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"Measuring the Mix" of Policy Responses to COVID-19: Comparative Policy Analysis Using Topic Modelling

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ABSTRACT *Although understanding initial responses to a crisis such as COVID-19 is important, existing research on the topic has not been systematically comparative. This study uses topic modeling to inductively analyze over 13,000 COVID-19 policies worldwide. This technique enables the COVID-19 policy mixes to be characterized and their cross-country variation to be compared. Significant variation was found in the intensity, density, and balance of policy mixes adopted across countries, over time, and by level of government. This study advances research on policy responses to the pandemic, specifically, and the operationalization of policy mixes, more generally.*

Keywords: comparative policy analysis; COVID-19; machine learning; policy design; policy mixes; topic modeling

Introduction

The sudden and unexpected spread of the novel coronavirus SARS-Cov-2 (COVID-19) since the beginning of 2020 has accompanied significant policy activities around the world as countries attempt to manage the pandemic and deal with its consequences. Not only does the pandemic serve as a natural experiment for scholarly learning on phenomena such as the state–society relationship, leadership, knowledge utilization, policy diffusion and implementation, but also a case of a crisis that can facilitate lesson-drawing to inform governance (Weible et al. 2020). While ongoing policy responses to COVID-19 have naturally received much attention from practitioners, analysts, and

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scholars alike, the first phase in such a crisis is crucial and needs to be better understood from a comparative perspective.

Scholars have examined these initial policy responses to COVID-19 based on psychological, institutional, and political characteristics (Capano et al. 2020; Maor and Howlett 2020). While some studies have assessed responses comprehensively, they have typically limited their scope to selected case studies (Capano 2020; Lee et al. 2020; Mei 2020; Yan et al. 2020). In contrast, other studies have covered a large-*N* sample, for example in Europe or South America, but have limited their focus to the timing of adoption or stringency of selected policies (Toshkov et al. 2020; González-Bustamante 2021). As a result, existing research is not systematically comparative, limiting the generalizability of knowledge and lesson-drawing from the pandemic.

The objective of this study is to describe variation in policy responses in the initial phase of COVID-19. We analyzed over 13,000 policies adopted around the world between January and July 2020 using the conceptual lens of policy mixes. Following Schmidt and Sewerin (2019), we characterized policy mixes based on the intensity (content), density (number), and balance (distribution) of policies adopted by governments (see also Knill et al. 2012; Schaffrin et al. 2015). Building on the approach of Capano et al. (2020), we employed topic modeling to "measure" policy content to characterize and compare variation in countries' policy mixes. The findings of this study shed light on the ways in which initial policy responses to COVID-19 were similar and different around the world.

The remainder of this article is structured in the following manner. In the next section, we describe the methods of analysis. Subsequently, we present the findings pertaining to the characteristics of the COVID-19 policy mix. Finally, we discuss the implications of this research and conclude the article.

Methods

We adopted a comparative methodology for this study. First, we used topic modeling to inductively compare policies and classify them based on the types of responses. Second, we employed descriptive statistics to shed light on the mixes by comparing them over time, among countries, and across levels of government.

We applied this approach to policies in CoronaNet: the COVID-19 Government Response Event Dataset (Cheng et al. 2020b). This dataset is compiled by a team of over 450 research assistants, recruited from around the world, using a Qualtrics survey instrument (see Cheng et al. 2020a for further information). Each entry consists of several policy attributes, including a policy identifier, the announcement date, start date, end date, entry type (new policy or update), update type (where applicable, policy change or policy termination), country, level of government initiating the policy (national, provincial, and municipal), and policy description (in English). The data are updated on a continual basis and checked periodically for errors and inconsistencies. The version we used for this analysis was downloaded on July 29, 2020.

The CoronaNet dataset used for this study included over 13,000 unique policies, announced by over 190 countries, from December 31, 2019 until July 6, 2020. While 8,129 policies were announced by the national government, 4,924 were announced by the provincial government and 812 by the municipal government. Further, 86 per cent of the

entries (n = 11,942) describe new policies and a relatively small number pertain to policy change (n = 701) or policy termination (n = 457). The countries with the highest number of policies in this dataset were: United States (n = 1,971), Russia (n = 814), Japan (n = 390), China (n = 357), and Nigeria (n = 351). Finally, the median length of the policy description was 31 words while the mean length was 41 words; over 75 percent of the policies were described in 50 words or fewer.

