for *non-renewable energy*, business- and state-owned papers have a strong positive influence on the likelihood of framing climate change in terms of "energy solutions," while opposition party outlets generally avoid discussion of these issues. We also find a negative effect of a Putin presidency on discussions of climate change with respect to energy issues (log-odds = -0.17, CI = [-0.36, -0.002]). However, yet again, this effect is substantively small: newspapers during a Putin presidency are 0.2% less likely to discuss climate change in the context of energy.

5. Discussion

Newspaper attention to climate change has risen steadily ever since the issue was identified as an international problem. A key question for both scholars of climate communication and Russian politics centers on the similarities and differences of Russian media coverage to other major actors in climate politics. We start by considering overall trends in coverage of the issue. Boykoff et al. (2015) demonstrates how interest by the global press increased rapidly starting in late 2006 and remained high for the following few years (see also Schmidt et al. 2013). This increase coincided with important events such as the release of the IPCC Fourth Assessment Report (AR4), the release of Al Gore's *An Inconvinient Truth*, and the awarding of the Nobel Peace Prize to Al Gore and the IPCC. There is another pronounced spike in attention in late 2009 that was triggered by the Copenhagen Conference (COP-15) on climate change and the "Climategate" scandal that preceded it. Our data suggest that Russian newspaper attention generally followed this pattern and, in particular, we find noticeable similarities between Russian coverage and that of the U.S. prestige press (see Figure 1). Yet,

although the general trends are similar, there are several key differences. First, and perhaps most importantly, our analysis confirms that Russian newspaper coverage of climate change is relatively low in absolute terms (Poberezhskaya 2015). As demonstrated in Figure 1, a single major American newspaper (*The New York Times*) has published more articles on climate change than 23 of the most widely circulated papers in Russia. This low level of media attention may offer an explanation of why, when compared to 40 developing and developed nations, Russians are the *most likely* to report that "global climate change is not a serious problem" (Stokes et al. 2015). Second, while it seems that international media have picked up their interest in climate change in recent years and it has again acquired "celebrity status" (Pepermans and Maeseele 2014 p. 217; see also Fischer 2015), we find that Russian newspaper coverage has been steadily decreasing since 2010, with a pronounced drop starting in late 2013. This decline in coverage, moreover, corresponds to an increase in media attention associated with the Russian economic crisis and the onset of the security crisis in Ukraine.

Next, moving from trends in general attention to the correlates Russian climate coverage, we find that the state of the economy is crucial for predicting both whether climate change makes onto the media agenda and the way in which the issue is framed. When economic conditions are bad (as measured by high inflation), the media tend to avoid discussion of global warming and discuss climate change less in the context of science and international commitments, but more with respect to geopolitical concerns. In other words, instead of portraying climate change as an environmental problem, during hard times, the media will present climate change as just another item of discussion in the international arena, outlining opportunities which could be realized with a shift in global climate conditions. The influence of the economy on climate change communication has been identified in other countries as well. For instance, Carvalho (2005 , p. 21), in her analysis of the UK media points out how "free-market capitalism and neo-liberalism" restrict climate public discourse by encouraging the avoidance of problematic topics (e.g. restrictions of the economic growth in order to mitigate the problem). Holt and Barkemeyer (2012) also find negative effects of poor national economic performance on coverage of climate change in a large comparative study of 112 newspapers from 39 countries. As such, our analysis provides additional evidence that economic conditions plays an important role in governing the well-known "issue attention cycle" (Downs 1972).

Previous research also suggests that Russian media coverage of climate change is sensitive to political factors (Poberezhskaya 2015). Interestingly, our study provides little evidence of substantive variation in climate change coverage or attention to various climate change related themes between different presidential administrations (Putin vs. Medvedev). Further, we do not find conditional presidential administration effects on how state-owned newspapers or papers that are loyal to the Kremlin discuss climate change. That is, newspapers that are beholden to the government do not discuss global warming differently when Putin or Medvedev are serving as President. Also, non-state-owned newspapers that are loyal to the Kremlin do not seem to systematically differ from the base-

line case in their reporting of global warming. These results contribute to the on-going academic debate on the role of the personality of the state leaders in shaping climate discussion in Russia (Henry and Sundstrom 2012). The weak evidence found in our study could be explained by the constant powerful impact of Putin's politics regardless of whether he is the Prime Minister or President. On the other hand, as Andonova (2008) states, Russian climate policy cannot simply be explained by the will of the executive but rather by a combination of various political processes.

We also find a much weaker role for natural disasters in explaining variation in coverage of global warming and framing of the issue by the Russian press. Our results indicate that the occurrence of climate-related natural hazards, such as extreme temperature, drought and storms, are associated with an increase in discussions of climate science and climate impact. However, we find little evidence of a disaster effect on overall coverage rates or discussion of energy, geopolitics, or international climate negotiations. Given these findings, we might speculate that natural disasters bring climate change to the realm of popular scientific discourse by trying to explain events, providing advice or raising the alarm of the observed (or possible) negative outcomes. This correlates with Wilson Rowe's (2013) argument that while Russian climate scientists rarely act as "policy entrepreneurs" but rather concentrate on educating policy-makers and the public by explaining the scientific side of the problem.

