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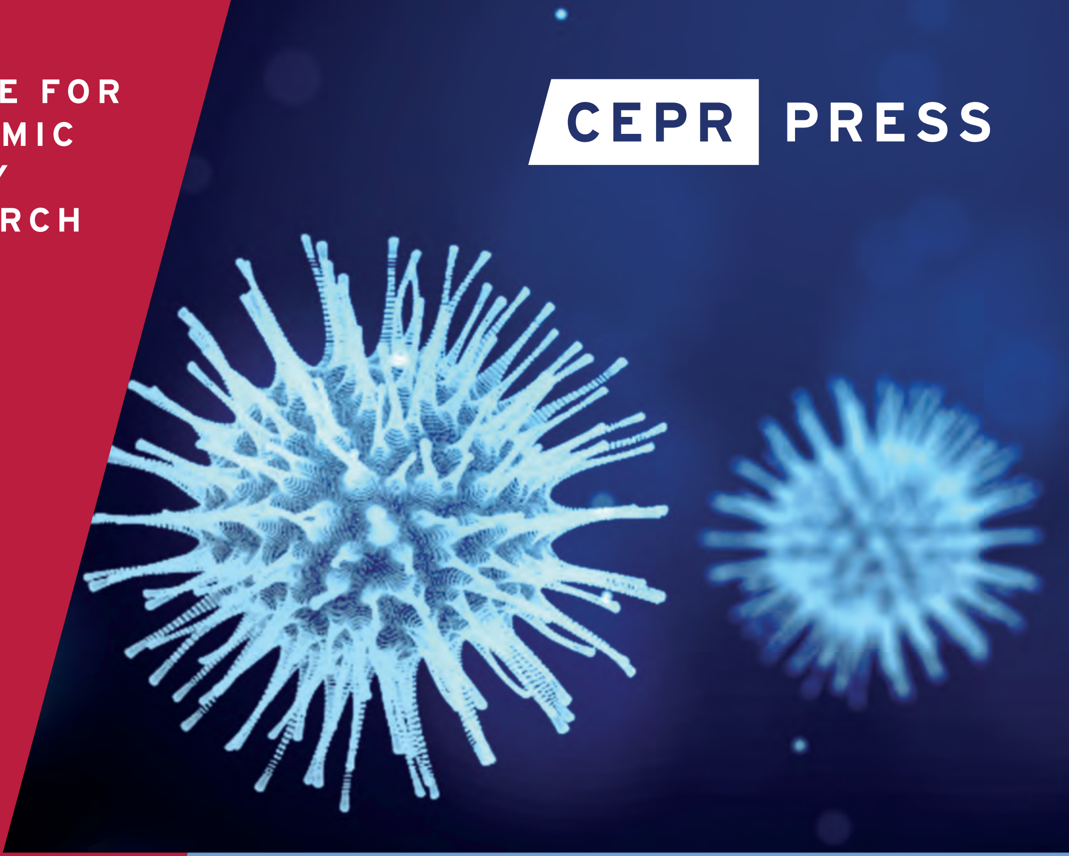

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COVID ECONOMICS

VETTED AND REAL-TIME PAPERS

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Covid Economics
Vetted and Real-Time Papers

Covid Economics, Vetted and Real-Time Papers, from CEPR, brings together formal investigations on the economic issues emanating from the Covid outbreak, based on explicit theory and/or empirical evidence, to improve the knowledge base.

Founder: Beatrice Weder di Mauro, President of CEPR
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Contact: Submissions should be made at https://portal.cepr.org/call-papers-covid-economics. Other queries should be sent to covidecon@cepr.org.

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Ethics

Covid Economics will feature high quality analyses of economic aspects of the health crisis. However, the pandemic also raises a number of complex ethical issues. Economists tend to think about trade-offs, in this case lives vs. costs, patient selection at a time of scarcity, and more. In the spirit of academic freedom, neither the Editors of *Covid Economics* nor CEPR take a stand on these issues and therefore do not bear any responsibility for views expressed in the articles.

Submission to professional journals

The following journals have indicated that they will accept submissions of papers featured in *Covid Economics* because they are working papers. Most expect revised versions. This list will be updated regularly.

American Economic Review
American Economic Review, Applied Economics
American Economic Review, Insights
American Economic Review, Economic Policy
American Economic Review, Macroeconomics
American Economic Review, Microeconomics
American Journal of Health Economics
Canadian Journal of Economics
*Econometrica**
Economic Journal
Economics of Disasters and Climate Change
International Economic Review
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*Journal of Econometrics**
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Journal of Monetary Economics
Journal of Public Economics
Journal of Public Finance and Public Choice
Journal of Political Economy
Journal of Population Economics
Quarterly Journal of Economics
*Review of Corporate Finance Studies**
Review of Economics and Statistics
*Review of Economic Studies**
Review of Financial Studies

(*) Must be a significantly revised and extended version of the paper featured in *Covid Economics*.

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Divided we fall: International health and trade coordination during a pandemic[1]

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Date submitted: 1 December 2020; Date accepted: 1 December 2020

We analyse the role of international trade and health coordination in times of a pandemic by building a two-economy, two-good trade model integrated into a micro-founded SIR model of infection dynamics. Uncoordinated governments with national mandates can adopt (i) containment policies to suppress infection spread domestically, and (ii) (import) tariffs to prevent infection coming from abroad. The efficient, i.e., coordinated, risk-sharing arrangement dynamically adjusts both policy instruments to share infection and economic risks internationally. However, in Nash equilibrium, uncoordinated trade policies robustly feature inefficiently high tariffs that peak with the pandemic in the foreign economy. This distorts terms of trade dynamics and magnifies the welfare costs of tariff wars during a pandemic due to lower levels of consumption and production as well as smaller gains via diversification of infection curves across economies.

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1 We thank George Mailath, Volker Nocke, Raghu Sundaram, Michèle Tertilt, and Mathias Trabandt for comments. Steven Zheng provided excellent research assistance. Von Thadden thanks the German Science Foundation for support through grant CRC TR 224, C03.

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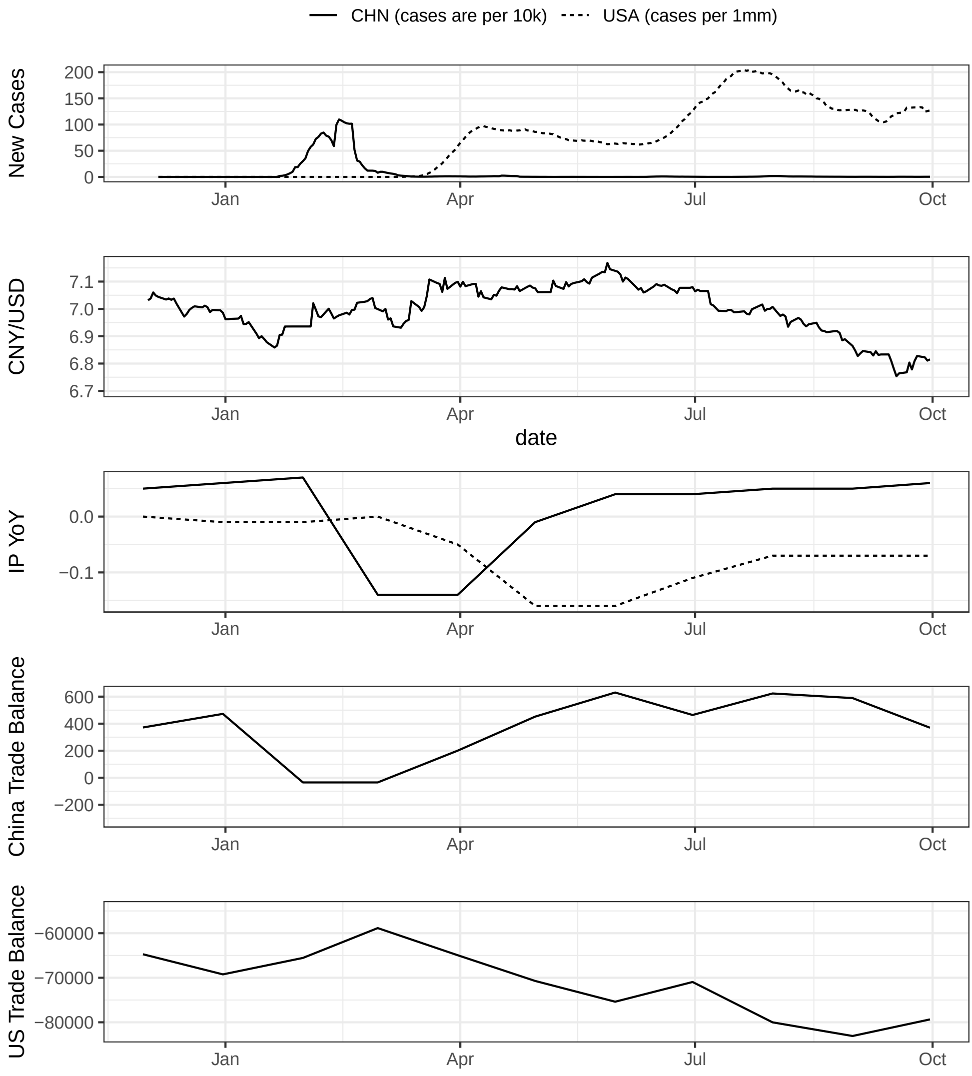
The Covid-19 Pandemic has been truly international, spreading globally through health and economic linkages between countries and regions. To understand the impact of pandemics on the global economy and to analyze the role of coordination in international trade and health, we generalize the Macroeconomic SIR literature to an international context by introducing trade. Our model helps understand how the outbreak of a pandemic in one country is transmitted to other countries by trade (which includes tourism and services), and how national containment measures impact the spread of the pandemic in other countries. Given that the policy response to the pandemic in 2020 has been mostly along national lines, the question of the role and the value of international coordination in combatting the pandemic is of great importance.

By way of motivation, consider the stylized facts for China and the United States presented in Figure 1 for the period December 2019 to October 2020: the evolution of the pandemic (top panel); the exchange rate measured as CNY/USD, i.e., Renminbi per US dollar (second panel); the year on year (y-o-y) growth in industrial production in the two countries (third panel); and, the trade balance for China and the US (bottom two panels, respectively). The pandemic peaked in China in terms of new infections during mid-February to mid-March 2020, while the US reached its second peak in August 2020, with infections remaining higher thereafter relative to its first peak attained during April 2020. Unsurprisingly, the y-o-y change in industrial production evolved in each country according to the pandemic, dipping as the pandemic took grip and recovering (in case of China) as the pandemic subsided.

Significant from an international trade perspective are the observations that (i) each country imported more relative to exports (negative trade balance) during the period it witnessed the pandemic; and, (ii) the terms of trade (expressed in terms of the exchange rate) deteriorate in the country experiencing the pandemic, with USD depreciating sharply relative to CNY during the second wave of the pandemic in the US. Can these outcomes be reconciled with uncoordinated health and tariff policy decisions of national governments? Are these outcomes desirable from a social efficiency standpoint? Put differently, what would the outcomes be if national governments were to coordinate their health and tariff policies? Indeed, how do health and tariff policies affect each other, and in turn, the attendant health and trade outcomes, during a pandemic? By introducing a micro-founded SIR dynamic for international disease transmission in an otherwise standard and simple model of trade, our paper provides a theoretical framework for answering these important policy questions.

It has been widely noted in the recent economic literature (Eichenbaum, Rebelo and Trabandt, 2020; Brotherhood et al., 2020, and others) that if a pandemic hits an economy, local consumption and production create health externalities among its individuals. Our model's key insight

Figure 1: Pandemic and Economic Outcomes in China and the U.S.



Note: Health and economic outcomes in China and the United States during the 2020 pandemic. Daily new cases for China are per 10,000 people and per 1,000,000 for the United States. Industrial production is measured year-over-year. Trade balance is total exports minus total imports in millions of USD.

is that international trade offers a risk-sharing alternative, as it can help sustain consumption in pandemic-affected economies without excessively aggravating its health externalities through production-related transmissions. However, international trade exposes the foreign economies to the pandemic, requiring an eventual reversal of the roles played by the economies in risk-sharing through trade. In spite of the transmission of infection across borders, the socially efficient arrangement does in general involve trade-based risk-sharing that reflects high contingency on the state of the pandemic in different economies; in particular, tariffs are lowered to counteract the economic fallout on the foreign economy when its infection is peaking, and they can even be negative, i.e. be replaced by import subsidies.

In contrast, uncoordinated, i.e., Nash equilibrium, trade policies adopted by national-mandate governments robustly feature inefficiently high tariffs, which are only reduced during the peak of the pandemic at home and peak when the pandemic in the foreign country peaks. While uncoordinated tariffs are inefficiently high even in the absence of a pandemic (a well known-result from trade theory), the inefficiencies are magnified in the presence of a pandemic, manifesting in the form of lower levels of consumption and production, smaller health gains via diversification of infection curves across economies, and weaker post-pandemic economic recovery. In summary, health outcomes in Nash equilibrium are inferior in terms of a higher incidence of deaths and in terms of less economic burden-sharing via trade compared to the case of policy coordination.

