



Efficiency of government policy during the COVID-19 pandemic

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Abstract

We introduce country-month indices of efficiency of government policy in dealing with the COVID-19 pandemic. Our indices cover 81 countries and the period from May 2020 to November 2021. Our framework assumes that governments impose stringent policies (listed in the Oxford COVID-19 Containment and Health Index) with the single goal of saving lives. We find that positive and significant correlates of our new indices are institutions, democratic principles, political stability, trust, high public spending in health, female participation in the workplace, and economic equality. Within the efficient jurisdictions, the most efficient ones are those with cultural characteristics of high patience.

Keywords Frontier methods · Government efficiency · COVID-19 pandemic · Oxford COVID-19 Government Response Tracker · Determinants of efficiency

1 Introduction

Governments have formulated a wide range of measures to protect their citizens from the scourge of COVID-19. The Oxford COVID-19 Government Response Tracker (OxCGRT) by Hale et al. (2021) provides comprehensive information on these policies, including information on containment and closure (e.g., movement restrictions and schools closure), income support to citizens, and health system policies (e.g., provision of tests, investment in health care, and vaccination). The variability in these policies is significant both across countries and months since the outbreak of the pandemic. Specifically, the cross-country mean of the

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general OxCGRT index takes values from 0 to 100 (100 = strictest), and ranges from 29 to 89 points.

Even though the OxCGRT indices record policy stringency across countries and months, they do not readily reflect government efficiency in protecting their citizens from COVID-19. Other performance indices, such as the one from the Lowy Institute, measure performance from equally-weighted averages of metrics including information from confirmed cases, deaths, and COVID tests, thus not combining these with policy stringency.

In this paper, we examine to what extent the different policy approaches were successful in protecting citizens in different countries. We conduct this exercise by providing a new government *policy* efficiency index. We stress the word ‘policy’, because we measure the efficiency of measures in minimizing COVID-related deaths, assuming that death prevention is the ultimate reason for which governments are taking stringent measures.

Our empirical analysis on the construction of the government policy efficiency indices resorts to frontier-based methods, namely the data envelopment analysis (DEA) and the stochastic frontier approach (SFA). These methods are ideal for measuring a government’s ability to limit the pandemic’s effects (the output) using a set of government policies (the inputs). For the DEA, we use the models of Simar and Wilson (1999, 2000, 2007). We favour this approach because it introduces a stochastic element in the deterministic DEA methods, as well as allowing to consistently study the determinants of government efficiency. For the SFA, we resort to the model of Greene (2005), because it allows inclusion of country and month fixed effects while simultaneously studying the determinants of government efficiency. We more eclectically view the indices obtained from the two approaches as complementary (rather than competing).

We examine government policy efficiency in containing specific adverse effects of COVID-19 (primarily the prevention of deaths), and not general government efficiency across other societal or economic dimensions. We suggest that mixing health-related policy outcomes with socioeconomic-related policy outcomes clouds any inferences, predominantly (but only) because the socioeconomic outcomes are endogenous to several country-specific traits that in turn correlate with policy initiatives and their effectiveness. In contrast, COVID-related deaths are endogenous to these traits only to the extent that governments do not link the traits to their policy initiatives (thus being inefficient). As an example, consider two countries, one with strong enforcement of institutional quality (country A) and another with weak (country B). The government of A might decide to impose mild restrictions knowing that the good institutions imply better enforcement of the mild restrictions, which would be sufficient to protect citizens. The government of B might prefer stricter (or different) restrictions knowing that poor enforcement of mild restrictions can lead to more deaths. This optimal choice of policies by governments (considering the country traits) to limit deaths is what we study in this paper. Any socioeconomic outcome would need a non-exhaustive (and unknown) set of additional inputs.

To this end, the OxCGRT index -reflecting containment, closure, and health system policies- serves as the sole input in government efforts to contain COVID-related deaths. In turn, these deaths serve as the sole output, as they represent the ultimate goal of governmental policy actions to protect their citizens from COVID-related death.

The precise measure of deaths to be used as the output variable is another important choice. This is mainly because the reporting of deaths varies by country and time, given the existence of ‘across country’ differences in reporting, but also within-country time variation in the reporting methods. This reflects measurement error in the outcome variable, which is clearly important in DEA estimations (albeit not much of a problem given the stochastic nature of the Simar and Wilson DEA model). To create a level playing field between countries

and within countries across months, we first estimate a model of the daily new deaths (weekly smoothed) on their daily lag and country $\times$ month fixed effects. The predicted values from this regression (inverted to show better outcomes from fewer deaths) serve as our output variable.

Our empirical analysis covers 81 countries and produces a strongly balanced panel of 1,539 country-month efficiency estimates. Our results show that based on the average efficiencies by continent, Oceania has been the most efficient, probably reflecting the geographic characteristics of its countries that assist with travel restrictions and checks. From a country perspective, the top seven ranked countries are Japan, Estonia, Malawi, Finland, Taiwan, New Zealand, and Iceland. Poor performing countries are usually found in Latin America.

We next use hundreds of country-specific variables to examine correlates of government policy efficiency. In this analysis, we abstain from making causal claims, but suggest that identifying these correlates is an important first step to inform policy and set the pathway for new research in the field. We show that countries with high efficiency scores are generally those that possess quality institutions, democratic principles, political stability and rule of law, and protection of property rights. This goes against the premise that authoritarian countries have been more efficient in dealing with the pandemic. Interestingly, high public spending on health (as a share of GDP) is a strong positive correlate of government policy efficiency, while the opposite holds true for high private spending on health.

An important finding is that there is a strong negative correlation between measures of economic inequality and government policy efficiency. This highlights the need of government policy to better inform and protect the economically vulnerable, consistent with prior studies suggesting that any crisis predominantly hurts economically uneven societies. Another quite interesting finding is that culture significantly matters in improving government policy efficiency, with societies characterized by power distance culture reducing government efficiency, and patient and trusting societies improving government efficiency. Importantly, within the group of countries sharing quality and democratic institutions, the most efficient ones are those with high patience. This reflects an important role for these cultural elements in nurturing the effectiveness of government policy, and notes that governments must consider the cultural characteristics of their countries in designing optimal policies and protecting their citizens.

Finally, our study brings two key novelties:

- First, we provide a new database that includes country rankings on the effectiveness of containment, closure, and health system policies in limiting COVID-related deaths.
- Second, we analyse the determinants (correlates) of the efficiency indices and highlight which country characteristics are associated with improved government policy efficiency.

In what follows, Sect. 2 reviews the relevant literature, Sect. 3 explains the problem formulation and introduces the proposed model, Sect. 4 discusses the obtained results and Sect. 5 concludes this study.