While national-level factors are predictive, paper-level characteristics also play a role, with papers varying in how they frame the issue. In terms of newspapers' political affiliation and ownership, there is some evidence to suggest that the media outlets on the political right are less likely to address climate change in terms of science and impact. However, when such papers do discuss climate science, they typically provide a rational account of anthropogenic climate change with descriptions of its cause and consequences. Newspapers on the extreme political left and right bring into their discussion of climate science sensationalism and in some cases governmental critique:

> The region is not yet experiencing climatic difficulties, and its problems are due to the irrational management of agricultural production and water waste (Pravda 9/01/2004)

On the other hand, newspapers of the political center express a range of views on the issue. Moreover, when taking a closer look at the corpus—particularly among state-owned papers—there are clear instances of climate scepticism. For instance:

> Global warming will soon finish (Rossiiskaia gazeta 19/09/2007)

> Maybe the president's advisor, Andrey Illarionov [an infamous Russian climate sceptic], is right in his stubborn resistance to the Kyoto Protocol? (Rossiiskaia gazeta 31/08/2005)

This finding also correlates with the development of the state's climate policy, which until a few years ago was dominated by sceptical discourse. Newspapers

with connections to the energy sector mostly tend to look at the problem from the position of international security which often involves discussion of Russian energy interests. For instance, when surveying climate-related articles in our corpus with a high probability of containing a topic related to geopolitics, we found numerous discussions of global competition for the Arctic's resources by papers with energy interests:

> Russia continues to strengthen its positions in the unavoidable division of the Arctic [...] The Arctic shelf presumably contains up to 25 per cent of the world's hydrocarbon reserves, and in connection with global warming, the possibility of their extraction becomes real. (Izvestiia 24/12/2008)

A similar pattern was detected with oppositional and right-wing newspapers also being more likely to discuss climate change in relation to international relations. However, these papers differ slightly in their approach, where the media outlets from the political right provide a more straightforward account of the potential losses and gains in the geopolitics of climate change. In contrast, newspapers belonging to the extreme left and right tend to briefly mention climate change in their elaborate analyses of global politics:

> Today Anglophone plans are implemented under the guise of a stateless "globalization" and ultra-Malthusian scam called "global warming," pushed by former US Vice President Al Gore' (Zavtra 18/4/2007)

Our study also demonstrates that ownership structures impact the way Russian newspapers approach energy-related topics, with business-owned and state-owned papers not only mentioning climate change within energy discussions more often, but also paying greater attention to "energy solutions" (e.g., renewables and energy efficiency). *Izvestiia*, for example, has pointed to American excess when discussing how, "until recently uneconomical and environmentally 'dirty' cars were the most popular choice among American consumers" (Izvestiia 13/02/2004). Business owned papers were likely to express an interest in energy conservation as well:

> The country has a long-term commitment to provide energy for export. It is currently almost the only real means of Russia's political influence [...] Therefore, Russia has to seriously think about a more rational use of its energy resources, as well as of the use of energy-saving technologies' (Kommersant 19/10/2005).

A similar pattern was noticed in how these types of newspapers tackle the topic of international environmental agreements by strategically assessing Russia's gains and losses from the process:

> Russia needs to fit into a new global climate order. While Russia does not persevere in promoting their GHG emission reduction projects, in April 2009 a new US administration has claimed its global leadership

> in the fight to preserve the environment and to development the ideas of global "climate control" (Rossiiskaia gazeta 6/05/2009).

Our data also show how media coverage is influenced by similar considerations as the Russian state's climate policy. Interest in the issue began to "take off" after policy makers began to consider mitigation efforts for their potential benefits to the country (e.g. introducing renewables into the national market in order to increase fossil fuel exports , reducing energy costs, attracting investments, etc.). Though this approach may be seen as "green washing," in the Russian case, it offers a tangible—and even optimal—solution for attracting the interest of the state. Moreover, this approach allows for increased attention without causing a political confrontation among key stakeholders by demanding economic sacrifice and allocating blame for over-reliance on the fossil fuel industry.

6. Conclusion

This study offers a systematic and comprehensive analysis of Russian newspaper coverage and discussion of climate change since the end of the Yeltsin era. Employing methods from machine learning and natural language processing, we have been able to classify a large set of climate-relevant newspaper articles into distinct themes related to global warming. Using a sub-sample from these data, we investigate whether a set of national and newspaper-level factors help explain variation in Russian newspaper coverage of climate change as well as how newspapers frame the issue over the period 2000-2014. Overall, our analysis has helped us to understand *when* climate change is more or less likely to enter Russian public discourse (the first level of the agenda-setting function of mass media (McCombs and Shaw 1972), and *how* newspapers cover climate change during its peaks and lows of attention (the second level of media agenda-setting function (ibid)). We find that national level factors such as the state of the economy are highly predictive of coverage, while paper-level indicators are less consistently related to changes in the media discourse.

While the current study focuses on the issue of climate change, our empirical findings raise broader questions on the political economy of media production in Russia. First, it is clear from our analysis that economic considerations—general economic conditions and energy interests—play a vital role in what the media choose to present. Second, it is striking just *how little variation* one observes across newspapers with very different underlying ideologies and ownership structures. These findings, moreover, are at odds with scholarship based on Western countries—primarily in the US and UK—which suggests that the ideological predispositions of media outlets significantly influence which issues are discussed and how these issues are framed (for ideology and climate change coverage, see for instance Carvalho 2007, Schmid-Petri et al. 2015), though there is evidence that Dutch newspapers are also not affected by ideological disposition on the issue of climate change (Dirikx and Gelders 2010). Similarly, changes at the executive level—from an arguably skeptical Putin to the environmentally-minded

Medvedev—did not appear to systematically alter how the media covered climate change. And though speculative, the consistency of coverage across (seemingly) diverse media outlets underscores the challenge of getting the issue of climate change onto the political agenda and perhaps offers an observable implication of wider changes in the Russian media market, which has become increasingly centralised and controlled over the last decade (Lehtisaari 2015). While it is difficult to know the extent to which these findings generalize to other political issues, the analysis does raise questions regarding how media operate in Russia and the ways in which corporate elite influence the media landscape.