We show these results on the need for international coordination on health and trade in a dynamic two-country model with complete SIR dynamics, a micro-founded international transmission of the pandemic operating via both consumption and labor, policy instruments for domestic containment and international tariffs, and an analysis of uncoordinated international activity in the form of infinite-horizon Nash equilibrium play.

We calibrate our model so that the pandemic starts in one country and spills over to the other country such that the infection in the second country peaks when the infections in the first country have subsided thanks to herd immunity. This is the simplest model to capture the international transmission of the health externality; we do not consider more complicated policy shifts that can give rise to several infection waves in one country. The pandemic induces households to endogenously cut down their consumption and labor provision in order to reduce the probability of getting infected. However, as has been widely noted, households do not internalize health externalities on other agents. In fact, our model features what are probably the two most important such externalities (see, e.g., Garibaldi, Moen and Pissarides (2020) for a careful discussion) and extends them to the international context. First, self-interested infected individuals ignore the health impact of their activity on others. Second, even susceptible individuals ignore the dynamic

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externality on other not yet infected individuals, as they risk getting infected and thus posing a risk to others in the future. While these externalities have been widely analyzed in the recent macro-SIR literature (see our discussion below), they also constitute an international externality through international trade.

Our model allows us to investigate the optimal domestic containment and tariff policies with and without international coordination. In both the coordinated and the uncoordinated outcomes, the governments impose domestic containment policies (which we model as a possibly non-remunerative “tax" on domestic consumption) during the course of the domestic infection. This policy contains the spread of the pandemic, as it discourages households from consuming goods and internalizes the health externalities. Under our calibration, the domestic containment policy can amount to the equivalent of a tax as high as 70% during the peak of infection, which substantially decreases economic activity. Both uncoordinated governments and the coordinated planner reduce the amount of infection during the pandemic, at the expense of lower consumption and production in both countries. In fact, the levels of consumption and production in each country largely track the evolution of infected cases in each country due to both the government’s containment policies and the households’ endogenous responses.

In addition to the domestic containment policies, our model considers tariffs as a second instrument addressing the international dimension of the problem, and predicts novel import tariff patterns. In the absence of a pandemic, our model features standard tariffs wars. When countries take uncoordinated (Nash) policy decisions, they choose import tariffs that are too high relative to the coordinated (social planner) case. Such tariffs lead to poor consumption levels and poor choice between domestic and foreign goods, resulting in a significant loss of welfare. The pandemic fundamentally alters the temporal structure of tariffs, inducing in them a variation that is linked to the relative state of the pandemic in the two countries, with important welfare consequences.

Consider first the uncoordinated (Nash equilibrium) case. When the pandemic hits the first country, it seeks to limit transmission of the disease domestically by imposing strong containment measures on domestic consumption; this puts a downward pressure on its domestic price level, resulting in both a competitive disadvantage to foreign goods as well as an increase in the risk of infection to the foreign country since it incentivizes imports from the infected country. In response, the foreign country *raises* its import tariffs beyond the case without a pandemic. This weakens the infected country’s output even further and limits its consumption possibilities. On the other hand, the infected country *lowers* import tariffs below the case without a pandemic, in order to encourage its domestic households to consume more foreign goods which are less conducive to infection. In other words, the pandemic modulates the tariff structure in a manner that skews the terms of trade

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against the infected country's production, aggravating economic risk-sharing possibilities in the midst of a pandemic. The loss of risk-sharing manifests itself in the form of a high domestic bias in the infected country's consumption basket; nevertheless, the home bias reduces as the pandemic peaks in the infected country given its response of limiting import tariffs to support the economy. As the infected country reaches herd immunity and the pandemic peaks in the foreign country, their roles are reversed in this loss of risk-sharing.

Consider now the case where the two countries coordinate on a jointly optimal outcome. The pandemic modulates the structure of tariffs in this case too, but in a manner that is exactly the *opposite* of the uncoordinated case. As domestic containment measures required to reduce domestic infections aggravate production and consumption in the infected country, the planner lowers the import tariffs in the foreign country and raises the import tariffs in the infected one. The structure of these tariffs is intriguing at first pass because they encourage both countries to consume more goods produced by the more infected country and therefore raise the likelihood of infection. On the other hand, terms of trade are now skewed in favor of the infected country's goods to ameliorate its economic situation. As in the uncoordinated case, these roles reverse once the infected country reaches herd immunity and the pandemic peaks in the foreign country, so that each country ends up with more favorable terms of trade and higher income during the peak of its domestic infection. The better economic risk-sharing manifests itself in the form of efficient home bias in each country, in particular, a home bias far lower than in the uncoordinated case.

It is worth noting that risk sharing in this context refers to individual risk. As is common in the basic SIR models, there is no aggregate risk in our model. Once national policies are determined, the disease runs its course deterministically, with aggregate transmissions determined by the Law of Large Numbers. Government policies, however, influence the laws of motion of the domestic transmissions and can shift aggregate infection rates internationally, since the economies are linked through international trade and infections. This then results in changing infection risks for the individuals in each country. A key result of our analysis is that this intertemporal economic risk-sharing also leads to sharing of health risk: the foreign country imports a part of the infections by facilitating trade with the infected country, which encourages the infected country to shift consumption towards foreign goods and therefore prevents its domestic infection rates from peaking too fast; this risk-sharing then benefits the foreign country at the peak of its own infection.

This implies, from a normative standpoint, that cooperation on trade in times of a pandemic can result in both superior economic and health risk-sharing outcomes across countries. Hence, there is no tradeoff between economic and health performance in the international context. In fact, while Nash equilibrium behavior in tariffs leads to lower international disease transmission compared to

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laisser-faire policies, uncoordinated behavior still produces worse health outcomes in each country than socially optimal, because it fails to generate the intertemporally optimal modulation of the terms of trade.

This is by no means obvious, as a simple variant of our model shows in which there are no tariffs. If tariffs are exogenously fixed and constant (for example by international trade rules), then both countries are still linked by international trade and infections, but set their domestic containment policies independently. In this model, this leads to outcomes that are, of course, overall inferior to the coordinated outcome, but that result in fewer infections and deaths. In fact, the lack of coordination in Nash equilibrium leads to excessive economic containment, exactly because an instrument to coordinate international economic activity at least implicitly is missing. In this sense, the tradeoff between economic and health performance is resolved differently by uncoordinated governments than in the coordinated outcome, who tolerate more infections in exchange for higher consumption.

From a technical point of view, our analysis is, as far as we know, the first to study Nash Equilibrium in fully dynamic economic and health policies. This is computationally demanding, because strategies are high-dimensional vectors and each iteration of the best-response algorithm requires solving a full dynamic macroeconomic equilibrium model. In order to get sufficiently fast convergence we therefore model economic, health, and policy interactions as parsimoniously as possible.

From a positive standpoint, our model can help to explain why in the real-world scenario of uncoordinated decision-making by countries, terms of trade and economic outcomes may end up being excessively dire for the infected countries. An important insight is that the purely epidemiological consideration of imposing “border controls" on trade and travel to limit the spread of infections should be weighed against its implications for loss of economic risk-sharing; indeed, our model suggests that even health outcomes tend to end up being superior with some coordination on trade.

Our analysis is also informative about the dynamics of health and economic outcomes under uncoordinated policies. In fact, our simulations consistently generate the pattern that Nash equilibrium “does too much too late". This is most striking for the evolution of aggregate consumption, which in Nash equilibrium remains high in the non-affected country for more than half a year after the outbreak in the first country, and then drops dramatically in a short period when the infections hits. In contrast, international coordination reduces consumption even in the non-affected country right from the start of the pandemic, but the overall drop is much smaller. Similarly, in Nash equilibrium tariffs in the originally non-affected country stay high until well into the outbreak and are then reduced drastically, well below levels chosen under coordinated policy. In our benchmark case this results in durations of the pandemic that are around 5% longer in Nash equilibrium than in the coordinated outcome.

Related Literature. Our paper is related to an emerging literature that studies the nexus between economics and disease[1]. On a single country level, Eichenbaum, Rebelo and Trabandt (2020) embed SIR disease dynamics into a macroeconomic model and study the tradeoffs involved with suppression policies. In one of the few papers on the economic consequences of disease dynamics before 2020, Greenwood et al. (2019) analyzed the dynamics of HIV in Africa and its economic consequences. Building on this work, Brotherhood et al. (2020) analyze a rich set of behavioral patterns and show the importance of heterogeneous lockdown policies for the Covid-19 environment. Alvarez, Argente and Lippi (2020) is an early paper studying the optimal lockdown policy in a single country as a planning problem in a macreconomic disease model. Foundational work on the health externalities arising from Covid-19 is, among others, Garibaldi, Moen and Pissarides (2020) and Assenza et al. (2020). A number of papers investigate different containment policies, such as Berger, Herkenhoff and Mongey (2020) on the role of testing and case-dependent quarantine, Alon et al. (2020) on age-specific lockdown policies among sets of developing and advanced economies, and Jones, Philippon and Venkateswaran (2020) on work from home policies. There is a large body of work on national fiscal and macroeconomic stabilization policies in response to the pandemic, on which we build in order to simplify the policy space as much as possible, but that is too large to review here.

Our paper extends these studies to multiple countries and international trade in multiple goods, with associated domestic and trade policies to manage the pandemic. It thus relates to other recent contributions studying hetereogeneity in macroeconomic SIR dynamics, such as Acemoglu et al. (2020) who develop an SIR model with heterogeneous groups and lockdown policies, and Kaplan, Moll and Violante (2020) who integrate the SIR disease dynamics in a heterogeneous agent new Keynesian model and study the distributional consequences of different containment strategies, with a focus similar to Glover et al. (2020). Fernandez-Villaverde and Jones (2020) estimate and simulate an SIR model by using disaggregate data from various locations and provide an impressive overview of the international evolution of the disease on their website.

A very rich recent paper written parallel to ours and with a similar focus on international trade and health, is Antràs, Redding and Rossi-Hansberg (2020). They develop a two-country model of household interaction in equilibrium with spatial frictions that provides a microfoundation for the

[1]This literature has grown impressively during the last six months, and we cannot do justice to it here. See Brodeur et al. (2020) and references therein for a broad overview.

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international spread of a disease similar to the one developped here and a gravity model of international trade. Different from our work, they do not consider governments, strategic national policies, and international coordination. This latter theme is the focus of Beck and Wagner (2020) who study cooperation across countries in containment policies in a simple two-stage model that leaves aside the macroeconomic dynamics at the core of our model. Leibovici and Santacreu (2020) studies the role of international trade in essential goods during a pandemic with a multi-country, multi-sector model. Bonadio et al. (2020) examine the role of global supply chains' impact on GDP growth across countries, while Meier and Pinto (2020) study the specific disruption of China-US supply chains and its impact on US production in March/April 2020 in detail. Early empirical work comparing pandemic policies internationally includes Ullah and Ajala (2020), who analyze effects of testing and lockdown in 69 countries, and Noy et al. (2020) who estimate measures of exposure, vulnerability and resilience to Covid-19 across countries.

McKibbin and Roshen (2020) and Liu, Moon and Schorfheide (2020) estimate a DSGE model and a Bayesian panel VAR, respectively., while We explicitly model the international trade and health coordination by studying the dynamic interaction between the SIR dynamics, international trade, and local and global containment policies.

Our paper is also related to the large literature on international business cycles (Backus, Kehoe and Kydland, 1992; Stockman and Tesar, 1990). While the business cycle dynamics in these papers are driven by productivity, investments and savings, the dynamics in our paper are driven by disease and health policies that give rise to interesting cross-country co-movements (as analyzed in different contexts, e.g., by Imbs (2004); Rose and Spiegel (2009)). We identify these co-movements and analyze how different tax and tariff policies affect them.

1 The Model

In thinking about the importance of coordinating health and trade outcomes during a pandemic, a simple two-period consumption and trade model with two countries (sketched in Appendix A.1) provides a useful starting point. Suppose that each country has an initial group of infected individuals and a susceptible group that may become infected by coming in contact with the domestic (foreign) infected group while consuming the domestic (foreign) goods. Two key externalities arise, one in the context of health due to the cross-country spread of the pandemic, and another — more traditional one — in the context of trade. Each government has two instruments, one controlling domestic infections via domestic containment policies, and one controlling imports via tariffs. The two externalities are evaluated differently depending on whether decisions are made by a co-

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ordinated “planner" maximizing the sum of the objectives of the two countries or by uncoordinated governments in Nash equilibrium.

On the health front, the infected group in each country exposes the susceptible group in the other country to the risk of infection. This “health externality” is not internalized by uncoordinated governments while setting containment policies, i.e., when effectively choosing consumption, for their respective infected groups. Hence, the coordinated planner imposes stricter domestic containment policies on consumption in each country than the uncoordinated planners. Second, a “trade externality” materializes as is standard in the literature (Brander and Spencer, 1985; Ossa, 2014). Each country views its net imports as a cost to its welfare and chooses a level of consumption of the foreign good for its citizens that is lower than that under coordination, where imports and exports are simply cross-country transfers. Clearly, both instruments are at least partially conflicting, and the health and the trade externalities interact with each other, depending on the state of the pandemic in the two countries

To analyze this broader problem, we study a full dynamic two-country model with complete SIR dynamics, production and costly deaths that builds on the insights from the simple two-period model, but is micro-founded in its domestic and international transmission mechanism and derives richer implications on the need for international coordination on the health and trade fronts.