2 Literature review

2.1 COVID-19: trade-offs and government interventions

Following the outbreak of the COVID-19 pandemic, a strand of literature aiming to identify its effects emerged, in which operations research has significantly focused (Choi, 2021). Our analysis naturally relates to this strand. More closely related to our research are the few studies

measuring elements of trade-offs or the effectiveness of government interventions. Mitcham and Keisler (2022) investigate the issue of mitigating the impacts of COVID-19 and the trade-offs this comes with for life, liberty and the economy. They use Robust Decision-Making methods, used to handle decision-making under deep uncertainty, to simulate plausible outcomes for various strategies, and evaluate the trade-offs of policies across the dimensions of life, liberty and the economy. Investigating whether and how gendered leadership makes a difference in dealing with the COVID-19 pandemic, Park (2021) shows that female-led countries have epidemiologic patterns different from male-led countries, and this effect was contingent on the maturity of democracy and the degree of gender representation in both parliament and bureaucracy. Ghasemi et al. (2020) are the first to use early data on the pandemic from 19 countries and a DEA approach to evaluate government performance. However, as data on actual policies were not yet available, the authors are using population and population density as inputs. Breitenbach et al. (2020) use a similar approach for 31 countries to examine government efficiency in the first 100 days of the pandemic (inputs are number of days to lockdown, number of doctors and tests, and healthcare spending). Haug et al. (2020) assess the effectiveness of non-pharmaceutical interventions (policies) to mitigate the spread of SARS-CoV-2 (effectiveness of each policy to result in less infections) focusing on March and April of 2020, and Dergiades et al. (2021) quantify the effectiveness of governmental interventions at an early stage on slowing down or reversing the growth rate of deaths by identifying at structural changes in trends of death figures during the period January–April 2020.

2.2 DEA, government efficiency and COVID-19: the gap

DEA, first proposed by Charnes et al. (1978), is one of the most common tools used to measure performance of decision-making units (DMUs), by estimating an efficiency score of relative performance. The idea behind the proposal is to identify best practice DMUs, which efficiently utilise their resources and/or obtain outcomes -in a measurable form of inputs and outputs- that form a benchmark for inefficient units. Since the introduction of DEA, there has been a tremendous growth in both modelling aspects and empirical applications that span a wide range of sectors (see Cook & Seiford, 2009, for a review).

The turbulence caused by the COVID-19 pandemic is an ideal environment to study government policy efficiency, as it requires robust and swift policies. From this viewpoint, our study relates to a large literature using frontier methods (especially DEA) to estimate government efficiency (e.g., da Cruz & Marques, 2014; Doumpos & Cohen, 2014). A few relevant and recent studies forecast COVID-19 spread (e.g., Nikolopoulos et al., 2020; Khalilpourazari and Doulabi, 2021; Lotfi et al., 2022). Our paper takes a step back by establishing a monthly government policy effectiveness index that can be of potential use to relevant studies examining the effects or the sources of our efficiency scores. Put simply, the provided estimates move from a metric of performance (e.g. mortality rates), to one of efficiency that accounts for the levels of stringency each country imposes to obtain them.

Last, but not least, our first-stage analysis relates to studies highlighting the importance of benchmarking COVID-19 performance data (George et al., 2020), with a focus on measurement equivalence and thus comparative cross-country benchmarking, which is an important aspect enabling measurement and, subsequently, reflection on when it comes to crisis decision-making (Comfort et al., 2020). Based on the estimates obtained from the first-stage analysis, our second-stage correlation analysis also complements studies that look

at particular cases of success stories, such as those of South Korea (Moon, 2020) and Taiwan (Huang, 2020), by aiming to examine correlates of factors potentially affecting efficient governance at large.

Closing this section, Table 1 summarises the most relevant preceding studies, followed by the current study, in a tabular form by objective, methodology and sample.

3 Problem statement

Governments have formulated a wide range of measures to protect their citizens from the scourge of COVID-19. In this paper, we examine to what extent the different policy approaches were successful in protecting citizens in different countries. We conduct this exercise by providing a new government policy efficiency index that measures the efficiency of policies in minimizing COVID-related deaths. This first stage analysis provides a new database that includes country rankings on the effectiveness of containment, closure, and health system policies in limiting COVID-related deaths. At a second stage, we analyse the determinants (correlates) of the efficiency indices and highlight which country characteristics, across a broad range of categories, are associated with improved government policy efficiency. Whilst abstaining from making causal inferences, this is an important first step to inform policy and set the pathway for new research in the field. Figure 1 delineates the proposal of this study.

3.1 Proposed model

This section introduces the proposed model we use to construct the efficiency estimates at a first stage and find correlates at a second stage. In what follows, we define the indices, parameters and variables used in the rest of this section. *Indices* i index of countries; $i \in I = \{1, \dots, n\}$, t index of time period; $t \in T = \{1, \dots, s\}$. *Parameters* θ_i efficiency of estimator of country i , β_1 auxiliary parameter of lagged dependent used in the AR(1) process to estimate daily deaths, β_2 auxiliary vector of fixed effect parameters used in the AR(1) process to estimate daily deaths γ auxiliary parameter of bivariate linear regression model used in the second stage analysis *Variables* x_i input of country i in the efficiency estimation (containment and health index) y_i output of country i in the efficiency estimation (daily deaths per million)

C_i characteristic of interest of country i in year 2019 used in the second stage analysis.

We use two types of frontier models: DEA (see Cook & Seiford, 2009; Cooper et al., 2011, for a 30-year review of the literature) and SFA (Aigner et al., 1977; Meeusen and Van Den Broeck, 1977). DEA models assume that the set of decision-making units is homogenous, implying that all units have access to and possibly equally use their inputs and outputs—i.e., no structural reasons as to why they may not do so (Li et al., 2016). The input and output used in our study are consistent with this assumption. Moreover, the government “production function” has an unknown shape, and this makes DEA preferable to the parametric frontier methods which impose functional forms (even if these forms are flexible).

Similar to Andrews et al. (2021), we use the input-oriented constant returns to scale DEA model (Charnes et al., 1978), because governments decide on the input.¹ Let there

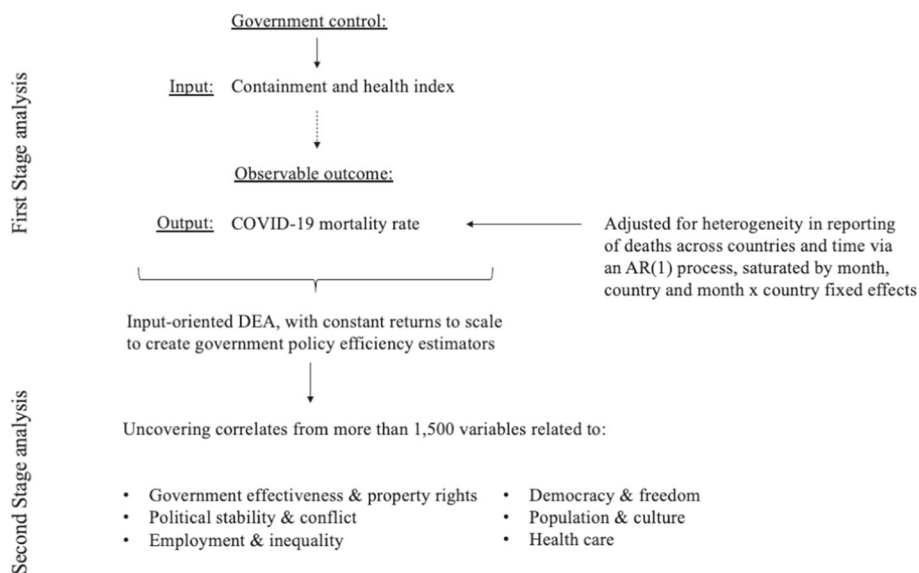
¹ Constant returns to scale seem appropriate because of the observation in the data that policy stringency almost linearly decreases our rescaled measure of deaths (with super lax countries facing very high numbers of rescaled deaths and super stringent countries facing almost zero rescaled deaths). If we allow for variable returns to scale, we obtain measures that are 95% correlated or more.