The study does, however, have a number of limitations. First, our analysis does not consider the sentiment and tone of the newspaper articles. For instance, when a paper is discussing climate science, we cannot determine whether the author is being skeptical or dismissive. This is an important drawback which should be addressed in future work. Second, the study relies exclusively on print media, while not including television, radio, and online media, which might present a more complete picture of climate discourse in Russia. Lastly, due to data availability, we were forced to exclude newspaper articles from the Yeltsin era. We, therefore, are not able to generalize our findings on newspaper coverage to the 1990s.

Nevertheless, our results offer a number of valuable insights into climate change communication in Russia. During the Paris COP-21 meeting in September 2015, President Putin re-affirmed Russia's pledge to contribute to the global fight against climate change through further GHG reductions. Some have thought that Putin could have been more ambitious in his claim since a reduction of 25-30% in GHG emissions to the 1990 level will not revolutionise Russia's energy market. On the other hand, considering Russia's ambiguous history of climate change policy, any move forward should be treated as a positive development where the interested parties (climatologists, environmental activists and the international community) should not only understand all of the intricacies of Russian climate discourse but should also learn how Russian media can be utilised in order to popularise climate-related discussions. In other words, focus should be shifted to when climate is more likely to receive attention from the Russian media and how it can be framed in order to involve various media actors regardless of their ownership structure, energy interests and political affiliation. It is our belief that this study makes a substantial contribution in this regard and can also be utilised as a platform for further inquiries into Russian public discourse of climate change-related topics.

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Supplemental appendix for "Measuring and Modeling Russian Newspaper Coverage of Climate Change."

Appendix A. Text analysis

Appendix A.1. Corpus

The corpus was compiled using newspaper articles gathered from the Eastview Russian Central Newspapers database, which may be accessed at http://www.eastview.com/. The Boolean search term used to identify relevant articles was as follows:

> "Изменение климата" OR "изменения климата" OR "изменению климата" OR "изменением климата" OR "изменении климата" OR "Изменения климата" OR "изменений климата" OR "изменениям климата" OR "изменениями климата" OR "изменениях климата" OR "Глобальное потепление" OR "глобального потепления" OR "глобальному потеплению" OR "глобальным потеплением" OR "глобальном потеплении" OR "Парниковый эффект" OR "парникового эффекта" OR "парниковому эффекту" OR "парниковым эффектом" OR "парниковом эффекте".

This search resulted in the retrieval of 11,131 articles from 65 newspapers over the period 3 May 1980 to 7 May 2014. Table A.3 displays the number of articles per newspaper and the time coverage of each newspaper (both in our corpus and in the Eastview database). It should be noted that there is considerable variation in newspaper duration within the corpus. The count of climate change related articles over the entire period is illustrated in Figure A.4. As can be seen in the plot, attention to climate change within our corpus begins to pick up in 1995, with pre-1995 coverage of climate change amounting to only 51 articles (Argumenty i fakty [n=12], Izvestiia [n=33], and Krasnaia zvezda [n=6]). The low number of pre-1995 articles should not be interpreted as a reflection of the true coverage rate of the Russian print media during this period. As is shown in Table A.3, the overwhelming majority of newspapers entered the Eastview database beginning in the late 1990s and early 2000s. For this reason, our analysis focuses on the 2000-2014 period.

Table A.3: Newspaper coverage of climate change in Russia

Newspaper	**Article**	**Temporal Coverage**	
		Corpus	*Eastview (UDB-COM)*
Argumenty i fakty	261	1983-2014	1983-
Argumenty nedeli	23	2011-2014	2011-
E'kho planety	148	2000-2008	2000-
E'konomika i zhizn'	46	1996-2014	1996-
E'kspert	204	1998-2014	1998-
Ezhenedel'nyi' zhurnal	10	2003-2004	2003-2004

Table A.3: (Continued)