To reveal variation in policy descriptions recorded in the CoronaNet dataset, we used topic modeling. Topic modeling is an unsupervised machine learning technique for discovering and ranking the latent "topics" in a document collection. It is based on the premise that each document in the collection (in our case, policy announcement) consists of one or more topics, which are in turn characterized by a set of key words (Blei et al. 2003). While several topic modeling algorithms exist, we used structural topic model (Roberts et al. 2014) because it allows for correlation among topics and captures the influence of level of government on policy content. We interpreted the topics resulting from this analysis as types of policy responses adopted to deal with COVID-19.

We prepared the policy descriptions for topic modeling in the following manner. First, we checked spellings and corrected typographical errors in the text. Second, we tagged parts of speech to identify phrases (or "n-grams") and removed proper nouns from policy description. Third, we lemmatized the text, which converts words to their base form (for example, "is" to "be"), to increase coherence. Fourth, we removed frequently occurring "stop words" in the English language (for example, "a", "and", and "the") as well as frequently occurring words in this dataset (for example, "announce", "covid", and "government"). Fifth, we "stemmed" words or phrases, which reduces them to their root form (for instance, both "distance" and "distancing" are replaced by "dist"), to further increase coherence. After preprocessing the text, we selected the number of topics (k = 16) based on an assessment of models with 5 to 20 topics and ran the topic model. The output of the topic model is the expected prevalence of each type of response in each policy. At the policy level, the sum of the prevalence of the types of response is, therefore, always 1.

We used the prevalence of each type of response for each policy, along with the policy identifier, the start date, and – where available – the end date, to create a policy mix dataset. First, if a policy within the dataset had been changed (that is, entry type was "update"), we set the end date of the previous version of the policy to the start date of the changed policy. Second, if a policy had been terminated (that is, update type was "end of policy"), we set the end date of the policy to the date of the announcement. Third, we created a longitudinal, weekly dataset of "active" policies based on their start date and end date. The result was a global policy mix dataset. We assessed the intensity of the mix by analyzing the types of response, the density by counting the number of active policies, and the balance by examining the distribution by type of response and by level of government.

Before characterizing variation in country policy mixes, we calculated the average prevalence by type of response at each level of government within the country. This averaging addressed variation in the number of provincial and municipal governments across countries, which would otherwise lead to misrepresentation in policy activities. Then we aggregated prevalence by type of response "vertically" (that is, across levels of government) to capture policy activities comprehensively regardless of distribution of authority within a country. The focus of the national government, for example, might be different in a federal system than in a unitary system and, by itself, would not accurately represent policy activities in the former.

The analyses were conducted using R 4.0 (R Core Team 2020) and the following key packages: ggplot2 (Wickham 2016), hunspell (Ooms 2018), stm (Roberts et al. 2014), streamgraph (Rudis 2019), tm (Feinerer et al. 2008), and udpipe (Wijffels 2020).

Results

Identifying Key Policy Responses to COVID-19

The intensity of a policy mix refers to the content of policies adopted in the mix. Based on decreasing order of their prevalence, the key policy responses to COVID-19 were the following: (i) declaration of curfews and lockdowns; (ii) announcement of border restrictions; (iii) information gathering, provision, and control; (iv) rules regarding quarantine and contact tracing; (v) administration of government services; (vi) regulation of (non-)essential businesses; (vii) restriction on public gatherings; (viii) provision of testing and treatment; (ix) measures for physical distancing; (x) closure (and reopening) of schools and universities; (xi) (travel) advisories and warnings; (xii) mobilization of funding and stimulus; (xiii) cancelation or postponement of public events; (xiv) sourcing and distribution of protective equipment; (xv) management of health resources; and (xvi) implementation of health screening (Figure 1).

These responses can be classified based on the governing resources – nodality, authority, treasury, and organization (Hood 1983) – on which they draw for effecting behavioral change and managing the pandemic. As shown in Table 1, in their early responses to deal with the pandemic, governments relied largely on their authoritative role. Many prominent responses, including declaration of curfews, emergencies, and lockdowns (Response 1), restrictions on movement across the international border (Response 2), and formulation of rules regarding quarantining and contact tracing (Response 4) demonstrate the use of this governing resource. Also, the organization role of governments is most evident in responses such as the administration of public services during the pandemic (Response 5), and the provision and management of testing and treatment facilities for the disease (Response 8). Further, the use of nodality as a governing resource is captured by the response on information management (Response 3), which involved creation of advisory committees, increasing public awareness, and curbing "fake news". Finally, the treasury function of governments is highlighted by Response 12 on mobilizing funding and stimulating the economy.