Table 1 Most relevant studies

References	Objective	Methodology	Sample
Mitcham and Keisler (2022)	Evaluating the trade-offs of the COVID-19 impact mitigation	Robust Decision Making methods	Simulated data based on scenarios of ranges
Park (2022)	Investigating whether and how gendered leadership affects pandemic responses	Regression analysis	OECD countries, January–July 2020
Ghasemi et al. (2020)	Evaluating government efficiency, where output is confirmed cases, inputs are population and population density	DEA	19 countries, March–April 2020
Breitenbach et al. (2020)	Evaluating government efficiency, where output is number of days left in a cycle after reaching persistent COVID-19 reduced infections, inputs are number of days to lockdown, number of doctors per 000 s population, tests per million population, spending on health (% of GDP)	DEA	31 countries, 100 days since the first reported case
Haug et al. (2020)	Assessing the effectiveness of non-pharmaceutical interventions (NPIs) to mitigate the spread of COVID-19	Regression analysis	226 countries, March–April 2020
Dergiades et al. (2021)	Assessing the quantitative impact of government interventions on COVID-19 related deaths	Regression analysis	32 countries, January–April 2020
Nikolopoulos et al. (2020)	Forecasting COVID-19 growth rates and the excess demand for products and services during the pandemic	Variety of statistical and epidemiological models	5 countries, January–April 2020
Lotfi et al. (2022)	Predicting the number of COVID-19 patients in Iran through the development of a regression-based Robust Optimization (RO) approach	Regression analysis	Iran, February–April, 2020

Table 1 (continued)

References	Objective	Methodology	Sample
Khalilpourazari and Doulabi (2021)	Develop a novel hybrid reinforcement learning-based algorithm applied to forecast COVID-19 cases in Quebec	Reinforcement learning	Quebec, January–July, 2020
This study	Introducing country-month indices of efficiency of government policy in dealing with the COVID-19 pandemic, and uncovering correlates from over 1,500 variables	DEA/SFA, Regression analysis	81 countries, May 2020–November 2021

**Fig. 1** Proposal of this study

be $i = 1, \dots, n$ countries, benchmarked on one non-negative input x_i and one non-negative output y_i , reflecting a production set Ψ of physically attainable points (x, y) . One may define the Farrell input measure of efficiency for a given point (x_i, y_i) as $\theta_i = \min\{\theta | \theta x_i \in X(y_i)\}$, where θ is the multiplier shrinking the input of a country i being evaluated if y_i was produced efficiently. The time dimension is treated as cross-sectional, essentially benchmarking all countries with themselves and their counterparts across the entirety of our panel to obtain comparable results.

As explained by Daraio and Simar (2007), given that efficiency is measured relative to an estimate of the frontier, the estimates of θ_i , i.e., $\hat{\theta}_i$, are subject to uncertainty due to variations in sampling. Put simply, a data generating process $\mathcal{P}$ generates a random sample $\mathcal{X} = \{(x_i, y_i) | i = 1, \dots, n\}$; thus $\hat{\theta}_i$ depends on $\mathcal{P}$, which is unknown. Simar and Wilson (1999) introduced the use of bootstrap in nonparametric envelopment estimators based on the idea that we can use a reasonable estimator $\hat{\mathcal{P}}$ to mimic $\mathcal{P}$ and evaluate bias-corrected estimators of θ_i .

As a starting point, we make no assumption, and use a naïve estimator of $\mathcal{P}$, the empirical distribution of which is smoothed through a kernel density estimate, and the bandwidth of which is chosen through cross-validation (Simar & Wilson, 2000). However, as the bootstrap procedure may not provide a consistent approximation of the desired sampling distribution (Simar & Wilson, 1999), at a second stage we complement it with an environmental (exogenous) variable $\mathbf{Z}$, which we discuss in Sect. 4. This is the two-stage procedure proposed by Simar and Wilson (2007). Therefore, for every different proxy in $\mathbf{Z}$, we obtain an alternative $\hat{\theta}_i$. The reported government policy efficiency is the one obtained from the first-stage estimation process. It should be noted, however, that when we use the principal components of $\mathbf{Z}$ to avoid multicollinearity in the estimation process and use all variables of interest to estimate $\hat{\theta}_i$, the correlation between the naïve estimation and that one conditional on all $\mathbf{Z}$ is nearly perfect.

Turning to our SFA model, it is the ‘true-fixed-effects’ model of Greene (2005). This is optimal in our case, because it allows disentangling time-varying inefficiency from unit-specific time-invariant unobserved heterogeneity, which might be important to further control for important country characteristics correlated with the efficiency scores, while also allowing the study of the determinants of government efficiency. The two sets of estimators may be similar from a conceptual viewpoint, but in order to make them more comparable in terms of their scales, first, we standardize them using z-scores; then, we create a probability score using the normal cumulative density function ($\mu = 0, \sigma = 1$) to smooth and contain them in the $[0, 1]$ space, representing the percentage of an infinitely large population of which an evaluated country would be better than (Gaganis et al., 2021).

Once the estimators of government policy efficiency have been obtained for every month t , at a second stage, we run linear bivariate regressions of the form $\theta_{it} = f(C_i; \gamma)$, estimated via Ordinary Least Squares (OLS) and clustered standard errors at the country level to observe correlates.

3.2 Data and variables

We explicitly define all variables used in our analysis in Table 2 and report summary statistics in Table 3. Data related to Covid-19 mortality figures are sourced from ‘Our World in Data’, downloaded from their GitHub repository² and cover the period from April 1, 2020 to November 30, 2021. This dataset has several limitations, which we aim to overcome via specific adjustments mentioned later in this section. We match these data with the Oxford Covid-19 ‘Containment and Health Index’, which is a reduced version of the ‘Government Response Tracker’ index (excluding the economic policies dimensions). The ‘Containment and Health Index’ comprises an equally weighted composite index structured in two dimensions: *containment and closure policies* and *health system policies*. These two dimensions

² The GitHub repository contains the most up-to-date figures. The link to the repository is: <https://github.com/owid/covid-19-data/tree/master/public/data>.