Finansovye Izvestiia	2	2002-2002	1998-2003
Gazeta	342	2003-2010	2002-2010
InterFaks-Vremia	5	1998-1999	1997-2000
Itogi	299	1996-2013	1996-2014
Izvestiia	959	1980-2014	1980-
Kommersant. Daily	555	1997-2014	1997-
Kommersant. Den'gi	34	1999-2008	1999-
Kommersant. Vlast'	54	1998-2008	1998-
Komsomol'skaia pravda	345	1997-2014	1997-
Konservator	4	2003-2003	2002-2003
Krasnaia zvezda	270	1992-2014	1992-
Kul'tura	48	2004-2014	2003-
Literaturnaia gazeta	125	1997-2014	1997-
Moskovskaia pravda	540	1998-2014	1998-
Moskovskie novosti	180	1998-2013	1998-2007; 2011-2014
Moskovskii' komsomolets	516	1997-2014	1997-
NG. Dipkur'er	5	2000-2001	2000-2001
NG. Figury i litsa	1	2000-2000	1997-2001
NG. Polite'konomiia	5	1998-2001	1997-2001
NG. Regiony	3	1999-2001	1997-2001
NG. Sodruzhestvo	2	1998-2000	1997-2001
NG. Stsenarii	5	1997-2001	1997-2001
Nasha versiia	30	2005-2008	2005-
New Times, The	42	2007-2013	2007-
Nezavisimaia gazeta	828	1997-2014	1995-
Novaia gazeta	159	1998-2014	1997-
Novoe vremia	25	2003-2006	2003-2007
Novye izvestiia	443	1998-2014	1998-
Obshchaia gazeta	38	1997-2002	1997-2002
Ogonek	176	2003-2014	2003-
Paradox	14	2002-2004	2002-2004
Politbiuro	26	2002-2003	2002-2003
Pravda	66	2004-2014	2003-
Pravda 5	4	1997-1998	1997-1998
Pravda 5. Daily	8	1997-1998	1997-1998
Pravoslavnaia Moskva	3	2000-2008	1999-
Prezident	25	2010-2013	2010-2014
Profil'	191	1998-2014	1998-
RBK Daily	19	2012-2014	2012-
Rossii'skaia gazeta	928	1997-2014	1997-
Rossii'skie vesti	101	1997-2013	1997-
Rossiia	73	2002-2010	2002-2010
Russkii' Telegraf	6	1998-1998	1998-1998
Russkii' kur'er	58	2003-2008	2003-2008
Sankt-Peterburgskie vedomosti	455	1997-2014	1997-
Segodnia	66	1997-2001	1996-2001
Slovo	49	1999-2013	1999-
Sovetskaia Rossiia	186	1999-2014	1999-
Tribuna	188	2004-2014	2004-2015
Trud	397	1997-2014	1997-
Uchitel'skaia gazeta	52	2005-2014	2005-
Vecherniaia Moskva	256	2000-2014	2000-
Vedomosti	10	2010-2014	2014-
Vedomosti (arkhiv)	403	1999-2013	1999-2013
Vek	50	1999-2002	1999-2002
Versiia	7	2004-2005	2003-2005
Vremia MN	146	1998-2003	1998-2003
Vremia novostei'	499	2001-2010	2001-2010
Zavtra	113	1998-2014	1996-

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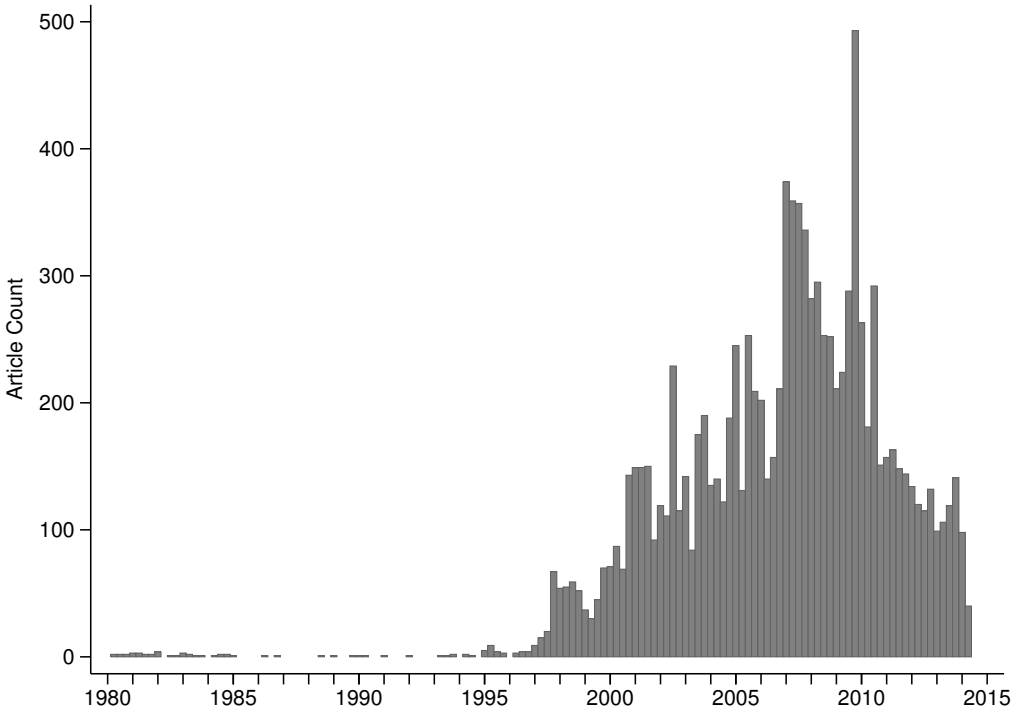

Figure A.4: *The number of climate change related newspaper articles over time.* Illustrates the temporal variation of climate change coverage for 65 Russian newspapers over the period 1980-2014. Quarterly article counts are displayed.

Appendix B. Probabilistic topic model

To reduce our text content into a manageable set of key themes, we utilize the latent Dirichlet allocation (LDA) model originally proposed in Blei et al. (2003) (see Blei 2012 for an accessible overview). Boussalis and Coan (2016 p. 92) provide a useful description of the LDA's assumed data generating process:

> "LDA provides a statistical framework for understanding the latent topics or themes running through a corpus by explicitly modelling the random process responsible for producing a document, assuming that each document is made up of a mixture of topics, as well as a mixture of words associated with each topic. For instance, the document you are reading at this moment includes a mixture of themes such as "climate scepticism" and "text analysis," and these themes tend to use different language—the topic "climate scepticism" is likely associated with the word "denial," whereas the topic "text analysis" is associated with the word "random." Moreover, this process is probabilistic in the sense that we could have used the term "stochastic" instead of "random" in the previous sentence."