The model considers 2 countries, $k = A, B$. Time is discrete, $t = 0, 1, 2, ...$ Each country has households, identical competitive firms, and a government.

For all variables we use the following notational convention. Variables describing consumption, production, or government activity in country $k \in \{A, B\}$ have the superscript k. When discussing a single country, the superscript $-k$ denotes the other country. To simplify the presentation, superscripts in equations referring to a single country are dropped whereever possible without ambiguity.

The households in each country are defined over a continuum of unit mass. Let S_t, I_t, R_t, and D_t denote the mass of susceptible, infected, recovered and dead people in any of the two countries. The total population of the country at any date t then is $N_t = S_t + I_t + R_t$. We do not distinguish between individuals and households. Households within each of the three living categories are identical. S_t^{-k}, I_t^{-k}, R_t^{-k}, and D_t^{-k} are the masses of the respective groups in the other country, if we discuss activity in one country k. $h \in \{s, i, r\}$ indicates the three health types.

1.1 The Economy

There are two goods $j \in \{A, B\}$, which are denoted by subscripts throughout the paper. Each period, good j is produced in country j only, by using country j labor according to the linear

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technology

$$y_t = z\left(\ell_t(s) + \phi \ell_t(i) + \ell_t(r)\right) \tag{1}$$

where $\ell_t(h) = \ell_t^j(h)$ is the amount of labor provided by employees of health status h, and $z = z^j$ is country $k = j$'s productivity, which is assumed to be constant. Infected individuals ($h = i$) have a lower productivity, as given by $\phi < 1$. Firms act competitively, maximizing profits and taking prices as given.

The prices of the goods in both countries are p_j, $j = A, B$. When discussing a single country k, p_{-k} denotes the price of good $j \neq k$. There are no transport costs or other physical trade frictions between countries.

Households in each country provide labor and consume a basket of the two goods A and B. Suppressing the time index for simplicity, denote the per household consumption of good j by households in country k by $c_j^k = c_j^k(h)$. Households in country k consume the goods as a basket composed by the standard CES aggregator

$$q(c_k^k, c_{-k}^k) = \left(\alpha (c_k^k)^{\frac{\sigma-1}{\sigma}} + (1-\alpha)(c_{-k}^k)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \tag{2}$$

where c_k^k denotes consumption of the domestic good, c_{-k}^k of the foreign good, $\alpha \in (0.5, 1)$ is the home bias for domestic consumption goods, and $\sigma > 1$ the substitution elasticity between the domestic and the foreign good. These two parameters are identical in both countries in order to focus on the pure effects of disease transmission in international trade.

At each time t, the representative households in any of the two countries have the following objective function, where we ignore the household's health status to simplify the presentation:

$$U_t = \mathbb{E}_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left[v(x_\tau) - \frac{1}{2}\kappa \ell_\tau^2 \right] \tag{3}$$

where $0 < \beta < 1$ is the discount rate, $x_\tau = x_\tau^k(h)$ is the composite consumption basket, $\ell_\tau = \ell_\tau^k(h)$ labor supplied, and

$$x_\tau^k(h) = q(c_{k,\tau}^k(h), c_{-k,\tau}^k(h)) \tag{4}$$

We assume for computational simplicity that the utility of consumption is of the constant-relative-risk-aversion type:

$$v'(x) = x^{-\rho},\ \rho > 0 \tag{5}$$

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In each country k, we denote aggregate consumption of the home good by

$$H_t^k = S_t^k c_{k,t}^k(s) + I_t^k c_{k,t}^k(i) + R_t^k c_{k,t}^k(r) \tag{6}$$

and by

$$M_t^k = S_t^k c_{-k,t}^k(s) + I_t^k c_{-k,t}^k(i) + R_t^k c_{-k,t}^k(r) \tag{7}$$

that of the foreign good ("imports"). Hence, the exports of country k are M_t^{-k}.

In each country, the government imposes measures to contain the spread of the pandemic. Since we are interested in the international interaction of health and economic policies, which is computationally intensive, we do not attempt to model these measures in their actual richness and complexity, as, e.g., Brotherhood et al. (2020) or Kaplan, Moll and Violante (2020). Without going into any institutional detail, we follow the minimalist approach taken by Eichenbaum, Rebelo and Trabandt (2020) and assume that these measures act like excise "containment taxes" $\mu^k = \mu_t^k$. This means that households in country k have to pay an extra $\mu^k p_j$ per unit of consumption of good j, $j = A, B$. These additional costs include the costs of safety measures, new regulatory product features, waiting times, product substitution, and all other additional costs induced by policies restricting contact and economic activity. Despite their formal similarity, the μ^k are not value-added taxes. They are material or immaterial and partially deadweight costs of consumption. Furthermore, the government may decide to implement additional measures for foreign goods, which may include border controls, the closure of harbours, the restriction of air travel, additional safety checks etc. These measures act like a further excise tax, which we call $\nu^k \geq 0$. Despite their formal similarity, the ν^k are not just import tariffs. They are material or immaterial and partially deadweight costs of consuming foreign goods, on top of those generated by μ^k.

In any of the two countries $k = A, B$, households then have to pay $(1 + \mu^k)p_k$ per unit of consumption of the domestic good and $(1 + \mu^k + \nu^k)p_{-k}$ per unit of consumption of the foreign good. For each country, we can thus simplify notation by defining the "consumer prices"

$$\widehat{p}_k = \widehat{p}_k^k = (1 + \mu^k)p_k \tag{8}$$

$$\widehat{p}_{-k} = \widehat{p}_{-k}^k = (1 + \mu^k + \nu^k)p_{-k} \tag{9}$$

for the domestic and foreign goods, respectively.

As noted, the μ^k and ν^k are frictions that do not necessarily generate government revenue. Let δ_μ^k and δ_ν^k be the fraction of these costs received by the government; δ_μ^k and δ_ν^k are exogenous. The fraction $1 - \delta_i^k, i = \mu, \nu$, is pure waste from a public finance perspective and represents

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pure frictions to reduce consumption activity or make it safer in health terms. To simplify the presentation, we assume that $\delta^k_\nu = 1$, i.e. that the friction on international trade comes in the form of pure tariffs. The domestic policy μ^k may raise money as it is related to consumption and business activity, but it is purely dissipative as long as it simply disrupts consumption to contain the pandemic. In our simulations, we consider the two extreme cases $\delta^k_\mu = 0, 1$.[2] δ^k_μ is a measure of the cost of containment measures: the lower δ^k_μ the more damaging the measures are economically.

The government's budget in either country therefore is

$$G^k_t = \delta^k_\mu \mu^k p_{k,t} H^k_t + (\delta^k_\mu \mu^k + \nu^k) p_{-k,t} M^k_t \tag{10}$$

In order to simplify the dynamics, we again follow Eichenbaum, Rebelo and Trabandt (2020), Brotherhood et al. (2020) and others, by assuming that households do not save or borrow. Hence, the only intertemporal link of household decisions is given by health concerns, and the budget constraint of a household of type h in country k at time t is static and given by

$$\widehat{p}_{k,t} c_{k,t}(h) + \widehat{p}_{-k,t} c_{-k,t}(h) = w_t(h)\ell_t(h) + g_t(h) + v_t. \tag{11}$$

where we have dropped the superscript k for notational convenience, and $w_t(h)$ is the domestic wage, $g_t(h)$ the per household government transfer to type h households, and v_t the per household profit of the corporate sector in the country. In our baseline framework we exclude redistributionary policy and let $g_t(h) = g_t$ for all h. Using our other simplifying assumptions, the government's budget constraint therefore is

$$G^k_t = (1 - D^k_t) g^k_t \tag{12}$$

where $1 - D^k_t$ is the size of the population at time t, determined by the disease dynamics to which we turn now.

1.2 The Disease

Like Eichenbaum, Rebelo and Trabandt (2020), Brotherhood et al. (2020) and other recent economic contributions, we augment the classic SIR model by economic activity. Different from these contributions we do not only include domestic economic interactions, but also interactions due to international trade. In the basic SIR model following Kermack and McKendrick (1932), an infectious individual in any given area can spread the virus at the rate ηS_t (so-called "mass action

[2] Like most of the literature, Kaplan, Moll and Violante (2020) recognize that, factually, containment measures mostly generate costs rather than revenue, but propose, in a normative sense, to replace pure frictions by equivalent Pigouvian taxes, i.e. to make δ^k_μ a policy instrument and set it as large as possible.

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incidence"), where S_t is the number of susceptibles in that area. Hence, the mass of newly infected people in that area at time t is given by $T_t = \eta S_t I_t$. Eichenbaum, Rebelo and Trabandt (2020) generalize this to transmission through consumption and work activities in a single country by splitting the individual transmission rate ηS_t into three components to obtain

$$T_t = [\pi_1 c_t(s) c_t(i) + \pi_2 \ell_t(s) \ell_t(i) + \pi_3] \, S_t I_t \tag{13}$$

where $c_t(h)$ and $\ell_t(h)$ are consumption and labor, resp., by the representative consumers.

We add an international economic channel to this transmission mechanism, taking into account that the consumption of imports leads to cross-border contacts that are potentially contagious. Typical examples of such imports of country k would be the delivery and installation of goods and equipment in k by producers from country $j \neq k$, tourists from country k in j, or services provided by j-firms in k. In Section A.3 in the Appendix we provide a micro-founded analysis of such an international transmission mechanism, which yields the following generalization of (13):

$$\begin{aligned} T_t^k &= \left[\pi_1 \left(c_{k,t}^k(s) c_{k,t}^k(i) + c_{-k,t}^k(s) c_{-k,t}^k(i)\right) + \pi_2 \ell_t^k(s) \ell_t^k(i) + \pi_3\right] I_t^k S_t^k \\ &+ \pi_4 \left[c_{k,t}^k(s) c_{k,t}^{-k}(i) + c_{-k,t}^k(s) c_{-k,t}^{-k}(i)\right] I_t^{-k} S_t^k \end{aligned} \tag{14}$$

As in (13), the first three terms capture infections from domestic contacts arising during consumption, work, and all other local activity, respectively. The fourth term describes infections arising from contacts with foreigners while importing or exporting.[3] This is the international disease transmission mechanism at the heart of our analysis, of which the single country case (13) is a special case obtained by setting $c_{-k}^k = 0$, for $k = A, B$.

As in standard epidemiological models, the evolution of the transmission in any country is now given by

$$S_{t+1} = S_t - T_t \tag{15}$$

$$I_{t+1} = I_t + T_t - (p_r + p_d) I_t \tag{16}$$

$$R_{t+1} = R_t + p_r I_t \tag{17}$$

$$D_{t+1} = D_t + p_d I_t \tag{18}$$

where p_r and p_d are the fractions of infected individuals that recover or die, respectively, during

[3]In order to simplify the model and the calibration, we do not include an international spillover-term from labor, as in π_2, which would be particularly relevant for the import and export of services. We have experimented with such a more general model, and our results would become stronger.

the period. Here, the transition probabilities p_r and p_d are in principle functions of I_t, because the functioning of the national health system depends on its use.[4] For computational simplicity we work with constant probabilities for now.

Note that the system (15)–(18) is deterministic, and the overall population, $N_t = S_t + I_t + R_t$, decreases by $p_d I_t$ each period. We normalize the initial population in each country to $N_1^k = 1$. As is commonly assumed in much of the epidemiological literature at the moment, we assume that recovered individuals remain in that category for sure (i.e. acquire at least temporary immunity).[5] Importantly, by (14), the epidemiological evolution in each country depends on that of the other.

We denote the current state of the disease by

$$\Theta_t = \left(S_t^A, I_t^A, R_t^A, S_t^B, I_t^B, R_t^B\right) \tag{19}$$

and consider a situation in which initially,

$$S_1^A = 1 - \varepsilon, I_1^A = \varepsilon, R_1^A = 0 \tag{20}$$

$$S_1^B = 1, I_1^B = R_1^B = 0 \tag{21}$$

where $\varepsilon > 0$ is a small number. Hence, the pandemic begins with a small number of infections in country A and then spreads endogenously to country B.

1.3 The role of government

As noted above, in the current simple model there is no role for redistributive policies $g_t(h)$. Policy therefore consists in setting the domestic containment policy μ_t^k that controls overall consumption and the tariff frictions ν_t^k that control imports. Once these are fixed, government spending g_t is given by the government budget constraint (12) and (10). The tariff can be used to achieve the following, partially conflicting goals of trade and health policy. First, of course, tariffs raise money that can be distributed directly to households. Second, as usual, tariffs manipulate the terms of trade in favor of domestic goods and thus higher domestic labor income. Third, high tariffs (or related frictions) reduce infections through foreign contacts. And fourth, tariffs can be used to influence the infection dynamics by attempting to shift production internationally to where infection rates are lower.

[4] The role of such "congestion externalities" has been emphasized and modelled in the work on optimal containment policies, e.g. by Brotherhood et al. (2020), Kaplan, Moll and Violante (2020), Favero (2020), and Assenza et al. (2020).

[5] At the time of this writing, there is some uncertainty about this claim, see (see e.g. Long et al., 2020).