The Temporal Trends of Policy Mixes

The density of a policy mix refers to the number of policies in the mix. The density of the global policy mix, and its temporal variation, is shown in Figure 2. Over 20 policies were announced in the week ending January 5, 2020 – primarily in China, Russia, and Taiwan – when the World Health Organization (2020) observed the emergence of a "pneumonia of unknown case" in Wuhan. Subsequently, countries neighboring China, in Central Asia, and in North America also undertook policy action. A discernible increase in density – with over 200 new policies – occurred in the week ending January 26, after confirmation of the first case of "novel coronavirus disease" outside China. The density of the mix increased steadily through February – dominated largely dominated by advisory and warning, information management, quarantine and tracing, and border restrictions – as the geographic spread of

Figure 1. Topics in the policy response to COVID-19 Each grid depicts the key terms associated with one topic. The x-axis – as well as the size of the term label – indicates the probability of occurrence of a term within that topic. The y-axis – as well as the intensity of the term label – indicates the exclusivity of a term to that topic. The topics have been ranked in order of prevalence in the dataset and sorted in descending order.

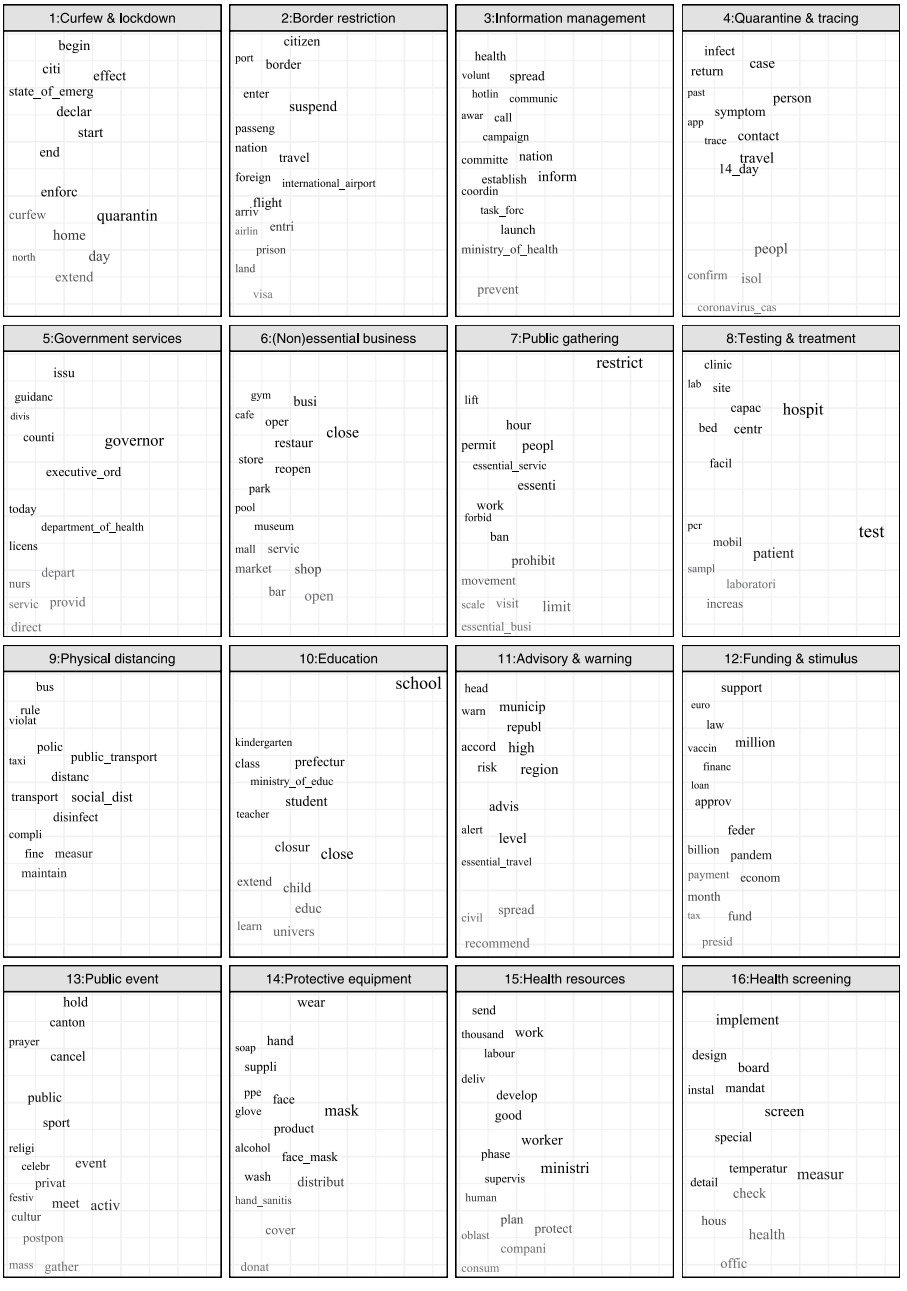


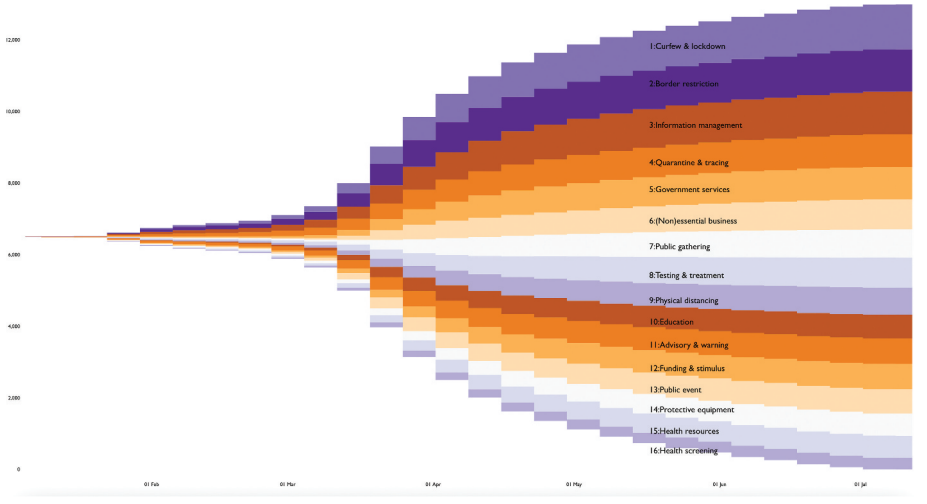
Table 1. Types of COVID-19 policy responses and the principal governing resources associated with them

Policy response	Illustrative action	Key resource(s)
1: Curfew and lockdown	- Impose a nighttime curfew - Declare a state of emergency or complete lockdown	Authority
2: Border restriction	- Deny entry to foreigners from specific countries - Schedule special flights for the return of citizens	Authority