Although most individuals do not equate the process of writing with randomness, this turns out to be a useful fiction when the goal is to cluster a large body of text into a small number of themes. More formally, Blei et al. (2003) assume 1) that words are exchangeable, each text is a combination of a specific number of topics (T_k), and topics are represented as a distribution of words (w) over a fixed vocabulary (see also Griffiths and Steyvers 2004). With these assumptions in hand, LDA assumes the follwoing generative process:

1. Each of the k topics are drawn from a topic distribution by
$$\theta \sim Dirichlet(\alpha)$$
2. The term distribution β for each topic is represented by
$$\beta \sim Dirichlet(\eta)$$
3. For each of the N words w_n:
   Randomly sample a topic $z_n \sim Multinomial(\theta)$.
   Choose a word w_n from $p(w_n|z_n, \beta)$.

We rely on the sparse Gibbs sampler described in Yao et al. (2009) to infer the topic structure and the hyperparameter optimization routine utilized in Wallach et al. (2009a) provided the most easily interpretable set of topics. Note also that the LDA requires one to specify the number of topics *a priori*. While a range of methods have been introduced in the literature to estimate the "natural" number of topics for a corpus based on the held-out likelihood (see Wallach et al. 2009b for an overview), there remains considerable debate on the utility of data-driven approaches and Chang et al. (2009) present evidence suggesting models which preform better in terms of held-out likelihood, may actually infer

less meaningful topics. However, for our analysis, we are using the LDA as a tool for data reduction and thus we chose the number of topics that we could read through and analyze using qualitiative methods.

Appendix B.1. Full List of Topics

This table provides the results of the 100 topic LDA for the Russian newspaper corpus, as descried in section X. We removed 10 "junk" topics (AlSumait et al. 2009) and four "non-applicable (NA)" topics where climate change related terminology is used in unrelated contexts (e.g. "greenhouse" used in the context of gardening). This left us with a final set of 86 relevant topics which cover a wide range of subjects. These topics where then grouped into higher order sets (meta-topics) based on subject similarity. For each topic, we present the topic ID, Dirichlet statistic, topic label, meta-topic label, and the top 5 most probable (stemmed) tokens (in Russian).

Table B.4: Climate change related topics in the Russian newspaper corpus

ID	Dirichlet	Topic	Meta-Topic	Token Keys
26	0.01707	Activism (Protests)	Activism	протест антиглобалист полицейск полиц акц
30	0.02717	Earth Hour	Activism	выставк акц час москв город
42	0.02772	Food security	Agriculture	цен хозяйств сельск производств продовольствен
4	0.02755	Arctic geopolitics	Arctic politics	арктик арктическ северн росс морск
35	0.0242	Archaeology	Climate impacts	учен древн мамонт человек животн
90	0.08167	Climate consequences (scientific forecast)	Climate impacts	климат изменен потеплен глобальн климатическ
73	0.0189	Climate impacts (Mountains and glaciers)	Climate impacts	курорт турист ледник гор снег
36	0.03449	Housing	Climate impacts	дом здан строительств жил работ
31	0.0756	Sea level rise	Climate impacts	потеплен глобальн температур учен земл
69	0.02127	Sea life	Climate impacts	мор вод морск рыб акул
27	0.02722	Water resources	Climate impacts	вод рек водн ресурс проект
41	0.03265	Wild life	Climate impacts	животн вид птиц медвед бел
22	0.05471	Carbon emissions	Climate science	газ атмосфер парников углекисл выброс
84	0.1319	Climate change (General)	Climate science	изменен климат последн фактор процесс
62	0.03049	Climate science (Oceans and climate)	Climate science	океа вод европ течен северн
24	0.0193	Meteorology (Roshydromet)	Climate science	прогноз погод метеоролог росгидромет дан
93	0.03666	Science (Atmosphere)	Climate science	атмосфер сло озонов учен вод
19	0.02448	Space (Celestial bodies)	Climate science	космическ земл планет марс венер
49	0.02689	Space science (Sun)	Climate science	земл солнц солнечн планет учен
95	0.02206	IR (China)	Comparative politics	кита китайск кит кнр пекин
68	0.03608	Politics (Elections)	Comparative politics	парт выбор президент политическ политик
5	0.01914	Politics (Germany)	Comparative politics	герман немецк меркел канцлер берлин
54	0.01186	Politics (South America)	Comparative politics	стран штат куб соединен фидел
33	0.02433	Politics (UK)	Comparative politics	британск великобритан блэр лондон браун
20	0.05483	Politics (USA)	Comparative politics	сша американск президент буш обам

Table B.4: (Continued)