Table 2 Variable definitions

Variable	Description	Source
Panel A: Government efficiency and components		
Monthly deaths (per million, smooth, estimates)	Sum of monthly estimated smooth mortality figures per million of population. See Sect. 2.1 of the manuscript for more details	Authors' elaboration on data obtained via 'Our World in Data'
Log distance to max monthly deaths (per million, smooth, estimates)	Output in efficiency estimation. Rescaled monthly deaths (pm, smooth, estimates) as $\text{Log}(1 + \max(X) - X_{it})$	Authors' elaboration on data obtained via 'Our World in Data'
Health and containment index	Component of the Oxford COVID-19 Government Response Tracker (OxCGRT). Equally weighted composite index structured in two dimensions: containment and closure policies and health system policies. For more information, see Hale et al. (2021)	Hale et al. (2021)
Government efficiency score (SW estimates)	Bias-corrected efficiency estimates from input-oriented DEA estimators with CRS according to Simar and Wilson (1998)	Authors' elaboration on data obtained via 'Our World in Data'
Normalised government efficiency score (SW estimates)	Probability score from a normal cumulative density function ($\mu = 0, \sigma = 1$) of the standardised Government efficiency score (SW estimates)	Authors' elaboration on data obtained via 'Our World in Data'
Government efficiency score (SF estimates)	Efficiency estimates from the "true fixed effects" SF model of Greene (2005)	Authors' elaboration on data obtained via 'Our World in Data'
Normalised government efficiency score (SF estimates)	Probability score from a normal cumulative density function ($\mu = 0, \sigma = 1$) of the standardised Government efficiency score (SF estimates)	Authors' elaboration on data obtained via 'Our World in Data'
Panel B: Second stage analysis		
Government effectiveness and property rights	Scale from 0 to 100, where 100 indicates very little corruption. Corruption erodes economic freedom by introducing insecurity and uncertainty into economic relationships	Heritage Foundation
Government integrity		

Table 2 (continued)

Variable	Description	Source
Regulatory quality	Regulatory Quality includes measures of the incidence of market-unfriendly policies such as price controls or inadequate bank supervision, as well as perceptions of the burdens imposed by excessive regulation in areas such as foreign trade and business development	World Bank
Corruption perceptions	Corruption Perceptions Index. Scale of 0–100 where a 0 equals the highest level of perceived corruption and 100 equals the lowest level of perceived corruption	Transparency International
Property rights	This factor scores the degree to which a country's laws protect private property rights and the degree to which its government enforces those laws. It also accounts for the possibility that private property will be expropriated	Heritage Foundation
Property rights	Equal access to property rights index evaluates whether married or unmarried women have equal access to property rights	Ease of Doing Business
Rule of law	Includes several indicators which measure the extent to which agents have confidence in and abide by the rules of society. These include perceptions of the incidence of crime, the effectiveness and predictability of the judiciary, and the enforceability of contracts	World Bank

Table 2 (continued)

Variable	Description	Source
Contract enforcement	Measures the gap between an economy's performance and the regulatory best practice on the Enforcing Contracts indicator components. It is calculated as the simple average of the scores for Time (days), Cost (% of claim value) and Quality of judicial processes index	Ease of Doing Business
<i>Political stability and conflict</i>		
Political stability	"Political Stability and Absence of Violence/Terrorism" measures perceptions of the likelihood of political instability and/or politically-motivated violence, including terrorism	World Bank
Fragile state	The Fragile States Index is highlighting not only the normal pressures that all states experience, but also when those pressures are pushing a state towards the brink of failure. By highlighting pertinent issues in weak and failing states, the FSI—and the social science framework and software application upon which it is built—makes political risk assessment and early warning of conflict accessible to policymakers and the public at large	Fund for Peace
Trust	The fraction of total respondents within a given country, from different waves of the World Values Survey conducted during the time period 1981–2008, that responded with "Most people can be trusted" (as opposed to "Can't be too careful") when answering the survey question "Generally speaking, would you say that most people can be trusted or that you can't be too careful in dealing with people?"	World Values Survey
<i>Employment and inequality</i>		

Table 2 (continued)

Variable	Description	Source
Labor force participation	The proportion of the population ages 15–64 that is economically active (ILO estimates); all people who supply labor for the production of goods and services during a specified period	World Bank
Female labor force participation	The proportion of the females ages 15–64 that is economically active (ILO estimates); all people who supply labor for the production of goods and services during a specified period	World Bank
Women business and the law index	Women Business and the Law Index Score (1–100) measures how laws and regulations affect women's economic opportunity. Overall scores are calculated by taking the average score of each of the eight areas (Going Places, Starting a Job, Getting Paid, Getting Married, Having Children, Running a Business, Managing Assets and Getting a Pension), with 100 representing the highest possible score	World Bank
Top 10% income share	Top 10% income share, equal-split adults. Pre-tax national income share held by a given percentile group. Pre-tax national income is the sum of all pre-tax personal income flows accruing to the owners of the production factors, labor and capital, before taking into account the operation of the tax/transfer system, but after taking into account the operation of pension system	World Inequality Database
<i>Democracy and freedom</i>		

Table 2 (continued)

Variable	Description	Source
Egalitarian democracy	The egalitarian principle of democracy holds that material and immaterial inequalities inhibit the exercise of formal rights and liberties, and diminish the ability of citizens from all social groups to participate. Egalitarian democracy is achieved when 1) rights and freedoms of individuals are protected equally across all social groups; 2) resources are distributed equally across all social groups; and 3) access to power is equally distributed by gender, socioeconomic class and social group	Varieties of Democracy
(V-Dem) Liberal democracy	The liberal principle of democracy emphasizes the importance of protecting individual and minority rights against the tyranny of the state and the tyranny of the majority. The liberal model takes a negative view of political power insofar as it judges the quality of democracy by the limits placed on government. This is achieved by constitutionally protected civil liberties, strong rule of law, an independent judiciary, and effective checks and balances	Varieties of Democracy
(V-Dem) Democracy	Revised Combined Polity Score: The polity score is computed by subtracting the p_autoc score from the p_democ score; the resulting unified polity scale ranges from + 10 (strongly democratic) to -10 (strongly autocratic)	Polity IV

Table 2 (continued)

Variable	Description	Source
Freedom	The index is founded upon objective components that reflect the presence (or absence) of economic freedom. The index ranges from 0–10 where 0 corresponds to less economic freedom and 10 to more economic freedom	Fraser Institute
<i>Population and culture</i>		
Power distance index (Hofstede)	Expresses the degree to which the less powerful members of a society accept and expect that power is distributed unequally	Hofstede Insights
Patience	The qualitative measure of patience is given by the respondents' self-assessment regarding their willingness to wait on an 11-point Likert scale, asking "how willing are you to give up something that is beneficial for you today in order to benefit more from that in the future?"	Global Preferences Survey (GPS)
<i>Health care</i>		
Government health care spending	Domestic general government health expenditure (% of GDP). Public expenditure on health from domestic sources as a share of the economy as measured by GDP	World Bank
Private health care spending	Share of current health expenditure funded from domestic private sources (% of total health expenditure). Domestic private sources include funds from households, corporations and non-profit organizations. Such expenditures can be either prepaid to voluntary health insurance or paid directly to healthcare providers	World Bank