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Since the international infection dynamic (14) is deterministic, the interaction between the two governments is an infinite-horizon, deterministic multi-stage game with observed actions (see Fudenberg and Tirole, 1991). In a single-agent framework, conditioning on the state of nature (here: the aggregate infection state) would therefore not be necessary, and every open-loop optimal path can be implemented by closed-loop strategies (i.e. strategies that depend on time t and the state) and vice versa. In a multi-agent framework, on the other hand, conditioning on the state of nature (i.e. considering Markov Nash equilibria) usually increases the set of equilibria. Here, for computational reasons we restrict attention to open-loop strategies, i.e. strategies that only depend on time t and not on the state. Hence, governments set their policy path initially once and for all.[6] To further simplify the computation, we assume that a vaccine or other cure is known to exist in a fixed, finite time T in the future. Hence, after date T there are no more infections and the economies operate without any SIR-dynamics.[7]

As discussed, households maximize their expected discounted utility, given government policy and the evolution of the disease. Let

$$u_t^k(h_t) = v(x_t^k(h_t)) - \frac{1}{2}\kappa \ell_t^k(h_t)^2 \tag{22}$$

denote the flow utility of households of health status h_t in country k at the household's optimum, and

$$V_t^k(h_t) = \mathbb{E}_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} u_\tau^k(h_\tau) \tag{23}$$

the corresponding value functions. By symmetry, we assume that the government of country k maximizes the utilitarian welfare function

$$V^k = S_1^k V_1^k(s) + I_1^k V_1^k(i) + R_1^k V_1^k(r) \tag{24}$$

Uncoordinated Policy: Without coordination, we assume that the two governments play a non-cooperative game, where each chooses open-loop policy paths as described, such as to

$$\max_{\{\mu_t^k, \nu_t^k\}_t} V^k$$

[6]Uniqueness of equilibrium is, of course, an issue. We have conducted extensive computational searches for other equilibria from different starting values, but always found the single Nash equilibrium reported in Section 4.1 below.

[7]In fact, for the parametrizations we have studied, the pandemic has run its course at T and both countries have reached herd immunity. So this restriction is not binding.

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taking the other government's policy path $\{\mu_t^{-k}, \nu_t^{-k}\}_t$ as given. A Nash equilibrium consists of two policy paths that are each optimal responses to each other.

Coordinated Policy: Alternatively, we consider the benchmark of a single social planner who makes the containment and tariff decisions for both countries in order to maximize the sum of the two countries' welfare:

$$\max_{\{\mu_t^k, \nu_t^k, \mu_t^{-k}, \nu_t^{-k}\}_t} V^A + V^B \tag{25}$$

2 Equilibrium Analysis

Given government policy μ_t^k, ν_t^k, and g_t^k in each country, firms maximize profits and households expected utility taking prices and the economic and epidemiological constraints as given.

2.1 Firm behavior

Because of the constant-returns-to-scale structure (1) firms make zero profits in equilibrium and hire as much labor as is supplied by households. Hence, in equilibrium, aggregate output in each country is

$$Y_t = z\left(S_t\ell_t(s) + \phi I_t\ell_t(i) + R_t\ell_t(r)\right) \tag{26}$$

wages are

$$w_t(h) = \begin{cases} \overline{w}_t & \text{for } h = s, r \\ \phi\overline{w}_t & \text{for } h = i \end{cases} \tag{27}$$

$$\overline{w}_t = p_t z \tag{28}$$

and firm profits are $v_t = 0$.

2.2 Household behavior

Households of each country at each date maximize expected utility U_t given by (3) subject to the budget constraint (11). Dropping the country superscript k, they choose their levels of domestic consumption $c_{k,t} = c_{k,t}(h)$, foreign consumption $c_{-k,t} = c_{-k,t}(h)$, and labor $\ell_t = \ell_t(h)$. They know their own health status h,[8] and the current state of the disease Θ_t, given by (19).

[8]Hence, we ignore the problem of asymptomatic or presymptomatic infections. See, for example, von Thadden (2020) for a detailed discussion.

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Using (23), in recursive terms, households thus choose current labor and consumption to maximize

$$v(x_t) - \frac{1}{2}\kappa \ell_t^2 + \beta \mathbb{E}_t V_{t+1}(h_{t+1}; \Theta_{t+1}) \tag{29}$$

where the expectation operator refers to the distribution of personal health h_{t+1} next period.

Susceptible Households. For a susceptible individual there are only two possible future health states - either she remains in s or she gets infected and transits to i. Given (14), there are four possibilities to get infected. First, she may get infected from local contacts while consuming (shopping, eating out, etc.). This probability is increasing with her own time spent on that activity and the total time infected domestic or foreign individuals do the same. This corresponds to the first part of the π_1-term and of the π_4-term in (14), respectively. Second, she may get infected at work with a similar logic, which corresponds to the π_2-term. Third, she may get infected in general encounters with infected people locally, not related to consumption or work, summarized by the π_3-term. Fourth, she may get infected during the consumption of goods and services abroad or coming from abroad, which is summarized by the second part of the π_1- and of the π_4-term. While the first three terms refer to infections from domestic households, the fourth explicitly highlights the consumption risk from imports and exports and the associated interaction with foreigners.

As shown in Section A.3 in the Appendix, when choosing $(c_k^k(s), c_{-k}^k(s), \ell^k(s)) \geq 0$, and thus the consumption basket $x^k(s)$ at time t, a susceptible will transit to the infectious state with a probability that is approximately equal to

$$\begin{aligned} & \tau(c_k^k(s), c_{-k}^k(s), \ell^k(s); c_k^k(i), c_{-k}^k(i), c_k^{-k}(i), c_{-k}^{-k}(i), \ell^k(i)) \\ = \;& \left[\pi_1 \left(c_k^k(s)c_k^k(i) + c_{-k}^k(s)c_{-k}^k(i)\right) + \pi_2 \ell^k(s)\ell^k(i) + \pi_3\right] I^k \\ + \;& \pi_4 \left[c_k^k(s)c_k^{-k}(i) + c_{-k}^k(s)c_{-k}^{-k}(i)\right] I^{-k} \end{aligned} \tag{30}$$

where $c_k^k(i), c_{-k}^k(i), c_k^{-k}(i), c_{-k}^{-k}(i), \ell^k(i)$ are the equilibrium decisions by domestic and foreign infected households. We assume that susceptible households take this probability into account when making their decision, and use the linear approximation (30) in the remainder of our analysis.

Bringing back the time index, at time t the s-household therefore has the following problem:

$$V_t^k(s) = \max_{c_{k,t}^k(s), c_{-k,t}^k(s), \ell_t^k(s)} v(x_t^k(s)) - \frac{1}{2}\kappa \left(\ell_t^k(s)\right)^2 + \beta \left[\tau_t^k(s) V_{t+1}^k(i) + (1 - \tau_t^k(s)) V_{t+1}^k(s)\right]$$

subject to

$$x_t^k(s) = q(c_{k,t}^k(s), c_{-k,t}^k(s)) \tag{31}$$

$$\widehat{p}_{k,t}^k c_{k,t}^k(s) + \widehat{p}_{-k,t}^k c_{-k,t}^k(s) = \overline{w}_t^k \ell_t^k(s) + g_t^k \tag{32}$$

where $\tau_t^k(s) = \tau(c_{k,t}^k(s), c_{-k,t}^k(s), \ell_t^k(s))$. Here, (31) describes the household's consumption basket according to (2) and (32) is its budget constraint.

If λ_t^{ks} is the Lagrange multiplier of the budget contraint (32), the first-order conditions for the consumption of the domestic good, the consumption of the imported good, and labor are

$$\begin{aligned} x_t^k(s)^{-\rho}\frac{\partial x_t^k(s)}{\partial c_{k,t}^k(s)} + \beta\left(\pi_1 c_{k,t}^k(i)I_t^k + \pi_4 c_{k,t}^{-k}(i)I_t^{-k}\right)\left(V_{t+1}^k(i) - V_{t+1}^k(s)\right) &= \lambda_t^{ks}\widehat{p}_{k,t}^k \\ x_t^k(s)^{-\rho}\frac{\partial x_t^k(s)}{\partial c_{-k,t}^k(s)} + \beta\left(\pi_1 c_{-k,t}^k(i)I_t^k + \pi_4 c_{-k,t}^{-k}(i)I_t^{-k}\right)\left(V_{t+1}^k(i) - V_{t+1}^k(s)\right) &= \lambda_t^{ks}\widehat{p}_{-k,t}^k \\ \kappa\ell_t^k(s) - \beta\pi_2\ell_t^k(i)I_t^k\left(V_{t+1}^k(i) - V_{t+1}^k(s)\right) &= \lambda_t^{ks}\overline{w}_t^k \end{aligned}$$

where the second terms in each equation reflect the fact that consuming foreign goods and services increases the chances of getting infected through contacts with foreigners. Eliminating λ_t^{ks} and simplifying yields the following two first-order conditions for the optimal choices of susceptible individuals:

$$\begin{aligned} & \overline{w}_t^k\left[\alpha x_t^k(s)^{\frac{1}{\sigma}-\rho}c_{k,t}^k(s)^{-\frac{1}{\sigma}} + \beta\left(\pi_1 c_{k,t}^k(i)I_t^k + \pi_4 c_{k,t}^{-k}(i)I_t^{-k}\right)\left(V_{t+1}^k(i) - V_{t+1}^k(s)\right)\right] \\ = & \left[\kappa\ell_t^k(s) - \beta\pi_2\ell_t^k(i)I_t^k\left(V_{t+1}^k(i) - V_{t+1}^k(s)\right)\right]\widehat{p}_{k,t}^k \qquad (33) \\ & \overline{w}_t^k\left[(1-\alpha)x_t^k(s)^{\frac{1}{\sigma}-\rho}c_{-k,t}^k(s)^{-\frac{1}{\sigma}} + \beta\left(\pi_1 c_{-k,t}^k(i)I_t^k + \pi_4 c_{-k,t}^{-k}(i)I_t^{-k}\right)\left(V_{t+1}^k(i) - V_{t+1}^k(s)\right)\right] \\ = & \left[\kappa\ell_t^k(s) - \beta\pi_2\ell_t^k(i)I_t^k\left(V_{t+1}^k(i) - V_{t+1}^k(s)\right)\right]\widehat{p}_{-k,t}^k \qquad (34) \end{aligned}$$

Together with the aggregation condition (31) and the budget constraint (32), (33)–(34) determine the behavior of s-individuals as a function of current prices, the state of the pandemic, the current choices of infected agents and the policy parameters g_t^k and μ^k, ν^k (which are inherent in the consumer prices $\widehat{p}_{k,t}^k, \widehat{p}_{-k,t}^k$).

Infected Households. The behavior of infected households is simpler. Their behavior has no consequences for their future health, which is exogenously given by either recovery, with probability p_r, or death, with probability p_d.

A type i household at time t therefore chooses $(c_{k,t}^k(i), c_{-k,t}^k(i), \ell_t^k(i)) \geq 0$ such as to optimize

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the static decision problem

$$\begin{aligned} V_t^k(i) &= \max v(x_t^k(i)) - \frac{1}{2}\kappa\left(\ell_t^k(i)\right)^2 + \beta\left[(1-p_r-p_d)V_{t+1}^k(i) + p_r V_{t+1}^k(r) + p_d V_{t+1}^k(d)\right] \\ \text{subject} & \quad \text{to} \\ & x_t^k(i) = q(c_{k,t}^k(i), c_{-k,t}^k(i)) \quad (35) \\ & \widehat{p}_{k,t}^k c_{k,t}^k(i) + \widehat{p}_{-k,t}^k c_{-k,t}^k(i) = \phi \overline{w}_t^k \ell_t^k(i) + g_t^k \quad (36) \end{aligned}$$

Letting λ_t^{ki} denote the multiplier of the budget constraint, the problem yields the first-order conditions

$$\begin{aligned} x_t^k(i)^{-\rho}\frac{\partial x_t^k(i)}{\partial c_{k,t}^k(i)} &= \lambda_t^{ki}\widehat{p}_{k,t}^k \\ x_t^k(i)^{-\rho}\frac{\partial x_t^k(i)}{\partial c_{-k,t}^k(i)} &= \lambda_t^{ki}\widehat{p}_{-k,t}^k \\ \kappa\ell_t^k(i) &= \lambda_t^{ki}\phi\overline{w}_t^k \end{aligned}$$

These conditions can be further simplified and even solved explicitly for $\rho = 1$, which we do in Appendix Section A.2. Together with the aggregation condition (35) and the budget constraint (36), they determine the behavior of i-individuals as a function of current prices and the policy parameters g_t^k and μ^k, ν^k.