45	0.04216	Catastrophe (Futuristic predictions)	Disasters/Extreme Weather	земл катастроф человечеств планет будущ
60	0.04093	Catastrophe (Response/MCHS)	Disasters/Extreme Weather	област росс регион кра мчс
0	0.02266	Nature disaster (Forest fires)	Disasters/Extreme Weather	лес лесн пожар дерев площад
58	0.05216	Nature disaster (Hurricanes and floods)	Disasters/Extreme Weather	наводнен бедств землетрясен урага катастроф
39	0.06588	Weather abnormalities	Disasters/Extreme Weather	температур градус погод тепл жар
66	0.02545	Winter abnormalities	Disasters/Extreme Weather	зим мороз снег холод зимн
1	0.07459	Budgeting climate risk	Economy/Business	млн млрд доллар тыс проект
6	0.04502	Business	Economy/Business	компан бизнес рынк крупн проект
59	0.08378	Corporate responsibility	Economy/Business	должн наш возможн помощ нов
86	0.08094	Economy (Sustainable development)	Economy/Business	развит стран экономическ экономик нов
29	0.03492	Economy (General)	Economy/Business	экономик цен кризис финансов рост
23	0.0315	Education	Education	школ дет образован язык студент
52	0.00196	Education (University competition)	Education	задан участник как факультет математик
99	0.03547	Energy (Gas)	Energy (Non-renewable)	нефт газ цен добыч нефтян
48	0.01637	Energy (Nuclear)	Energy (Non-renewable)	атомн ядерн аэс энергетик реактор
8	0.03108	Energy (Sustainable sources)	Energy (Renewable)	энерг энергетик топлив источник электроэнерг
82	0.03162	Energy (Efficiency, Emission reduction)	Energy efficiency	выброс энерг газ энергетическ технолог
17	0.01763	Transport (Cars)	Energy efficiency	автомобил машин двигател бензин нов
15	0.02056	Transport (Mostly aviation)	Energy efficiency	самолет аэропорт авиакомпан пассажир полет
47	0.03596	Health	Health	заболеван болезн здоров врач люд
78	0.02056	IT	Information technology	технолог систем создан разработк информацион
28	0.05005	Climate politics (COPs)	IR (Environmental)	стран выброс климат конференц газ
61	0.04297	Climate politics (Kyoto Protocol)	IR (Environmental)	протокол киотск выброс росс газ
10	0.00949	Climate research (Russian-Belarusian)	IR (Environmental)	союзн сред государств беларус программ
34	0.01791	IR (ASIA-APEC)	IR (Non-security)	япон японск стран атэс ток
83	0.04451	IR (bilateral relations)	IR (Non-security)	росс отношен сотрудничеств российск вопрос
64	0.03212	IR (summits)	IR (Non-security)	восьмерк стран саммит самм встреч
53	0.03153	Politics (EU)	IR (Non-security)	европейск европ евросоюз стран франц
21	0.04276	UN (and Russia)	IR (Non-security)	оон форум международн организац конференц
55	0.04586	IR (power politics)	IR (Security)	мир стран международн миров нов
94	0.02611	IR (security-conflicts)	IR (Security)	стран президент франц ирак израил
65	0.03344	Military (weapons, tactics)	IR (Security)	воен оруж ядерн сша вооружен
98	0.02428	Russian foreign policy	IR (Security)	украин польш стран нат европ
50	0.02846	Russian national security	IR (Security)	росс российск путин москв отношен
67	0.01529	Russian national security policy	IR (Security)	безопасн российск федерац национальн обеспечен
14	0.04719	Junk	Junk	стат дан глобальн опубликова the
18	0.11096	Junk	Junk	росс стран российск наш вопрос
37	0.04236	Junk	Junk	весн апрел март месяц нов
38	0.16944	Junk	Junk	перв нов стал последн сам
44	0.02054	Junk	Junk	фильм режиссер фестивал кин театр

Table B.4: (Continued)

72	0.10996	Junk	Junk	говор вопрос наш дума как
80	0.14946	Junk	Junk	дел сам одн так люб
81	0.18603	Junk	Junk	вопрос мнен решен счита сторон
85	0.05983	Junk	Junk	глобальн дел потеплен никак говор
92	0.03711	Junk	Junk	сообща город летн женщин сообщ
56	0.02579	Gardening	NA	растен вин дерев сорт гриб
77	0.04576	Relationship/feelings	NA	женщин жизн друг люб люд
16	0.08431	Trivia	NA	дом рук сво голов мест
32	0.01479	TV announcements	NA	программ кана телевиден зрител канал
12	0.02011	Antarctic	Polar science	антарктид озер антарктическ учен антарктик
89	0.0198	Arctic (science)	Polar science	экспедиц северн арктик полярн полюс
87	0.0064	Environmental protection (Air pollution)	Pollution	воздух атмосферн вредн выброс веществ
57	0.05049	Environmental protection (General pollution)	Pollution	экологическ сред окружа эколог природ
79	0.04054	Moscow	Russian cities	город москв московск столиц городск
9	0.00408	Medvedev's politics (Russian politics)	Russian politics	наш росс стран нов политическ
13	0.04664	Politics (Russian officials meet)	Russian politics	росс правительств заседан председател совет
51	0.07288	Russian diplomacy	Russian politics	президент росс российск путин медвед
2	0.00542	Russian legislation	Russian politics	пункт услуг работ налогов товар
40	0.00909	Russian mitigation legislature	Russian politics	российск федерац федеральн рубл тыс
91	0.00222	Russian politics (Ministries/docs)	Russian politics	росс программ государствен заказчик год
71	0.05431	Russian science	Science (other)	наук научн учен институт исследован
96	0.02807	Scientific discoveries (Genetics)	Science (other)	учен исследован ген мозг организм
11	0.03126	Art (Film/music industry)	Society and culture	групп сша концерт сам музык
25	0.03048	Art (Music)	Society and culture	александр владимир росс никола петербург
63	0.01657	Fashion	Society and culture	одежд бел мод нос кож
3	0.03082	Historical mysteries	Society and culture	древн земл мест остров город
7	0.03976	Justice (Crime)	Society and culture	суд дел закон прав сотрудник
75	0.018	Literature	Society and culture	книг русск писател автор рома
88	0.01814	Nobel Prize	Society and culture	прем нобелевск гор лауреат наград
43	0.03377	Philosophy	Society and culture	человечеств человек век природ земл
76	0.04062	Politics and Society	Society and culture	обществ социальн власт прав стран
46	0.08575	Population growth	Society and culture	стран рост населен миров мир
74	0.02317	Religion	Society and culture	русск век культур храм церкв
97	0.01731	Sport	Society and culture	олимпийск спорт соч игр команд
70	0.02096	USSR	Society and culture	советск ссср народ войн союз