Table 3 Summary Statistics

Variable	Obs	Mean	SD	Min	Max
Panel A: Government efficiency and components					
Monthly deaths (per million, smooth, estimates)	1653	54.95	89.23	0.00	728.36
Log distance to max monthly deaths (per million, smooth, estimates)	1653	7.50	0.24	1.00	7.59
Containment and health index (Lag 1)	1653	61.38	11.28	29.17	89.02
Government efficiency score (SW estimates)	1653	0.48	0.10	0.05	0.97
Normalised government efficiency score (SW estimates)	1653	0.46	0.27	0.00	1.00
Government efficiency score (SF estimates)	1653	0.93	0.12	0.00	1.00
Normalised government efficiency score (SF estimates)	1653	0.55	0.22	0.00	0.72
Panel B: Second stage analysis					
<i>Government effectiveness and property rights</i>					
Government integrity (Heritage Foundation)	1539	51.12	21.12	12.20	95.70
Regulatory quality (World Bank)	1539	0.56	0.88	−2.28	2.13
Corruption perceptions (Transparency International)	1539	51.95	19.63	17.00	89.00
Property rights (Ease of Doing Business)	1520	−0.03	0.16	−1.00	0.00
Rule of law (World Bank)	1539	0.46	0.93	−1.79	2.05
Contract enforcement (Ease of Doing Business)	1539	60.37	13.01	22.21	84.53
<i>Political stability and trust</i>					
Political stability (World Bank)	863	0.13	0.87	−2.43	1.62
Fragile state (Fund for Peace)	841	54.22	23.63	16.90	99.91
Trust (WVS)	852	1.59	0.58	1.00	3.49
<i>Democracy and freedom</i>					
Egalitarian democracy (V-dem)	1539	0.69	0.21	0.17	0.96
Liberal democracy (V-dem)	1539	0.73	0.23	0.09	0.97
Democracy (Polity V)	1501	5.98	5.93	−10.00	10.00
Freedom (Fraser Institute)	1539	7.28	0.72	4.60	8.70
<i>Health Care</i>					
Government health care spending (World Bank)	1501	4.33	2.34	0.38	9.27
Private health care spending (World Bank)	1501	38.90	16.55	11.96	77.91
<i>Employment and inequality</i>					
Labor force participation (World Bank)	1520	71.69	8.31	48.58	88.35
Female labor force participation (World Bank)	1520	61.58	14.69	22.16	85.77
Women business and the law index (World Bank)	1520	80.12	18.53	26.90	100.00
Top 10% income share (World Inequality Database)	1482	0.43	0.09	0.25	0.65
<i>Culture</i>					
Power distance index (Hofstede)	1330	54.95	20.89	11.40	104.00
Patience (GPS)	1349	0.26	0.42	−0.43	1.07

capture policies and restrictions such as school, workplace, and public transport closure; cancellation of public events and restrictions on gatherings; internal movement and international transport for the first dimension; public campaigns, testing, vaccination or facial covering policies; contact tracing, emergency investments in healthcare and vaccines; and policies on protection of the elderly. The index is defined in the range [0–100], such that the larger the value the more stringent the policies.³

Including all countries is impossible because many countries (especially small and remote ones) have not faced a substantial Covid-19 outbreak, or they lack data on testing. For instance, Jamison et al. (2020) rank 35 countries from all continents (excluding Africa) having 85% of all cases as of April 16, 2020. The Lowy Institute ranks 98 countries on its ‘Covid Performance Index’ on the basis of data availability on cases, deaths, and testing (Lowy Institute, 2021). In its ‘Resilience Ranking’, Bloomberg ranks 53 countries with a GDP of more than US \$200 billion prior to the pandemic (Chang & Hong, 2021). Understandably, there is always an arbitrary element regarding which countries to include. We find the methodology of the Lowy Institute convincing and start from 98 countries. However, additionally, we drop 17 countries for which we find a negative relation between the Containment and Health Index and Covid-19 mortality figures one month onward, which is completely counterintuitive. This leaves our final sample consisting of 81 countries across the globe: 31 in Europe, 24 in Asia, 10 in North America, 5 in South America, 9 in Africa and 2 in Oceania. These countries are listed in the Appendix.

Even regarding these 81 countries, there is substantial heterogeneity in reporting of deaths across countries and time, and we need to create a level playing field. First, we calculate 7-day rolling averages to avoid the well-known differences in reporting on different weekdays. Second, and most important, we transform the daily mortality figures for each country in a panel setting based on an AR(1) process, saturated by month, country, and month $\times$ country fixed effects. This regression is:

$$\widehat{\text{Daily deaths per million}}_{it} = \beta_1 \text{Daily deaths per million}_{it-1} + \beta_2 FE_{it}, \quad (1)$$

where i denotes country and t denotes day. We estimate Eq. 1 using daily data over January 1, 2020 – November 30, 2021. The month $\times$ country fixed effects are the most important, because they capture all month-varying country characteristics (and associated differences) that affect the reporting of deaths, leaving the fitted values of Eq. 1 to denote a level field across countries and months. In other words, these fixed effects “purify” the effect of the within country-month changes in policy (within-country month policy events) on COVID-related deaths from the effects of other country-related policies and discrepancies in reporting.

The predicted⁴ mortality rate from Eq. 1 is the output of our frontier efficiency models, and the containment and health index (Hale et al., 2021) is the input.⁵ The underlying intuition is that governments take necessary actions through the form of curfews and policies designed to diminish the cases and, as a result, the number of deaths (normalized per million citizens). As our output is naturally considered to be something to minimize – often referred

³ Data for all versions of the index are available from: <https://www.bsg.ox.ac.uk/research/research-projects/covid-19-government-response-tracker#data>. Methodological information is at: https://github.com/OxCGRT/covid-policy-tracker/blob/master/documentation/index_methodology.md. The components of the index are available at: <https://github.com/OxCGRT/covid-policy-tracker/blob/master/documentation/codebook.md>.

⁴ Although we use the term ‘predicted’, let us note that this is not a projection exercise like Lotfi et al. (2022). We simply use fitted values to adjust for reporting quality across countries.

⁵ These fixed effects naturally also encompass information on COVID-related policy. This is why we use the prediction from Eq. 1 as our output variable and not the residuals. From the fitted value, we extract the policy-related part in the frontier efficiency analysis.

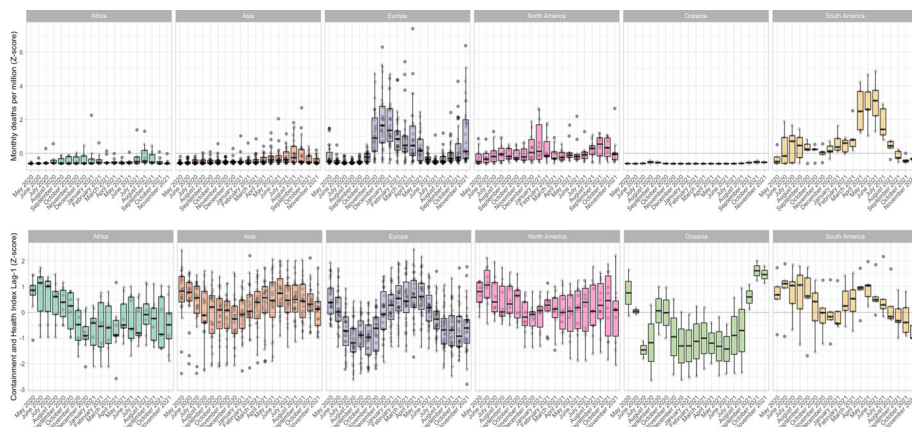


Fig. 2 Boxplot of total monthly deaths and government policies per continent. This first row of figures shows by continent and month the monthly deaths (per million, smooth data, predicted values as described in the text). The second row shows the equivalent for the Containment and Health Index in the preceding month. Both figures expressed in z-scores. We also plot scatter points reflecting countries. The boxplots are colored according to the continent

to as ‘bad’ output – we rescale it as the distance from the maximum-attained output in the sample. Additionally, to account for nonlinearity in the increase in deaths, we take the natural logarithm of the rescaled output and add a constant $c = 1$ to account for countries that have zero total deaths per million in any given month.