3: Information management	- Create a website to provide reliable information - Monitor misinformation and rumors	Nodality
4: Quarantine and tracing	- Mandate quarantine or self-isolation for travelers - Authorize use of mobile app for contact tracing	Authority
5: Government services	- Amend annual leave procedures for state employees - Issue emergency medical licenses to physicians	Organization/ authority
6: (Non-)essential business	- Close retail outlets until further notice - Permit only delivery and take-out at restaurants	Authority
7: Public gathering	- Restrict gatherings to a maximum of five people - Ban all social and religious gatherings	Authority
8: Testing and treatment	- Acquire COVID-19 testing machines and cartridges - Convert existing hospitals into COVID-19 facilities	Organization
9: Physical distancing	- Limit occupancy in public transport - Formulate rules for "stay at home"	Authority
10: Education	- Close schools and universities for one month - Plan gradual reopening of educational institutes	Authority
11: Advisory and warning	- Issue advice to avoid non-essential travel - Raise level of travel alert for a set of countries	Nodality/authority
12: Funding and stimulus	- Borrow from the central bank for healthcare spending - Release fund to alleviate economic impact of COVID	Treasury
13: Public event	- Postpone sporting competitions - Cancel religious festivities	Authority
14: Protective equipment	- Purchase protective equipment for health staff - Order wearing of face masks in public	Organization/ authority
15: Health resources	- Donate medical supplies to a neighboring country - Support manufacturing of testing equipment	Treasury/ organization
16: Health screening	- Introduce thermal screening at ports of entry - Require self-assessment of health for recent travelers	Authority

the epidemic started becoming evident. By the end of the month, over 1,200 policies were in operation to deal with COVID-19.