Appendix C. Statistical analysis

Appendix C.1. Newspapers included in the analysis

Table C.5: Ownership, Interests and Ideology of 23 Prominent Russian Newspapers

Newspaper	**Year**	**Ownership**		**Interests & Ideology**		
		Owner (Name)	*Owner (Type)*	*Energy*	*Kremlin*	*Ideology*
Argumenty i fakty	1995	Unknown	Journalists	No	No	Center
Argumenty i fakty	2002	Promsvyaz'kapital	Business	No	Yes	Center
Argumenty i fakty	2014	Moscow City Government	State-owned	No	No	Center
Argumenty nedeli	2011	SVR-Media, SWR group	Journalists	No	Yes	Center
E'konomika i zhizn'	1995	Independent	Journalists	No	Yes	Center
E'kspert	1998	Unknown	Journalists	No	No	Right
E'kspert	2000	Unknown	Journalists	No	Yes	Right
E'kspert	2007	Oleg Deribaska, Expert Media Holding	Business	Yes	Yes	Right
Itogi	1997	Media Most, Gusinskiy	Business	No	No	Right
Itogi	2001	Gazprom Media Holding	Business	Yes	Yes	Right
Izvestiia	1995	Journalists collective	Journalists	No	No	Right
Izvestiia	1997	Lukoil, Oneksimnabk	Business	Yes	Yes	Right
Izvestiia	2005	Gazprom	Business	Yes	Yes	Right
Izvestiia	2008	National Media Group	Business	Yes	Yes	Right
Kommersant. Daily	1995	Vladimiri Yakovlev	Journalists	No	No	Right
Kommersant. Daily	1999	Berezovkiy & Basri Badartsikashvili	Business	No	No	Right
Kommersant. Daily	2007	Alisher Usmanov	Business	Yes	No	Right
Kommersant. Den'gi	1995	Vladimiri Yakovlev	Journalists	No	No	Right
Kommersant. Den'gi	1999	Berezovkiy & Basri Badartsikashvili	Business	No	No	Right
Kommersant. Den'gi	2007	Alisher Usmanov	Business	Yes	No	Right
Komsomol'skaia pravda	1997	Profmedia; Swedish group A-Pressen	Business	Yes	Yes	Right
Komsomol'skaia pravda	2007	Grigorii Berezkin, energy sector	Business	Yes	Yes	Center
Literaturnaia gazeta	1995	Independent	Journalists	No	Yes	Center
Moskovskaia pravda	1995	Muladjanov Shod, Editorial board	Journalists	No	No	Center
Moskovskii' komsomolets	1995	Pavel Gusev	Journalists	No	Yes	Right
Nasha versiia	2000	Sovershenо Sekretno	Journalists	No	No	Center
Nasha versiia	2007	Nikolai Zyatkov	Journalists	No	Yes	Center
Novaia gazeta	1995	Editorial Board; Aleksander Lebedev (39pc); Mikhail Gorbachyov (10pc)	Journalists	Yes	No	Right
Novye izvestiia	1998	Alliance Oil Company, Berezovskiy	Business	Yes	No	Right

Table C.5: (Continued)

Novye izvestiia	2003	Alliance Oil Company	Business	Yes	Yes	Center
Ogonek	1999	Berezovkiy	Business	Yes	No	Center
Ogonek	2003	Russian Media Ventures	Journalists	No	No	Center
Ogonek	2005	Telekominvest	Business	No	No	Center
Ogonek	2009	Alisher Usmanov	Business	Yes	Yes	Center
Pravda	1995	Communist party of the RF	Political Party	No	No	Far-left
Profil'	1995	Sergei Rodionov	Business	No	No	Right
Rossii'skaia gazeta	1995	Russian government	State-owned	Yes	No	Center
Sovetskaia Rossiia	1995	Independent	Journalists	No	No	Far-left
Trud	1995	Journalists	Journalists	No	No	Left
Trud	1998	Gazprom	Business	Yes	No	Left
Trud	2003	PromSvyazCapital	Business	No	No	Left
Trud	2012	Institute of Free Journalism (Sergei Tsoi, Valery Simonov, Yuri Ryazhsky)	Journalists	No	No	Left
Uchitel'skaia gazeta	1995	Independent	Journalists	No	No	Center
Vecherniaia Moskva	1995	Bank of Moscow	Business	No	Yes	Center
Vecherniaia Moskva	2011	Moscow government	State-owned	No	No	Center
Zavtra	1995	Prokhanov/Babakov (UR)	Political Party	No	No	Far-right

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Appendix C.2. Dependent variables