We convert the input and output to monthly variables by taking their monthly averages. As COVID-related deaths emerge, on average, 18–19 days after symptom onset, and symptom onset takes, on average, 5–6 days after exposure to the virus, we lag our input by 1 month to allow policy to take effect.⁶

Table 3, panel A, reports summary statistics for the input/output variables. The mean of monthly deaths (prediction from Eq. 1) is 54.95 per million people. The mean of the Containment and Health Index is 61.38. Figure 2 reports equivalent country-month means by continent. Oceanian countries have by far the lower death toll, and Africa and Asia have also been performing relatively well compared to South America, Europe, and North America. Oceanian countries have also been the laxer in the Containment and Health Index, with most restrictions relating to travel and entry restrictions, especially until the Fall of 2021. In contrast, Asian countries have stricter policies on average.

4 Results and discussion

4.1 Efficiency scores by country and continent

We report all country-month efficiency scores in the data appendix that accompanies our paper. Despite the largely different assumptions of the DEA and SFA models, we find a strong Spearman correlation between the two that equals 0.67. As expected, we observe substantial

⁶ For instance, according to the reopening plan of the UK Government, 5-weeks’ windows are left between different structural changes in the Covid-19 restrictions in place, so that the effects of each set of changes is reflected on the figures (Cabinet Office, 2021).

variability across countries and through time. Figure 3 provides a box-plot of country-specific mean efficiency scores, focusing on our preferred method, DEA. Japan, Estonia, Finland, Malawi, Taiwan, New Zealand, and Iceland are the seven most efficient countries on average. By contrast, Chile, Italy, Panama, India, Jamaica, Myanmar, and Malaysia are the seven worst performing countries.

Moreover, Fig. 4 reports continent-month means of the efficiency scores. Despite starting with low scores, the Oceanian countries have become largely efficient from July 2020 onward, despite this being wintertime for them. The European countries display the highest seasonality in their scores as well as considerable cross-country variability, with the northern countries being, in general, more efficient. In Africa there is also considerable cross-country variability, but the severe lockdowns seem to have contained the spread. Finally, North American countries started as less efficient, but picked up their values in the Fall of 2021, Asian

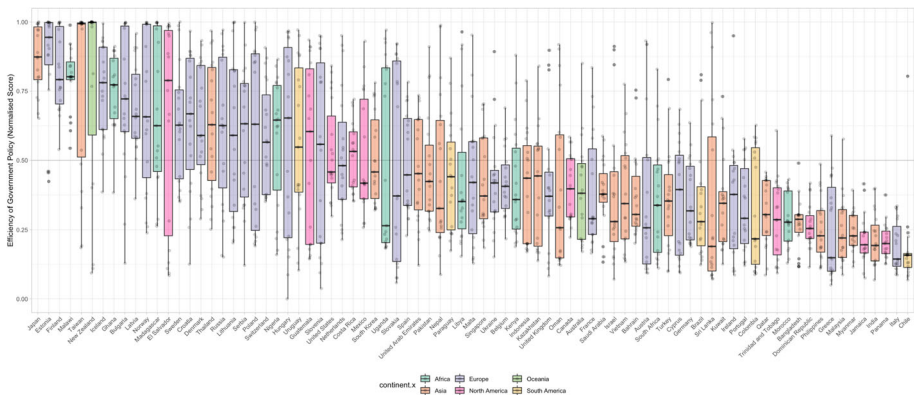


Fig. 3 Boxplot of efficiency scores per country along the time dimension. This figure shows the distribution of countries' (normalized) efficiency. We also plot scatter points reflecting country-month scores. We order the countries by their average efficiency score. The boxplots are colored according to the continent

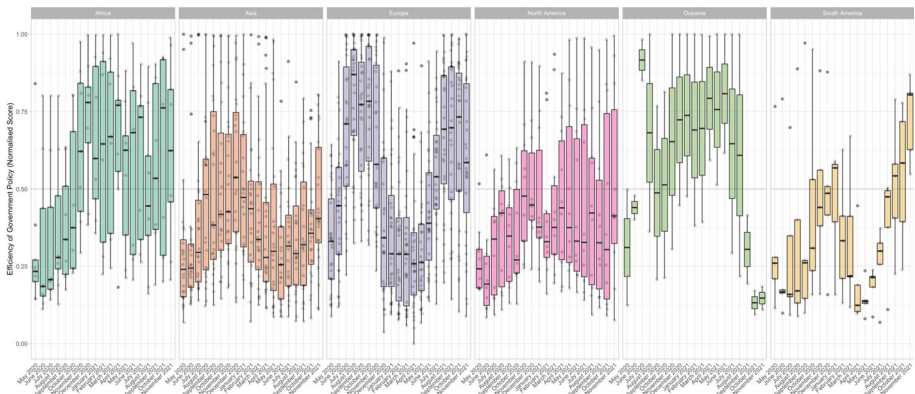


Fig. 4 Boxplot of efficiency scores by month per continent. This figure illustrates the distribution of countries' (normalized) efficiency scores by month per continent. We also plot scatter points reflecting countries. The boxplots are colored according to the continent

countries have been following the exact opposite course, while South American countries are, on average, the least efficient (with notable exceptions in the Fall of 2021).

4.2 Significant correlates of the efficiency scores

In what follows, we delve deeper into the cross-country differences, and provide a first account for the correlates of the efficiency estimates. We note upfront that we do not aim to show causal effects as this is extremely hard with cross-sectional data of 70–80 countries (most of the country-specific correlates of government efficiency are observed annually, preventing us from using the time dimension of our efficiency scores). Thus, aiming to identify causal effects with 60–70 degrees of freedom is not fruitful. However, correlations are still important for highlighting the characteristics of the good performers, and in understanding the mechanics of government efficiency in dealing with the pandemic. In a nutshell, this section aims to trigger new discussion and new research on these important issues.

We analyse bivariate regressions between our two main efficiency scores and literally more than 1500 variables. We obtain most of these variables from the QoG database, which collects and combines macro data from several open-source databases. Importantly, this database includes information for economic, political, institutional, and societal characteristics. We augment this information with variables reflecting historical, cultural, biological, and behavioural country-specific characteristics from several sources. Thus, we have a complete picture of all country-specific traits that might relate with government efficiency. We formally define all variables in Table 1 and provide summary statistics in Table 3.

We provide our most interesting, statistically significant, and intuitive results in graphical form (Fig. 5), using bivariate local polynomial regressions. In the case of parametric regressions (reported in Table 4), the results are statistically significant at the 5% level or higher. We focus on the DEA-based efficiency index, but results are qualitatively similar when using the SFA-based index.