As the virus spread to several countries around the world, a significant increase in density was witnessed in March. In the first week of that month, for example, over 400 new policies were adopted with a shift in focus from advisory and warning to restrictions in internal movement and physical contact among people, for example, through declaration of curfews or lockdowns, regulation of (non-)essential businesses,

Figure 2. The evolution of the global policy mix for COVID-19.
The y-axis represents the density (count) of the policy mix while the x-axis represents time (in weeks). The bands represent the intensity (type of response) of the policy mix. The responses are sorted in decreasing order of prevalence.



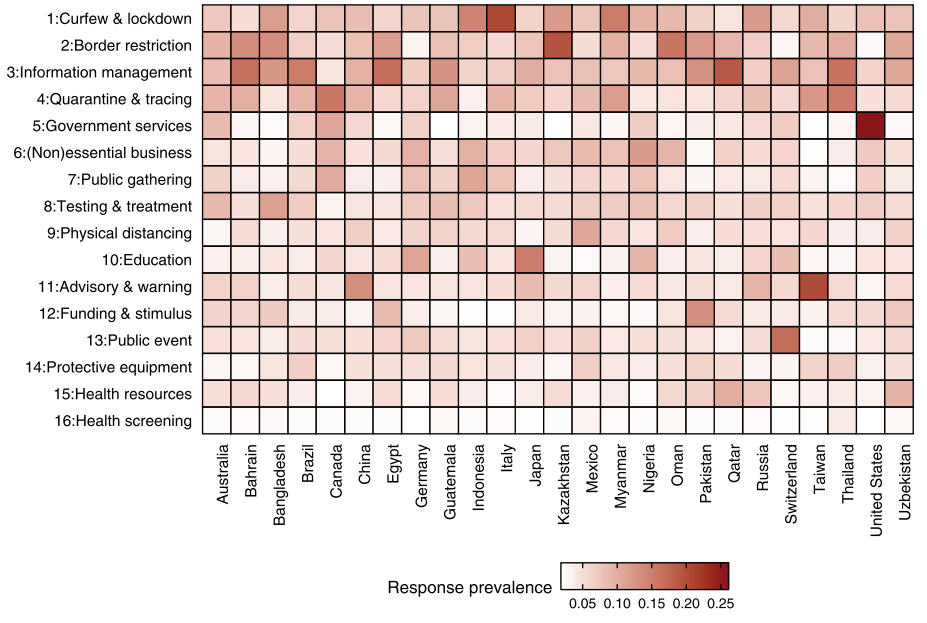
and cancelation of public events. Following the declaration of COVID-19 as a pandemic on March 11 (WHO 2020), nearly 1,500 new policies were adopted every week until the end of the month. During this time, closure of educational institutes, restrictions on public gathering, and measures for physical distancing also became more widespread. The density of the mix continued to increase during April–June and over 1,500 new policies were formulated each month in this period. By the beginning of July, nearly 13,000 policies had been adopted in response to COVID-19.

Comparing the Balance of the Policy Mix by Countries

The balance of a policy mix refers to the distribution of policy tools within the mix. At the global level, the balance of the policy mix is indicated by the prevalence of policy responses in the dataset (described above). However, the distribution of these responses exhibits significant cross-country variation. Illustratively, the balance of the policy mix for 25 countries with highest number of policy announcements is shown in Figure 3. Here, the value of each cell represents the share of that type of policy response in the aggregate policy mix of that country.