Recovered Households. Similarly, when recovered, a type r household at time t chooses $(c_{k,t}^k(r), c_{-k,t}^k(r), \ell_t^k(r))$ 0 such as to optimize the static decision problem

$$\begin{aligned} V_t^k(r) = & \quad \max v(x_t^k(r)) - \frac{1}{2}\kappa\left(\ell_t^k(r)\right)^2 + \beta V_{t+1}^k(r) \\ \text{subject} & \quad \text{to} \\ & x_t^k(r) = q(c_{k,t}^k(r), c_{-k,t}^k(r)) \quad (37) \\ & \widehat{p}_{k,t}^k c_{k,t}^k(r) + \widehat{p}_{-k,t}^k c_{-k,t}^k(r) = \overline{w}_t^k \ell_t^k(r) + g_t^k(r) \quad (38) \end{aligned}$$

Letting λ_t^{kr} denote the multiplier of the budget constraint, the first-order conditions are

$$\begin{aligned} x_t^k(r)^{-\rho}\frac{\partial x_t^k(r)}{\partial c_{k,t}^k(r)} &= \lambda_t^{kr}\widehat{p}_{k,t}^k \\ x_t^k(r)^{-\rho}\frac{\partial x_t^k(r)}{\partial c_{-k,t}^k(r)} &= \lambda_t^{kr}\widehat{p}_{-k,t}^k \\ \kappa\ell_t^k(r) &= \lambda_t^{kr}\overline{w}_t^k \end{aligned}$$

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As before, these conditions can be further simplified and even solved explicitly for $\rho = 1$, which we do in Appendix Section A.2. Together with the aggregation condition (37) and the budget constraint (38), they determine the behavior of r-individuals as a function of current prices and the policy parameters.

2.3 The macroeconomic synthesis

Each period, the following endogenous economic variables are determined in equilibrium:

- Households: 18 variables $c^k_{k,t}(h), c^k_{-k,t}(h), \ell^k_t(h)$, for $h = s, i, r$ and $k = A, B$
- Markets: 4 variables $p_{k,t}$, $\overline{w}^k_t$ for $k = A, B$, where prices, consumer prices, and government policy are linked by (8)–(9).
- Government expenditures: 2 variables g^k_t, $k = A, B$. In the absence of health dependent transfers $g_t(h)$, fiscal policy therefore is reduced to the balanced-budget rule (12).

As argued above, given the linear production technologies, the firm variables are trivial and follow automatically from the household decisions.

The governments or the common social planner set the epidemiological policy consisting of the 4 variables μ^k_t, ν^k_t, $k = A, B$, which are exogenous from the point of view of market participants. These variables are implicit in the consumer prices $\widehat{p}^k_{k,t}, \widehat{p}^k_{-k,t}$.

Counting equations, we have

- Labor markets: 2 equations in (28)
- Households: in each country 9 equations
  - for s: (32)–(34),
  - for i: (50), (51), and (47), with $w = \phi\overline{w}^k_t$, appropriately indexed.
  - for r: (50), (51), and (47), with $w = \overline{w}^k_t$, appropriately indexed.
- Goods markets: 2 equations

$$Y^k_t = H^k_t + M^{-k}_t \tag{39}$$

  for $k = A, B$, where output Y^k_t is given by (26), domestic consumption H^k_t by (6) and imports M^{-k}_t by (7).

There are 6 value functions to be solved, $V_t^k(s), V_t^k(i), V_t^k(r)$, for $k = A, B$. As usual, we normalize the value function $V_t^k(d) = 0$, assuming that the cost of death is the lost utility of life.

To help interpret the results, we define the terms of trade as the relative price of the output of country A to that of country B, before taxes and tariffs:

$$e = \frac{p^A}{p^B} \tag{40}$$

Finally, we define the aggregate consumption in each country as the population weighted sum of the consumption baskets of all health groups

$$X_t^k = S_t^k x^k(s) + I_t^k x^k(i) + R_t^k x^k(r) \tag{41}$$

3 Parameterization

Our parameterization builds on Eichenbaum, Rebelo and Trabandt (2020). Each period in the model is a week. To save on computational costs in our very complex environment, we assume log utility from consumption in the baseline model, i.e., we set $\rho = 1$, because this yields simple closed-form solutions to some expressions (see Appendix Section A.2).[9] We set $\beta = .96^{(1/52)}$ such that the value of life in autarky is approximately \$10 million.[10] Furthermore, we let $\phi = .8$, such that the productivity loss for infected individuals is 20%, and we set productivity $z = 39.835$ and $\kappa = 0.001275$ so that in the pre-pandemic steady state each person works 28 hours per week and earns $58,000$ per year, consistent with average data from the U.S. Bureau of Economic Analysis and the Bureau of Labor Statistics in 2018. Initial populations are normalized to 1. In the pre-pandemic steady state the countries are symmetric.

We follow Costinot and Rodríguez-Clare (2014) and set $\sigma = 6$. The home bias parameter α is chosen such that the pre-pandemic steady-state domestic consumption share is 66%.

To fix ideas we assume that the infection originates in country A with an initial infected population of 0.001 (0.1%). It then spreads to country B via international trade, at a speed that is endogenous to each country's policy. To parameterize our disease transmission we choose π_1, π_2, and π_3 such that in a closed economy 1/6 of transmission would occur through consumption, 1/6 of transmission through production, and the remaining 2/3 of transmission through other activities. We then choose π_4 such that without government intervention the peak of the infection in country

[9] Noting that ρ is also the inverse of the marginal rate of intertemporal substitution, Kaplan, Moll and Violante (2020) argue that also empirically $\rho = 1$ is a reasonable assumption.
[10] See, e.g., Hall, Jones and Klenow (2020) for a discussion.

B occurs approximately 6 months after the peak of the infection in country A where the disease originates. Moreover, we calibrate the transition probability p_r and p_d so that the mortality rate is 0.5% for the infected and it takes on average 18 days to either recover or die from infection.[11]

For our benchmark results we focus on a case where the pandemic ends definitively in 3 years from its beginning. While stylized, this case illustrates many of the key tradeoffs we are interested in this paper. Since estimates of the likely arrival time of the vaccine and the time to its global delivery, both measured from onset of the pandemic, were in the range of 18 months to 48 months, we take the “end” of the pandemic in our computation to be 3 years as a reasonable mid-point. If in our simulations we take 2 years instead of 3, the results are qualitatively unchanged.

We provide further details about the computation algorithm in Appendix Section A.4.

4 Results

4.1 Health and Economic Outcomes with No Government Policy

As a benchmark, Figure 2 illustrates the SIR dynamics and economic outcomes when there are no containment policies or tariffs. Starting with an initial infection rate of $I_0 = 0.001$ in country A, the pandemic quickly takes off in country A and slowly spreads to country B, where it begins to take off after around week 25. The share of infected households in country A peaks at 5.2% in week 34 and declines thereafter. Around week 50, infections in country B overtake those in A and peak at 5.2% in week 60. After week 91 the disease has run its course in country A, and after week 115 in country B, when both countries have reached herd immunity. Eventually, 53% of the population in both countries becomes infected, and a mortality rate of 0.5% implies that around 0.27% of the population in both countries dies.

The economic outcomes track local infection rates closely. When the first wave of infection hits country A, its consumption and labor decline quickly by almost 10 percent, while the values for country B.stay constant or even increase slightly. Similarly for country B, when the pandemic hits there. The decline in consumption is greater in magnitude than the additional leisure from lower labor, which leads to declines in the country-level utility during the peak of domestic infection. Here, aggregate utility of country k is the weighted sum of the flow utilities (22). Interestingly, during both peaks, i.e. when the domestic infection rates are either much higher or much lower than the foreign ones, domestic households increase foreign consumption. This is to reduce the

[11] Our calibration of the case fatality rate is at the lower end of the early estimates that we are aware of (see, for example, Fernandez-Villaverde and Jones (2020) or Verity et al. (2020)). These early estimates reflect high uncertainty, but also lack of experience with the treatment of severe cases.

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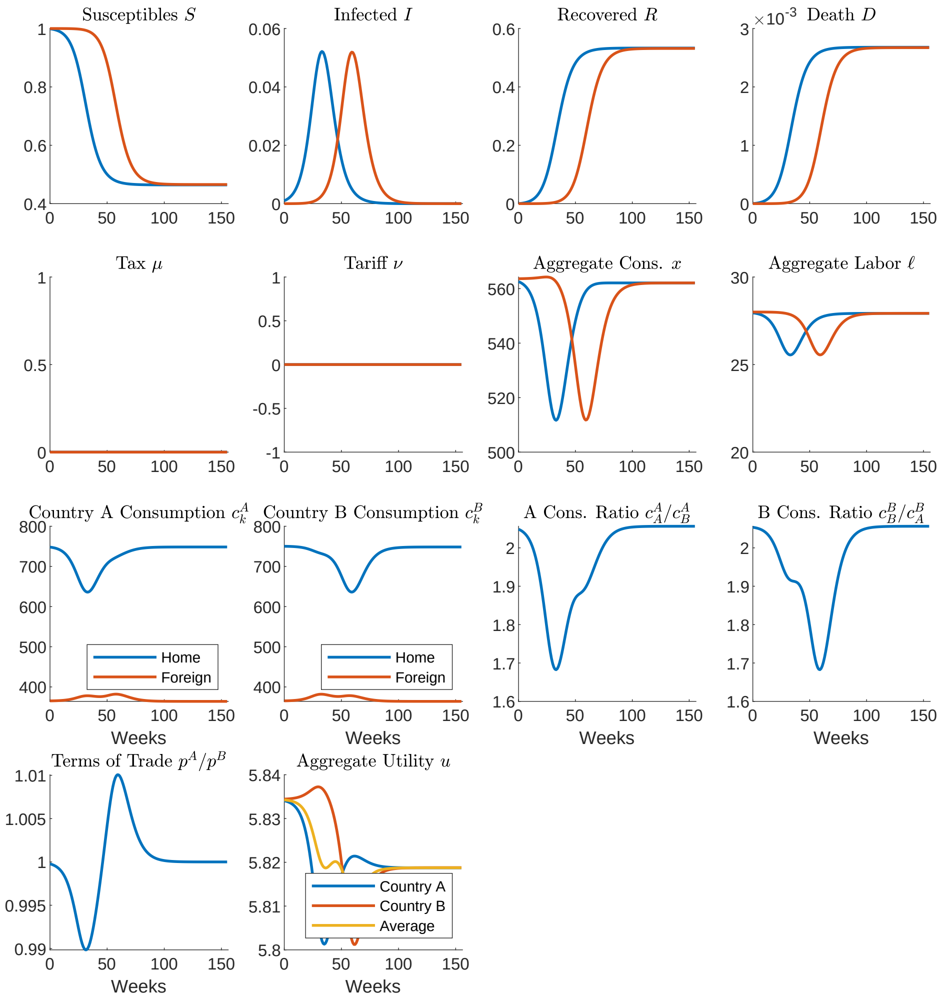
Figure 2: Benchmark SIR Dynamics



Note: Benchmark model with international transmission of pandemic. No government domestic containment policies or tariffs.

exposure to domestic infection or to profit form foreigners not wanting to consume their home production. These shifts in consumption shares only have a small impact on the terms of trade expressed by the relative prices of both goods (which change by at most 1 percent).

4.2 Government Policy by a Coordinated Planner, the case $\delta_\mu = 1$

Next, we consider the optimal policy by a coordinated planner who maximizes the sum of the welfare of both countries' households where the welfare of each country is calculated as the weighted average of utilities of its health groups. At time 0, this planner determines both countries' domestic containment policies and tariffs from week 1 to 156 until the vaccine arrives.

Figure 3 reports the equilibrium outcomes for the case of $\delta_\mu^k = 1$, i.e. the case in which containment policies are not very costly economically as they raise tax revenue. As in Figure 2, the pandemic quickly takes off in country A and slowly spreads to country B, where it begins to take off after around week 25. The share of infected households in country A peaks at 3.2% in week 35, almost the same time as in the unfettered outbreak, and declines thereafter. This peak is about 1/3 lower than in the case of an unfettered outbreak, shown in the benchmark in Figure 2. After around week 50, infections in country B overtake those in A and peak at 3.2% in week 63. Hence, the coordinated planner slows the spread of the disease from A to B, but not significantly. After week 122 the disease has run its course in country A, and after week 149 in country B. Eventually, 43% of the population in both countries become infected, which is significantly lower than that in the laissez-faire case in Figure 2 and leads to a lower death rate.

The economic outcomes react both to the infection rates and the domestic containment and tariff policies. When the first wave of infection hits country A, its consumption and labor decline much more than under laisser-faire. Differently from the laisser-faire case, also the consumption basket in country B decreases, while labor and production in B stay moreless constant. Only when the second wave of infection hits country B, its consumption and labor decline significantly. The decline in both consumption and labor is much more drastic than the laissez-faire case in Figure 2, which reflects the planner's tradeoff between economic welfare and health outcomes. The early reduction of aggregate consumption X_t in country B when the pandemic begins in country A is a remarkable sign of foresight intended to limit infections from imports.