We first examine regressions between our index and several government effectiveness indices from the World Bank, the ICRG, the Heritage Foundation, and the Fraser Institute. These indices in particular serve as validation of our measure: we expect that countries with generally efficient governments and quality institutions are better in managing the pandemic and protecting their citizens. In Fig. 5, we show that this is the case indeed. Countries with high regulatory quality (World Bank index) and superior rule of law (World Bank index) have higher government policy efficiency. According to the regression results reported in Table 4 (where we provide the results from several alternative indices), for a standard deviation of higher Regulatory quality (equal to 0.88), the government policy efficiency is higher by 0.04 points, or 8.6% compared to its mean value (equal to 0.467). Consistent with these findings, we also show that Government integrity, Corruption perceptions, Protection of property rights, and Contract enforcement are also highly statistically significant.

Next, we look at political variables. We find Political stability to be one of the strongest correlates of government policy efficiency, especially in countries with at least a -1 value and above on this index (see Fig. 5). According to the results in Table 4, one standard deviation of higher value on the World Bank measure (equal to 0.87) is associated with higher government policy efficiency by 0.045 points, or 9.6% compared to its mean value. We find equivalent negative effects using the fragility index from the Fund for Peace. Several other indicators reflecting terrorism, incoming immigrants, etc., are associated with lower government policy efficiency.

An interesting question that emerged with the pandemic is whether the cultural element of trust affects COVID-related policy outcomes (Robinson et al., 2020). Consistent with this literature, we find that trust positively and significantly correlates with our government policy efficiency index. Figure 5 shows that in countries where people claim on average that others cannot be trusted (scores of 0.2 out of 1 on the trust index) have average government policy efficiency of approximately 0.4. In contrast, countries with trust scores of approximately 0.7 have government policy efficiency of almost 70%. This is an important finding suggesting that governments must consider the trust levels of their citizens when designing COVID-related policies.

Another interesting discussion that emerged with the pandemic is whether democracies are effective in protecting their citizens. One hypothesis is that countries like China are more