The country with the highest number of policy activities in this dataset was the United States, driven primarily by its subnational policy response. As Figure 3 shows, nearly 25 percent of the policy activities in the US focused on one type of organizational tool: the administration of government services; the other themes received relatively less attention. In contrast, Russia – the country with the second highest number of policy activities – relied on a more diverse mix of policies, with an

Figure 3. The balance of the policy mix for countries with the highest number of COVID-19 policy announcements Rows represent types of response while columns represent countries. The intensity of each cell depicts the prevalence of that type of response in the country policy mix.



emphasis on curfew and lockdown, advisory and warning, and health resources. China adopted a mix in which advisory and warning were combined with curfew and lockdown, border restriction, information management, and quarantine and tracing. The policy mix in Japan, on the other hand, favored school and university closure, along with travel advisories and warnings, and information management to limit the movement of people. Nigeria, which had the fifth highest policy activity in this dataset, revealed a different strategy that relied on government authority through regulation of businesses, curfews and lockdown, and school and university closure.

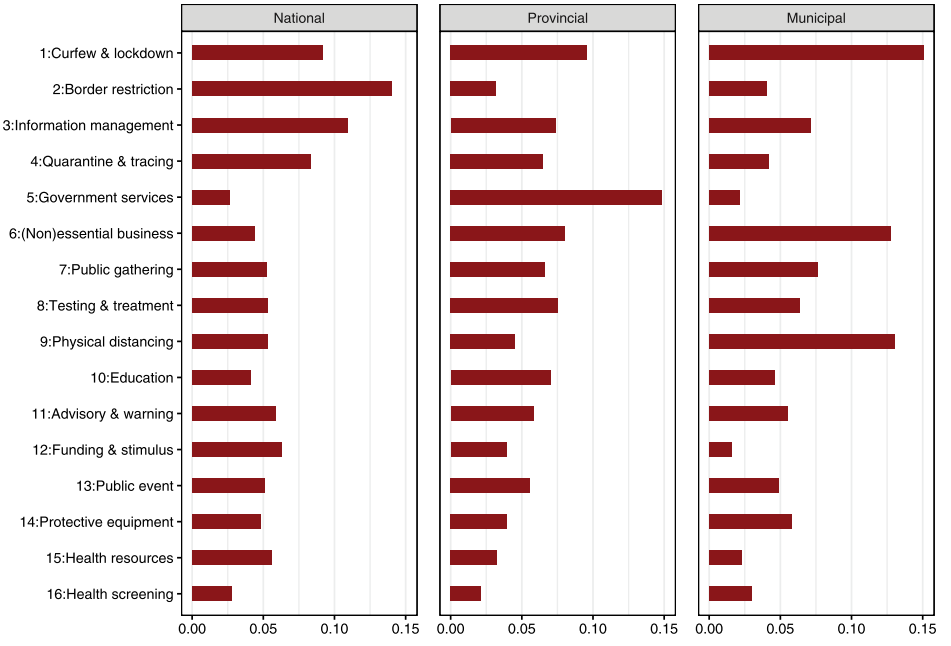
Among the other countries, Bahrain, Brazil, Egypt, and Qatar placed a slight emphasis on information management, Canada on quarantine and contact tracing, Italy on the lockdown, Kazakhstan on external travel restrictions, Switzerland on cancelation of public events, and Taiwan on travel advisories and warnings. Meanwhile, low- and middle-income countries such as Bangladesh, Guatemala, Thailand, and Uzbekistan have predominantly used a combination of curfew and lockdown, border restrictions, information management, and quarantine and tracing for dealing with the pandemic. Higher-income countries such as Australia, Germany, and Mexico, on the other hand, have used a more varied combination of policies.

Comparing the Balance of the Policy Mix by Levels of Government

Where applicable, the vertical dimension of the policy mix – that is, the distribution of policy responses initiated by the national, provincial, and municipal level – is also important for understanding the balance of the policy mix. While its implications would need to be considered in the context of the relationship among the different levels of government, an overview of the proportion of each type of policy response by level of government is shown in Figure 4 (the sum of proportions of policy responses at each level is 1). As can be seen, nearly 15 percent of the policies at the national level were concerned with external border restriction. The other prominent issues addressed at the national level – in comparison with the subnational level – were management of information, mobilization of funding, and provision of health resources. Meanwhile, issues concerning the administration of public services, internal travel, and school and university closure received relatively less attention at the national level.