The coordinated planner achieves these health and economic outcomes with a combination of domestic containment measures and tariffs. The severity of containment measures in each country roughly tracks the level of infection rates in the country, and its peaks at a tax rate of 67%. On the other hand, tariffs have a different pattern across time that is symmetric between the two countries. When the infection peaks in country A around week 34, the coordinated planner responds by

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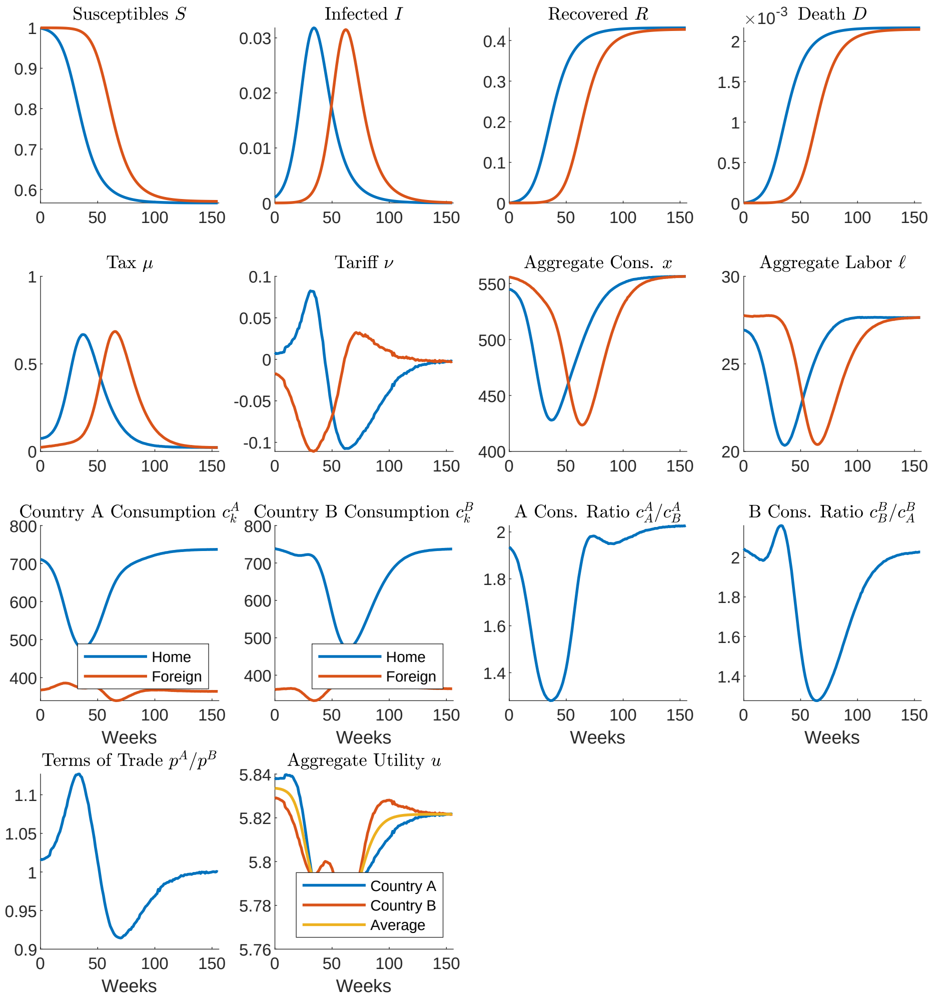
Figure 3: Coordinated Planning Equilibrium Outcomes, $\delta_\mu = 1$



Note: Benchmark model with international transmission of pandemic. Equilibrium domestic containment policies and tariffs are determined by a global social planner that maximizes the sum of both countries' welfare.

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raising a positive tariff of 8% in country A, while imposing a negative tariff of -11% in country B.

These tariffs are intriguing at a first pass because they encourage both countries to consume more of country A's goods, which transmits the pandemic via consumption- and labor-induced interactions in country A and via imports to country B. However, these health costs are dominated by the economic benefits — as the tariffs raise the terms of trade for country A during the peak of the infection, its households have higher income and enjoy a higher level of consumption. The tariffs act as an international transfer mechanism to smooth out the economic outcomes during the pandemic. Similarly, when the second wave of infection hits country B, the coordinated planner reverses the tariffs in both countries, leading to a more favorable terms of trade for country B and raising its households' consumption. Note that the terms of trade rise by more than 13 percent for country A during the peak of its pandemic, i.e. more than ten times the change under laisser-faire. This drastic swing of the terms of trade brought about by boosting tariffs allows risk-sharing between the two countries due to the asynchronous feature of the pandemic.

4.3 Government Policy in Nash Equilibrium, the case $\delta_\mu = 1$

We next consider the case where each country's government determines its own domestic containment and tariff policies in order to maximize the welfare of their domestic households, defined as the weighted average of their lifetime utilities. More precisely, at time 0, the governments determine the domestic containment policy and tariff from week 1 to 156 until the vaccine arrives, in a non-cooperative game where the equilibrium policies are best responses to each other.

Figure 4 reports the outcomes of the Nash equilibrium for the case of $\delta_\mu^k = 1$, i.e. the case in which containment policies raise tax revenue. The share of infected households in country A peaks at around 3.5% in week 33, whereas the share of infected households in country B peaks at 3.5% in week 62. Hence, infections peak more strongly and earlier under Nash than under coordinated planning. The disease is over after week 118 in country A, and after week 151 in country B.

The governments fight the disease by raising the containment tax on consumption, and its levels again track the levels of infection closely. The tax level peaks around 74% during the peak of infection in each country. In this aspect, the coordinated planner and the Nash governments engage in similar domestic containment measures, but the Nash players choose significantly stricter measures than the planner.

In contrast, the governments' tariff policies are very different between the uncoordinated and the coordinated cases. In the Nash game, both governments impose tariffs of up to 30%, as is typical in models of trade wars. In fact, in the current calibration, tariffs of around 23 percent

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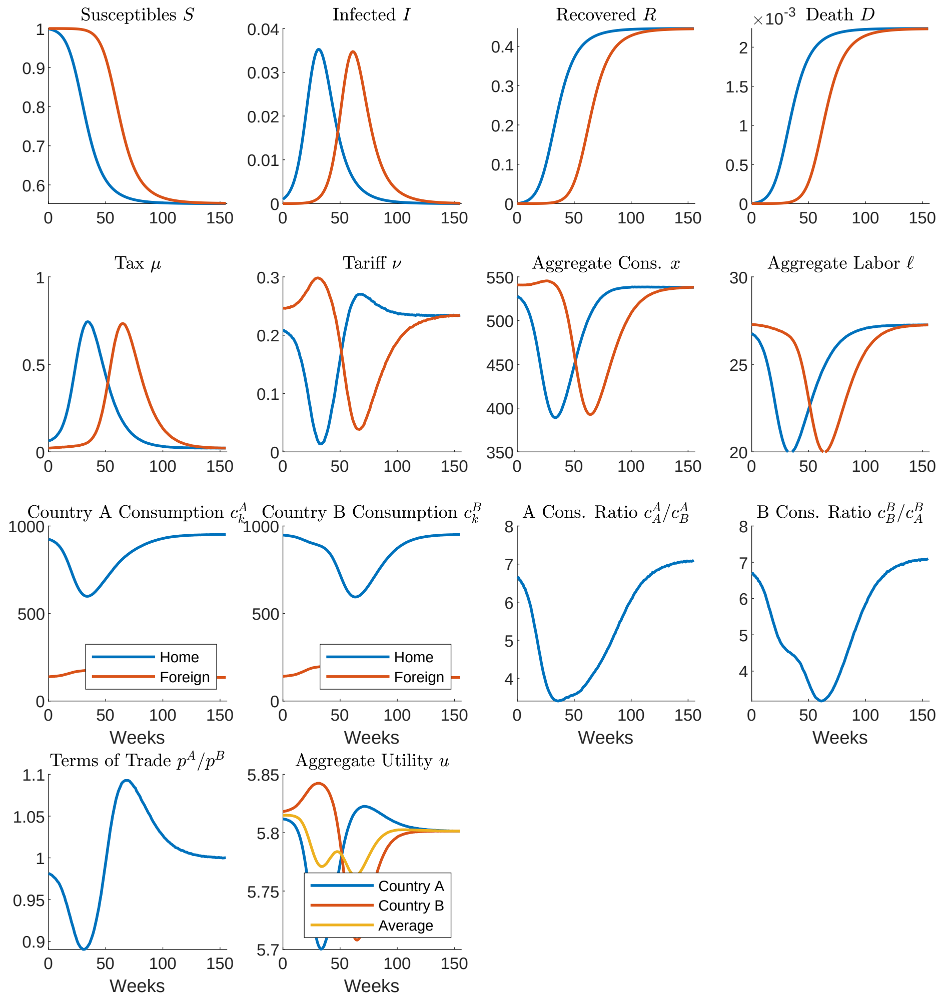
Figure 4: Nash Equilibrium Outcomes, $\delta_\mu = 1$



Note: Benchmark model with international transmission of pandemic. Equilibrium domestic containment policies and tariffs are the outcome of a Nash game between the two countries.

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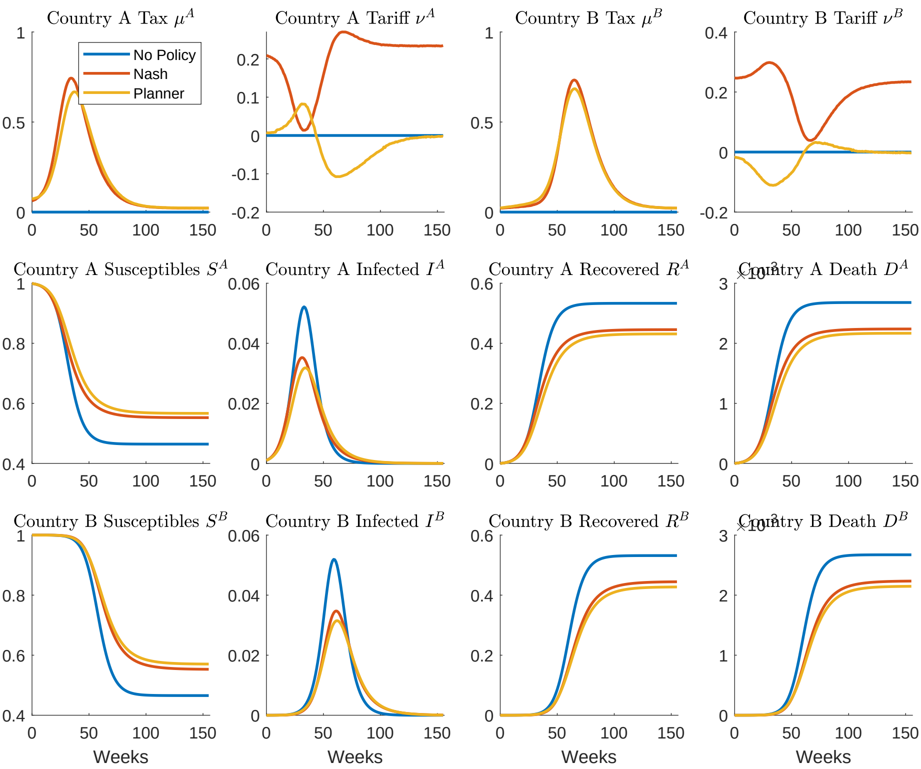
would be set in the equilibrium of a stationary trade game without a pandemic. As in standard trade wars, both governments attempt to manipulate the terms of trade and tilt the consumption share towards domestic goods - actions that offset each other. But in the case of the pandemic, as country A approaches the peak of infection, the government in country A lowers its import tariff to 2%, in order to encourage its domestic households to consume more foreign goods that expose them less to infection. Compared to the social planner, who raises tariffs up to 8 percent, government A does too much too late. On the other hand, the government in country B raises its import tariff to 30% during A's peak infection, in order to minimize the international transmission of the pandemic through the imports from country A. When the disease hits country B, the same happens with reversed roles, but, interestingly with an additional delay. 7 weeks after country B hits the peak of infection, in week 68, tariffs in country A reach their maximum, but at a level below the maximum of country B previously, because the marginal benefit is smaller since a large share of the population in country A has already gone through an infection and recovered.

4.4 Comparing the Policies, the case $\delta_\mu = 1$

Figure 5 compares the equilibrium government policies and pandemic dynamics in the three cases discussed above, for the case of $\delta_\mu^k = 1$. Both the Nash case and the Planner case feature similar paths of domestic containment policies, with higher peaks in the Nash case. In contrast, the Nash case has large swings in tariffs that drop with domestic infections and rise with foreign infections, just the opposite of what the planner would impose optimally. As discussed above, the Nash tariffs try to adjust the trade war logic that inefficiently attempts to benefit the domestic households at the expense of the foreign households, whereas the coordinated planner's tariffs act as international risk-sharing mechanisms.

In both cases, coordinated planning and Nash behavior, the combination of private demand reactions to the pandemic and government containment policies and tariffs induces severe economic recessions in both countries. In both cases, aggregate labor and production decline by more than 26 percent until the peak of the pandemic in each country. But in addition, in the Nash case, as the domestic government lowers tariffs during the peak of domestic infection while the foreign government raises tariffs, the demand for the domestic goods in the infected country collapses and magnifies the variation in the terms of trade that is induced by the precautionary motive of households discussed in Section 4.1. As Figure 6 shows, this leads to a highly unbalanced consumption basket in terms of domestic goods and imports, such that the domestic consumption basket X_t at the peak of the infection under Nash decreases more than under coordinated planning, and the weekly flow utility, which measures the consumption-leisure tradeoff, drops much more than in

Figure 5: Equilibrium Policy and SIR Dynamics, $\delta_\mu = 1$



Note: Comparison of domestic containment policies and SIR dynamics in three cases: benchmark, Nash, and Planner. In the no policy case there are no domestic containment policies. In the Nash case, equilibrium domestic containment policies and tariffs are the outcome of a Nash game between the two countries. In the planner case, equilibrium domestic containment policies and tariffs are determined by a global social planner that maximizes the sum of both countries welfare.

the coordinated solution.