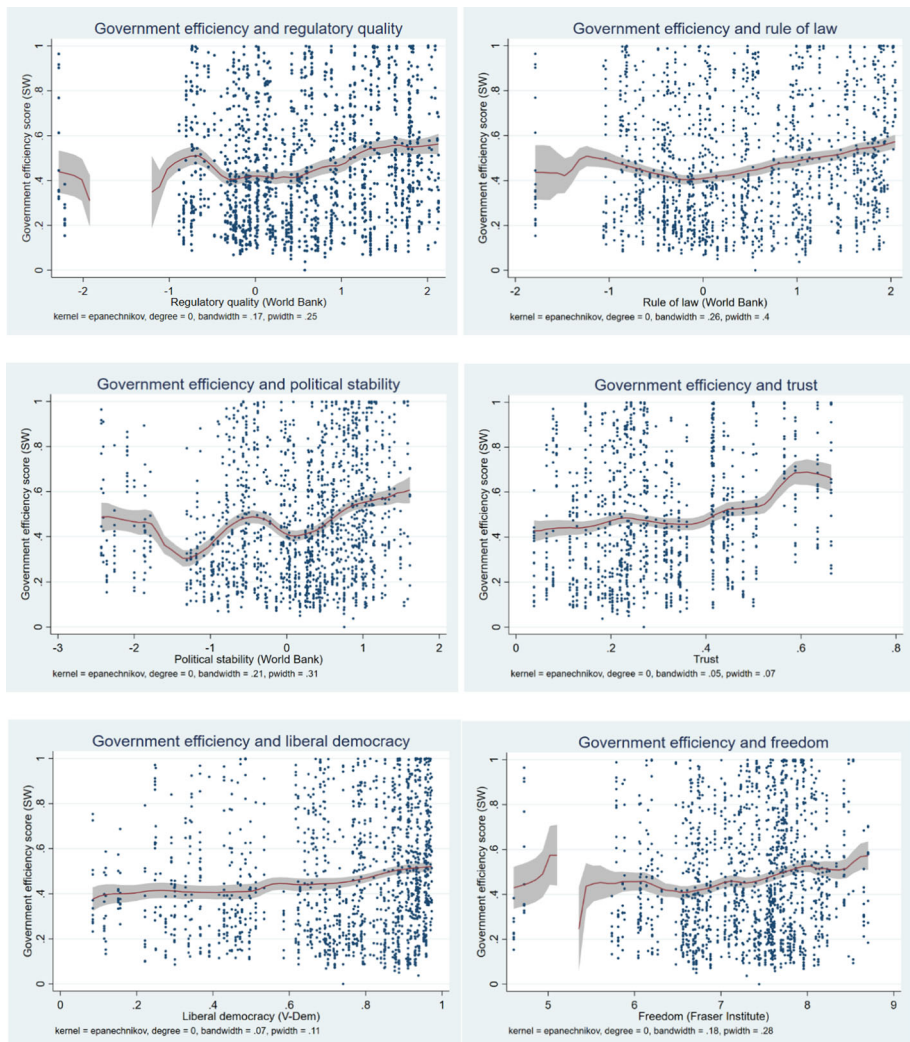


Fig. 5 Correlates of government efficiency

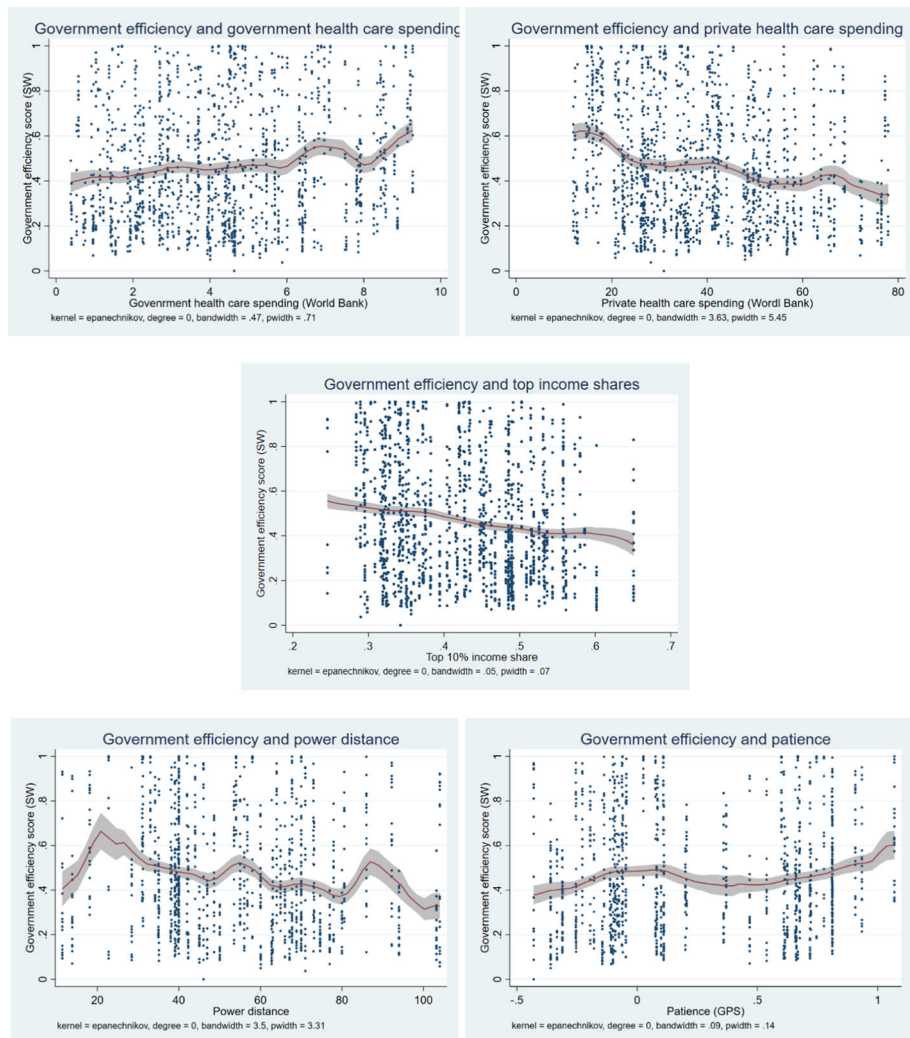


Fig. 5 continued

effective in taking the necessary measures to contain the pandemic because they are more ready to limit freedom of their citizens and also curtail human rights (e.g., Beauchamp, 2020; Mériau, 2020). We find no support for this hypothesis; in fact, the most effective governments are, on average, those of democratic countries, and this is prevalent in both measures of egalitarian and liberal democracy (V-Dem) and measures of constitutional democracy (Polity IV). In fact, Fig. 5 illustrates that the positive relation between liberal democracy and government policy efficiency is almost linear. The results also prevail with perception-based measures, such as the ones from the Freedom House or the Fraser Institute (results available on request).

Another lively debate is whether healthcare spending matters, with most academic studies demonstrating that it does (e.g., Kontis et al., 2020). Consistent with these studies, we find

Table 4 Correlates of government policy efficiency

	Estimate	t-statistic
<i>Government effectiveness and property rights</i>		
Government integrity (Heritage Foundation)	0.002**	2.52
Regulatory quality (World Bank)	0.047**	2.21
Corruption perceptions (Transparency International)	0.002**	2.49
Property rights (Ease of Doing Business)	0.260***	8.16
Rule of law (World Bank)	0.047**	2.39
Contract enforcement (Ease of Doing Business)	0.005***	4.16
<i>Political stability and trust</i>		
Political stability (World Bank)	0.052***	2.76
Fragile state (Fund for Peace)	−0.002**	−2.19
Trust	0.348**	2.59
<i>Democracy and freedom</i>		
Egalitarian democracy (V-Dem)	0.211**	2.40
Liberal democracy (V-Dem)	0.191***	2.83
Democracy (Polity V)	0.006***	3.04
Freedom (Fraser Institute)	0.044*	1.72
<i>Health care</i>		
Government health care spending (World Bank)	0.020**	2.47
Private health care spending (World Bank)	−0.004***	−3.29
<i>Employment and inequality</i>		
Labor force participation (World Bank)	0.007***	3.75
Female labor force participation (World Bank)	0.005***	5.07
Women business and the law index (World Bank)	0.003***	3.77
Top 10% income share (World Inequality Database)	−0.590***	−3.00
<i>Culture</i>		
Power distance	−0.002**	−2.12
Patience (GPS)	0.040	0.82
Patience * Liberal democracy	0.896***	3.93

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

that higher healthcare spending as a share of GDP, positively associates with government policy efficiency. However, in a very interesting finding, this correlation is entirely driven by government spending, implying that countries with large private healthcare systems (as a share of total healthcare expenditure) have been, on average, ineffective. Figure 5 reflects this inference, with countries spending the lowest in private healthcare being more than 0.6 efficient on average while countries spending the most being less than 0.4 efficient.

We also find two correlations that can potentially trigger interesting new research in the social sciences of the pandemic. The first relates to the roles of economic inequality and female participation in the workforce. In countries with higher income inequality (as reflected by either top income shares or uneven economic development), government policy efficiency is lower. This finding is consistent with recent studies on the uneven effects of COVID-19

on the socially vulnerable (e.g., Gaynor & Wilson, 2020; Wright & Merritt, 2020). Figure 5 shows that there is, on average, an approximately 20% gap in government policy efficiency between the most equal and the most unequal countries (inequality measured by the top 10% income share). We also show in Table 4 that labour force participation in general and a higher female labour force participation in particular are amongst the strongest correlates of government policy efficiency. Future research should analyse whether this result is related to more inclusive institutions on female empowerment or to the biological perseverance of females to COVID-19.

Quite notably, we look at the role of culture (using several indicators from several sources). We find significant coefficients at the 5% level, for the cultural characteristic of low power distance (the extent to which the less powerful members of institutions and organizations within a country expect and accept that power is distributed unequally) and patience. The two figures show that countries with a score of more than 100 (1) on the power distance (patience) index have more than 65% efficiency on average, whereas countries with a score of less than 20 (−0.5) have less than 40% efficiency on average. These results are consistent with the premise that patient and more obedient societies coped better with the restrictions and managed to limit the pandemic's consequences.

The most important characteristic of patience is that it explains variation in government policy efficiency within generally efficient and democratic countries. Specifically, we find a positive interaction term between patience and any index of democracy (last row of Table 4), showing significant variation in government efficiency within democracies and according to the cultural element of patience. In our sample, western-type countries like New Zealand, and most Scandinavian countries, enjoy a high share of government policy efficiency and patience, and the same holds true for countries like Taiwan. Thus, patience seems to be an important distinguishing element of government policy efficiency among countries with quality and democratic institutions.

5 Conclusions

We develop the first global government policy efficiency index during the pandemic by comparing the stringency of policy in each country and every month to the average estimated deaths in each country on the next month. We base our analysis on DEA and SFA techniques, with the two models yielding similar results. We have a slight preference on the DEA model because the form of the government production function is unknown. We use a specific DEA model that overcomes problems with the non-stochastic nature of simple DEA (models by Simar and Wilson). Our country-month indices cover 81 countries from May 2020 to November 2021 and we provide all our research output to the benefit of future research.

We also provide a starting point to identify correlates of efficiency. We show that:

- Countries with strong democratic institutions, rule of law, protection of property rights, and political stability are, on average, more efficient.

Two very interesting findings are that:

- Efficient countries rely more on public healthcare spending and have low levels of economic inequality;
- Within the democratic countries, the most efficient ones are those characterized by the cultural element of high patience.

Finally, our analysis opens important pathways for future research. Following the COVID-19 pandemic an emerging strand of literature aims to identify several of its aspects, and

operations research has a key role (Choi, 2021). Several studies focus on the trade-offs of COVID-19 and the impact government interventions have on a variety of aspects, which are mentioned in Sects. 1 and 2 of our paper. With this study, we first provide a way to account for cross-country and within-country variations in reported estimations due to a variety of potential factors (e.g., differences in reporting across decision-making units, or within each unit but different reporting standards across time), and then make use of frontier models to provide estimators of governmental efficiency. OR studies can use these inputs to predict trends that are less prone to measurement errors (compared to being based on reported estimates sourced from ‘Our World in Data’), or build upon our efficiency estimators with other techniques such as MCDA/M models or fuzzy theory, e.g. in the context of governmental decision-making and trade-offs evaluation. Additionally, exploratory statistical studies can be based on our provided estimates and develop causal inferences leading to governmental inefficiency in more complete and focused case studies. In this study, we refrained from that focus and only provided correlates highlighting which country characteristics are associated with improved government policy efficiency.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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