The balance of the policy mix at the subnational level differs from that at the national level. At the provincial level, for example, a large share of policy activities was focused on administration of public services. In addition, testing and treatment, education, and public events also received slightly higher attention at this level than at the other levels. On the other hand, provincial governments had limited ownership of policies concerning border restrictions and health screening. Finally, at the municipal level, the most

Figure 4. The prevalence of type of response by level of government Each grid represents a level of government. The y-axis represents a type of response in the policy mix. The x-axis represents the share of the type of response in the policy activities of that level of government.



commonly occurring policy responses concerned curfew and lockdown, (non-)essential business, and physical distancing. As one might expect, municipalities were less active in the adoption of policies regarding government services, funding and stimulus, border restrictions, and health resources. Overall, while the national government relied on a mix of different types of tools, subnational governments focused more on authority- and organization-based policy instruments.

Our intention is not to suggest that different levels of government should have, or even could have, adopted similar policies, but to highlight the significant variation in policy responses between levels of government, which needs to be carefully considered in any explanatory analysis of COVID-19 policy mixes.

Discussion and Conclusion

In this study, we have systematically compared early COVID-19 policy responses across countries in order to understand how they varied. To do so, we analyzed over 13,000 policies in more than 190 countries using the conceptual lens of policy mixes. We employed the unsupervised machine learning technique of topic modeling to "measure" countries' policy mixes and characterize and compare their cross-national variation.

The topic model revealed that the intensity (content) of the policy mix for the crisis can be broadly classified into 16 key responses. While the overall policy mix was dominated by authoritative policy tools – such as curfews and lockdowns, border restrictions, quarantine and tracing, and regulation of businesses – it still incorporated a range of other policy tools spanning nodality, treasury, and organization, such as measures for information management, advisories and warnings, administration of government services, and provision of testing and treatment. This is possibly reflective of the extreme crisis that governments faced, and a "normal" policy mix would likely involve the use of fewer, less diverse types of policy tools.

Further, the temporal trend of the policy mix showed that increase in policy activity and shift in policy strategies towards more authoritative tools matched the spread of the coronavirus globally, though possibly not the spread in each country. Finally, an examination of the balance of the policy mix highlighted the preference of different countries – and levels of government – for different (types of) policy tools. Overall, the topic model and descriptive analysis was useful for operationalizing key dimensions of mixes previously identified in the literature, such as the intensity, density, and balance.

Apart from characterizing variation in cross-national policy responses to the pandemic, this study contributes to the literature on policy mixes by offering a novel operationalization of the concept. The literature on the topic has mainly been conceptual, with limited effort at measuring policy mixes empirically (Reichardt and Rogge 2016). Due to the effort-intensive nature of the task, few scholars have operationalized the concept in large-*N* studies (Knill et al. 2012; Schaffrin et al. 2015; Schmidt and Sewerin 2019). We demonstrate the utility of employing topic modeling for analyzing policy responses and – in combination with policy metadata – measuring various dimensions of policy mixes.

The limitations of this study, however, should be borne in mind while interpreting its findings. First, the validity of our analysis depends on the quality of the data, most importantly the comprehensiveness or the correctness of the CoronaNet dataset. It is quite likely that the data captured in the CoronaNet dataset – though more exhaustive

than most other global datasets – is incomplete and actual policy mixes might differ from those identified here. In addition, manual collation of policy announcements – as done in the CoronaNet project – is error-prone and might have led to inaccuracies in the data. Second, we did not measure the scope, severity, and selectivity of policy responses, which could have resulted in a more nuanced characterization of policy mixes (Attwell and Navin 2019). Third, our comparison of the vertical dimension of policy mixes does not consider distribution of authority and other contextual differences among countries and the findings of that analysis should, therefore, be seen as indicative. Fifth, while we focus on policy adoption, variation in policy responses might also occur during policy implementation.

These limitations notwithstanding, this study provided a first systematic, comparative insight into the various dimensions of initial policy responses to the emerging COVID-19 pandemic and proposed an approach to operationalizing complex, dynamic policy mixes, on which future research can build. This can be done in the following manner. First, other datasets on policy responses to the pandemic can be examined using this approach for data triangulation. Second, the use of natural language processing to extract information on characteristics such as the scope, severity, or selectivity of policies in the mix could be explored. Third, the characterization of policy mixes presented here can serve as a dependent variable for a systematic explanation of variations across countries. Fourth, the approach we propose for operationalizing policy mixes should be applied to other policy areas to extend its generalizability. Finally, the models used for natural language processing can be trained using corpora of public policy documents to increase their accuracy for such analyses.

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