Interestingly, the Nash players do not do much worse than the Planner compared to the benchmark in terms of health outcomes when $\delta_\mu^k = 1$ (the coordinated planner reduces the ultimate death toll by 18.8%, while the Nash governments reduce it by 15.8% compared to laisser-faire). The reason is that domestic containment is less costly in economic terms and can thus be used to make up for the deficiencies in tariff policies, so that the Nash competitors "get it approximately right for the wrong reasons", as their aggressive trade policies limit the international spread of the infection. As discussed above, the real difference is the unbalanced shift in imports and thus the consumption baskets, which reduces economic welfare. The coordinated planner achieves a slightly better health outcome by using the policy instruments very differently, but much of her efficiency gain is reflected in the better economic outcomes.

These results highlight the contrast between health and economic externalities. Health externalities arise from the possibility that a country does too little to shut down its production and consumption activities, thus spreading the pandemic. Economic externalities arise from the possibility that a country will reduce its consumption of foreign goods in order to promote the interests of its own workers and firms. The coordinated planner fully internalizes this economic externality and uses tariffs to control the pandemic and smooth out its impact on both countries' economies. In this way, international trade can lead to better risk-sharing and facilitates global health diversification. Importantly, the two externalities interact. When the disease hits one country the demand for its good collapses for health reasons, leading to a collapse of its price. This, however, triggers a demand effect in the less affected country, where the risk of infection is overall lower, and thus provides a countervailing stimulus that is absent in the affected country. The government in that country reacts by increasing tariffs to contain that stimulus and at the same time benefit from domestic financial gain of tariffs. This leads to the apparently paradoxical situation, exhibited in the second row of Figure 6, that in Nash equilibrium imports in one country can peak when tariffs are highest.

The above comparison is made explicit in the decomposition of the overall policy effect in Table 1, which considers the case of revenue-generating containment measures $\delta_\mu^k = 1$. Table (a) reports the welfare of the full benchmark case with pandemic and government policy. We decompose the households' utility loss in each country relative to the pre-pandemic level into two components: the welfare loss due to economic recession, and the welfare loss due to death. The former is the present value of the utility change in the consumption and labor of living households, from period 1 to the infinite future; the latter is the present value of the foregone utility due to death. Their sum is the total utility loss relative to the alternative world with no pandemic and no

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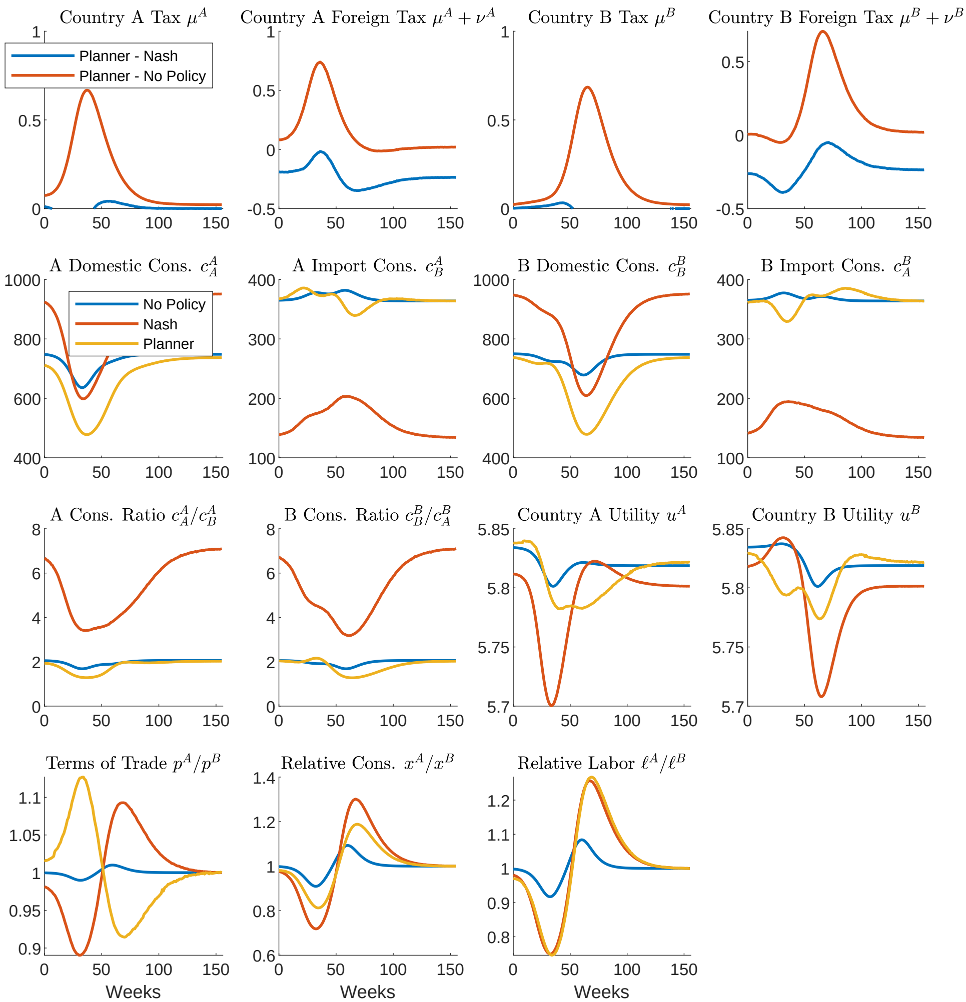
Figure 6: Equilibrium Policy and Economic Outcomes, $\delta_\mu = 1$



Note: Comparison of equilibrium outcomes and SIR dynamics for three cases: benchmark, Nash, and Planner. In the no policy case there are no domestic containment policies. In the Nash case, equilibrium domestic containment policies and tariffs are the outcome of a Nash game between the two countries. In the planner case, equilibrium domestic containment policies and tariffs are determined by a global social planner that maximizes the sum of both countries welfare.

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government tax and tariff.

Trivially, the coordinated outcome is better than that of no policy. More precisely, the planner lowers the utility loss due to death by partially shutting down the economy and causing a welfare loss due to economic recession relative to the no policy regime. In both countries, the economic loss is greater than under laisser faire, the loss of lives is smaller, and the sum of both losses is smaller. Clearly, the social planner implements a different consumption-work-health tradeoff than that resulting from laisser-faire, with more emphasis on health.

In contrast, the Nash equilibrium outcome is worse than laisser-faire, due to the damaging effect of high tariffs. To put this in perspective, Table 1(b) reports the welfare calculation in a world with no pandemic, where the welfare loss from tariffs is 25.23 units. In the world with the pandemic, the welfare loss due to economic recession is even greater due to the governments' containment policies and households' precaution. As noted earlier, the welfare loss due to death in Nash equilibrium is also greater than that in the coordinated case: Since the households have lower life-time utility due to high tariffs, a domestic government that weighs current losses against future gains also has less incentive to save lives. As we discuss below, this tradeoff depends on the

Table 1: Welfare Decomposition

Panel (a): With Pandemic and Domestic Containment Policy/Tariff						
	Country A			Country B		
	Total	Economy	Death	Total	Economy	Death
No Policy	-19.85	-0.48	-19.37	-19.41	-0.47	-18.93
Nash	-43.29	-27.18	-16.11	-42.74	-27.03	-15.71
Planner	-17.96	-2.34	-15.62	-17.50	-2.36	-15.14
Planner - Nash	25.33	24.83	0.50	25.24	24.67	0.57
Panel (b): With No Pandemic						
	Country A			Country B		
	Total	Economy	Death	Total	Economy	Death
No Policy	0.00	0.00	0.00	0.00	0.00	0.00
Nash	-25.18	-25.18	0.00	-25.18	-25.18	0.00
Planner	0.00	0.00	0.00	0.00	0.00	0.00
Planner - Nash	25.18	25.18	0.00	25.18	25.18	0.00

Note: We report the welfare loss relative to the steady−state level without pandemic and policy. We decompose the welfare loss in each country into two components. The *economy* loss is the present value of the utility loss of living households due to changes in consumption and labor during the pandemic episode, and the *death* loss is the present value of the foregone utility due to death.

relative economic costs and benefits of tariffs and is not present in a world with no tariffs ($\nu \equiv 0$).

4.5 Domestic Containment Policies with no Monetary Benefit: The Case $\delta_\mu^k = 0$

In this section we consider the case, in which domestic containment measures do not generate revenue, $\delta_\mu^k = 0$. The government budget (10) therefore only consists of tariff receipts, and domestic containment measures μ^k are pure frictions reducing economic activity, such as stay-at-home orders, social distancing rules, special hygiene prescriptions, etc. that discourage consumption but do not generate revenue.

Figures 7 and 8 report the coordinated and the Nash equilibrium outcomes. They differ from the case $\delta_\mu^k = 1$ in one striking dimension. Because domestic containment measures now are highly inefficient in economic terms, both governments do not use them under either scenario. This is remarkable as these measures would be saving lives. But the economic cost of using them is too high. As a consequence, infections peak much higher, and the ultimate death toll in the coordinated outcome is 2.7 deaths per 1000, 24% higher than in the case where domestic containment measures generate revenenues for the government. This outcome is a result of our simplifying assumption in (18) that death rates are independent of the health situation. If instead we assume that the probability of dying from an infection, p_d, increases in the number of infected I_t, i.e. if there are health congestions, then this picture changes, and domestic containment measures become more important.

A notable consequence of this reduced relative value of domestic containment measures is that in the case $\delta_\mu^k = 0$ the Nash outcome is clearly inferior to the coordinated one in terms of health. In fact, Figure 7 shows that the Nash outcome now has more than 6 percent more deaths than under coordinated planning. Hence, the superiority of coordination over non-coordination in both, the economic and the health, dimensions is more pronounced in the case $\delta_\mu^k = 0$ than if $\delta_\mu^k = 1$.

Furthermore, tariff policies in both cases are very similar to those in our benchmark specification in Figure 5: tariffs in the coordinated case facilitate international resource transfer by managing the terms of trade, while tariffs in the uncoordinated case are high on average, exhibiting exactly the same destructive dynamics as in the case $\delta_\mu^k = 1$ discussed above.

This setting also exhibits another feature of the interaction between health and economic externalities made above more clearly. In the uncoordinated case, governments attempt to improve their domestic welfares at the expense of the foreign welfares by raising import tariffs and enhancing their terms of trade. As shown in Figure 8, these tariffs lead to high consumption shares of domestic goods: While the consumption home bias c_A^A/c_B^A under coordination is approximately 2:1,

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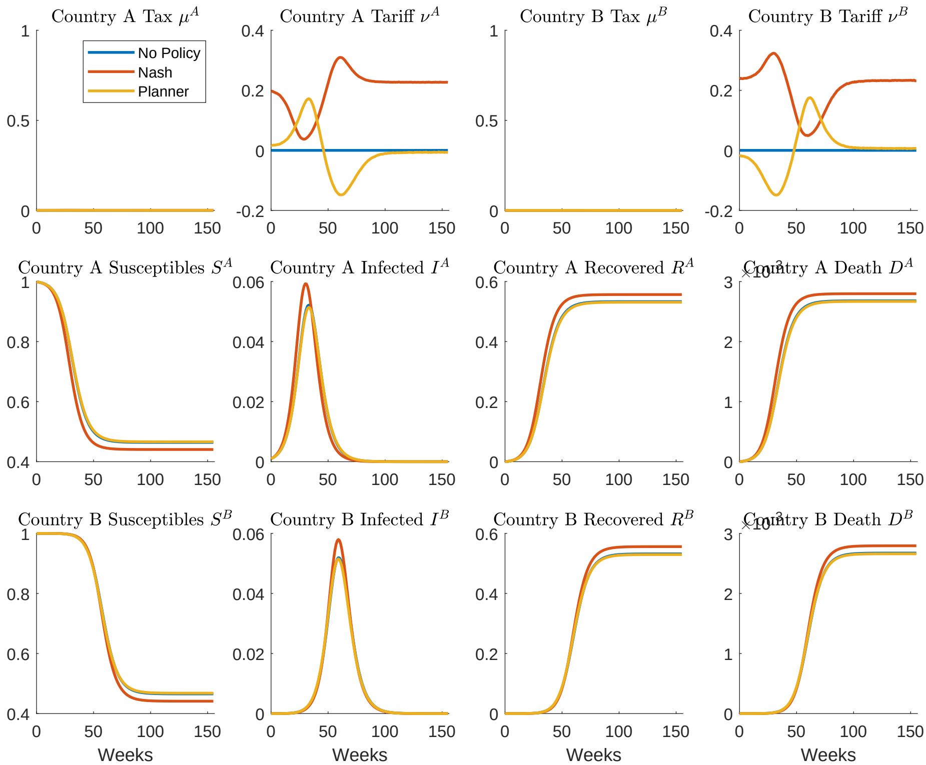
Figure 7: Equilibrium Policy and SIR Dynamics, $\delta_\mu = 0$



Note: Equilibrium outcomes in a model in which containment policy collects no revenue for the government.