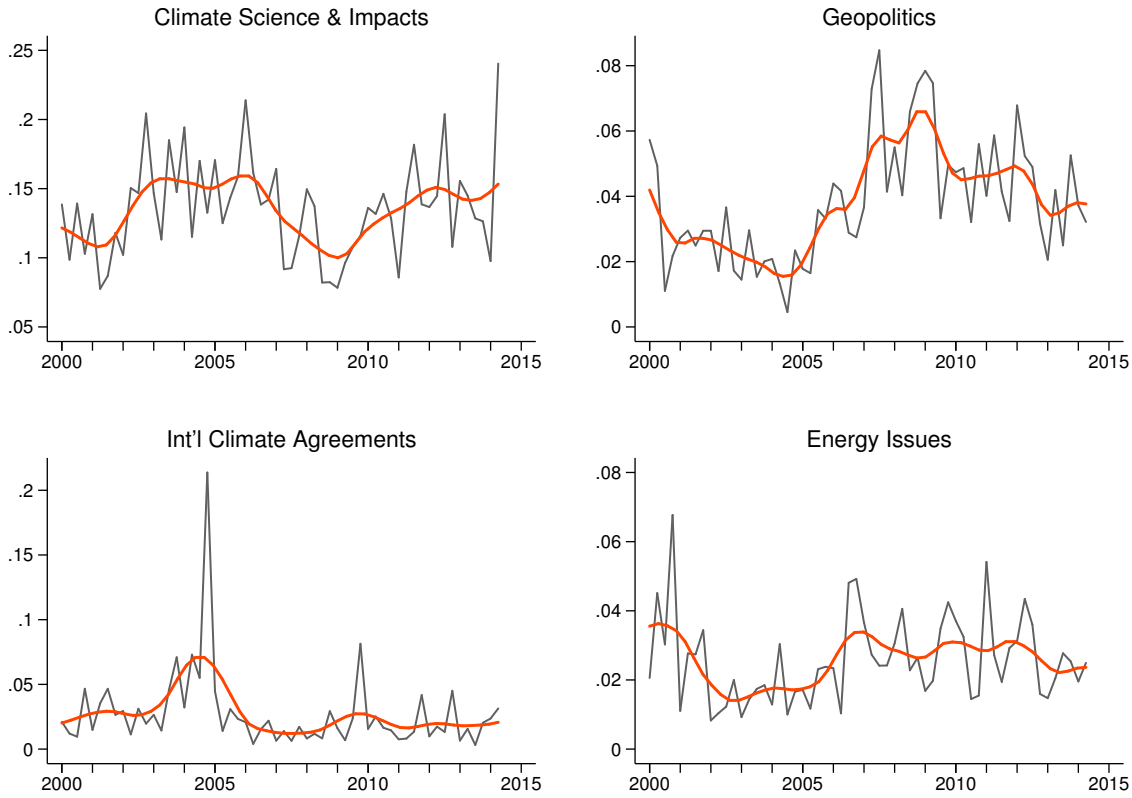

Figure C.5: *Temporal variation of dependent variables.* The proportion of all words devoted to the meta-topics that underlie a given dependent variable. Quarterly data from the 23 most prominent Russian newspapers over the period Q1/2000-Q2/2014 are displayed. A local polynomial line (orange) is displayed to aid interpretation. Note that y-axes are not on a common scale.

Appendix C.3. Statistical model

As briefly outlined in Section 4.3, we estimate variation in the intensity of news coverage employing a mixture of a Bernoulli distribution for the decision to cover the issue *at all* and a beta distribution to represent coverage *intensity*. Suppose y_{it} represents coverage for paper i during time period t. We assume the following probability model:

$$BernBeta(y_{it}|p,\mu,\phi) = \begin{cases} p & \text{if } y_{it} = 0 \\ (1-p)Beta(\mu,\phi) & \text{if } y_{it} > 0 \end{cases} \quad \text{(C.1)}$$

Note that p is the probability of *not* covering climate change in a particular period and the Beta distribution is expressed in terms of its mean (μ) and precision (ϕ) parameters:

$$Beta(\mu, \phi) = \frac{\Gamma(\phi)}{\Gamma(\mu\phi)\Gamma((1-\mu)\phi)} y^{\mu\phi-1}(1-y)^{(1-\mu)\phi-1} \tag{C.2}$$

where $0 \geq \mu \leq 1$, $\phi > 0$, and Γ is the gamma function. We follow the literature and parametrize $\mu = \frac{\alpha}{\alpha+\beta}$ and $\phi = \alpha+\beta$, where α and β are the shape parameters for the Beta distribution. We link the covariates described in Table 2 to p_{it} and μ using the logit link function.

Given that 1) the zero-inflated Beta model is a somewhat non-standard specification in the literature and 2) our data require the inclusion of random effects for repeated measures, we employ Bayesian inference. Specifically, we estimate the following model:

$$\begin{aligned}
y_{it} &\sim BernBeta(p_{it}, \mu_{it}, \phi_{it}) && \text{(likelihood)} \\
logit(p_{it}) &= \beta_{z=0}X + \alpha_{paper} + \alpha_{time} \\
logit(\mu_{it}) &= \beta_{z=1}X + \alpha_{paper} + \alpha_{time} \\
\phi &\sim U(0,1) && \text{(priors)} \\
\beta &\sim N(0,5) \\
\alpha_{papers} &\sim N(\mu_{papers}, \sigma_{papers}) \\
\alpha_{time} &\sim N(\mu_{time}, \sigma_{time}) \\
\mu_{papers} &\sim N(0,1) \\
\mu_{time} &\sim N(0,1) \\
\sigma_{papers} &\sim HalfStudentT(3,0,10) \\
\sigma_{time} &\sim HalfStudentT(3,0,10)
\end{aligned}$$

We thus assume diffuse priors throughout the model—yet the results are stable to alternative assumptions regarding prior specification. All of our models are estimated via MCMC using the No-U-Turn Sampler (NUTS) implemented in Stan (http://mc-stan.org).