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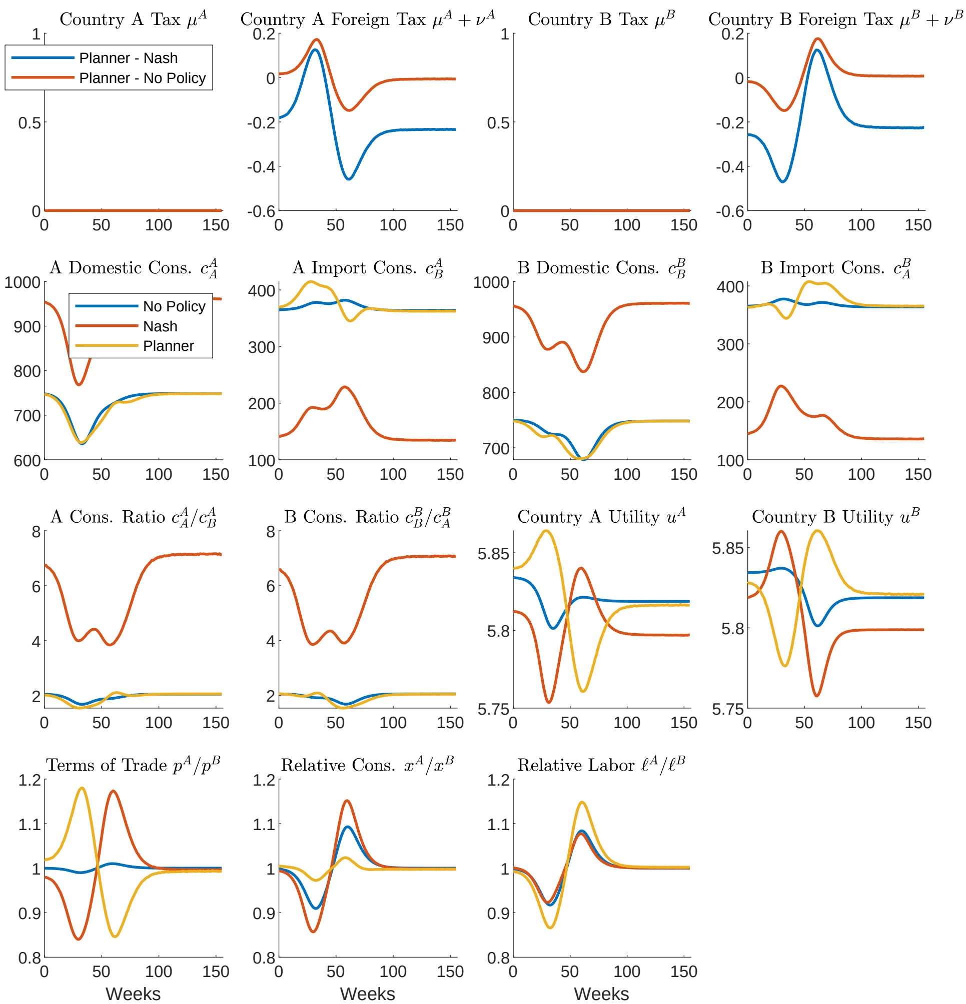
Figure 8: Equilibrium Policy and Economic Outcomes, $\delta_\mu = 0$



Note: Equilibrium outcomes in a model in which containment policy collects no revenue for the government.

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it is fluctuating between 7:1 and 4:1 in Nash equilibrium, where the third row of Figure 8 shows a double dip reflecting the attempts of domestic governments to react to the infection peaks in each country, as discussed above.

In fact, the high consumption home bias aggravates the health outcomes. When the infection rate peaks in country A around week 30, even though country A lowers the tariff to encourage its domestic households to consume foreign goods, the consumption home bias is still 4:1. Domestic households are thus stuck at consuming the domestic goods, which fasten the spread of the pandemic. As a result, the uncoordinated case has a higher cumulative infection rate and a higher death rate compared with the coordinated case. Again, the lack of international trade coordination leads to worse infection dynamics during a global pandemic.

4.6 Containment Without Tariffs: The Case $\nu \equiv 0$

An interest variant of our model obtains if we rule out tariffs, i.e. set $\nu \equiv 0$. This case certainly is realistic, as tariffs and other trade barriers are internationally regulated by trade agreements and cannot be changed flexibly in crises. Furthermore, in many parts of the world, most notably the European Union, tariffs have been abolished altogether.

We report the health and economic dynamics in this case for $\delta_\mu^k = 1$ in Figures 9 and 10, and again compare laisser-faire, Nash equilibrium, and coordination. In this case, and different from the case $\nu > 0$, the domestic containment policies adopted by the coordinated planner and the Nash governments are qualitatively very similar, and so are the outcomes. In particular, governments in Nash equilibrium now cannot use tariffs to counteract the risk-shifting policies that are optimal under coordination. Therefore, key variables such as terms of trade or imports now move very much alike under coordination and non-coordination. Thus, in terms of the observed dynamics, “Nash equilibrium broadly gets it right". However, this obervation masks important differences between the coordinated and the uncoordinated outcome. Most importantly, on the health front, total deaths are lower in Nash equilibrium than under optimal policy coordination. Table 2(a) reports the welfare comparison in this case and disaggregates it into its economic and health component as described above. The coordination failure in Nash equilibrium now lets each government adopt too stringent domestic containment measures, and since there are no international transfers via tariffs possible to offset this (partially and inefficiently), Nash is inefficiently aggressive on the health front and does not use the international risk-sharing through trade as well as a social planner would do during a pandemic.

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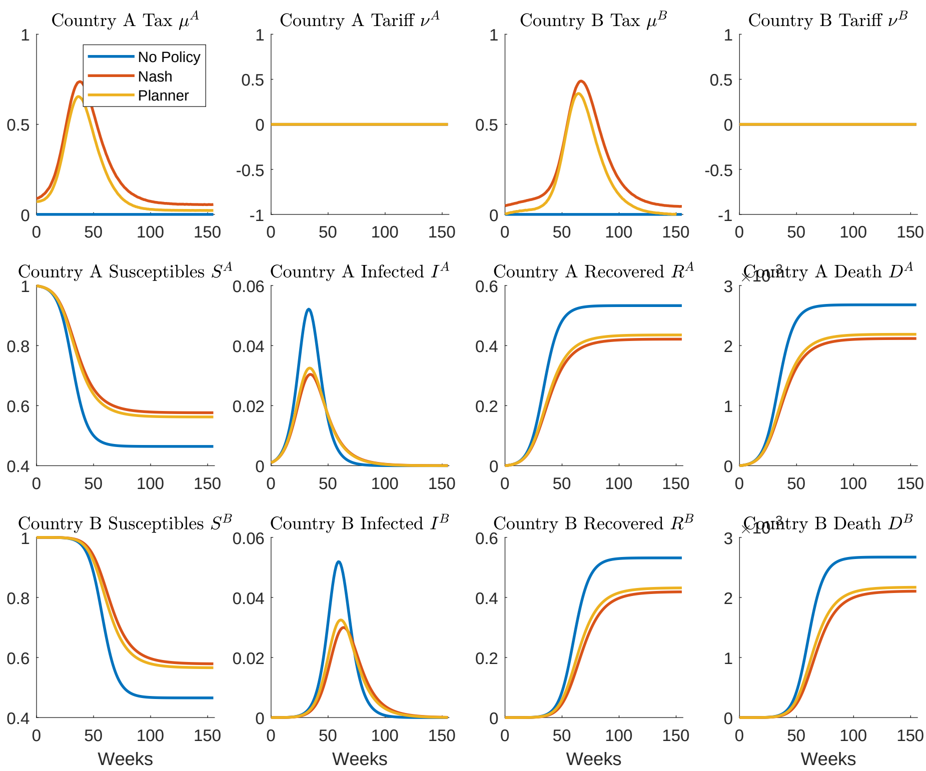
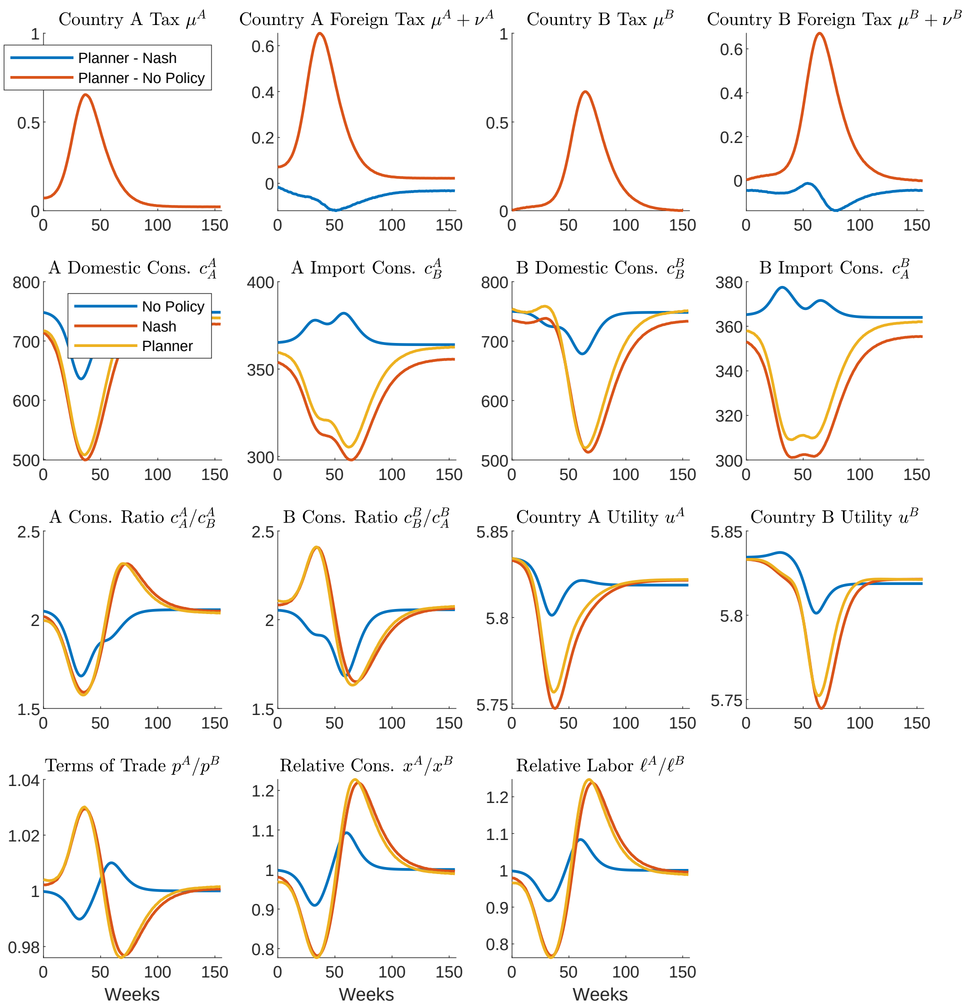
Figure 9: Equilibrium Policy and SIR Dynamics, $\nu \equiv 0$



Note: Equilibrium outcomes in a model with domestic containment policy but no tariff.

Figure 10: Equilibrium Policy and Economic Outcomes, $\nu \equiv 0$



Note: Equilibrium outcomes in a model with domestic containment policy but no tariff.

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Table 2: Welfare Decomposition: Different Specifications

Panel (a): No Tariff						
	Country A			Country B		
	Total	Economy	Death	Total	Economy	Death
No Policy	-19.85	-0.48	-19.37	-19.41	-0.47	-18.93
Nash	-18.16	-2.90	-15.26	-17.70	-2.88	-14.82
Planner	-18.04	-2.26	-15.77	-17.63	-2.32	-15.31
Planner - Nash	0.12	0.64	-0.52	0.07	0.57	-0.49
Panel (b): Dissipative Domestic Containment Policy on Consumption of Domestic Goods						
	Country A			Country B		
	Total	Economy	Death	Total	Economy	Death
No Policy	-19.85	-0.48	-19.37	-19.41	-0.47	-18.93
Nash	-45.51	-25.31	-20.21	-44.69	-24.95	-19.73
Planner	-19.99	-0.69	-19.30	-19.21	-0.36	-18.85
Planner - Nash	25.53	24.62	0.91	25.48	24.60	0.88

Note: We report the welfare loss relative to the steady−state level without pandemic and policy. We consider two additional cases. In Panel (a), we report the case in which governments cannot impose tariff. In Panel (b), we report the case in which governments can impose domestic containment policy but cannot remit the revenue on consumption of domestic goods back to the households.

5 Conclusion

In this paper, we have developed a model of epidemiology and international trade to study how international coordination and the lack thereof influences the impact of government policies on health and economic outcomes. By studying Nash equilibria over high-dimensional strategies that determine dynamic macroeconomic equilibria, the model introduces a relatively complex tool to study this complex and important question. This benefit comes at the price of simplifying each of the modelling components as much as possible. This relates to the notion of Nash equilibrium, where we restrict attention to open-loop equilibria, to the modelling of health policy, where we restrict attention to simple two-dimensional pairs of "containment taxes" and tariffs, to the role of aggregate risk, which, in line with much of the literature, we currently assume away, and to the macroeconomic dynamics, where we ignore important intertemporal linkages such as private savings or government debt. In ongoing work, we are undertaking a thorough sensitivity analysis to different model features and model parameterizations to enrich our understanding of the gains from coordination that we find in this paper. This includes analyzing the role of the finite horizon due to the arrival of a vaccine, the relative importance of transmission via consumption and labor, and the impact of the magnitude of household risk-aversion. In future work we plan to generalize the model to address the broader questions along the dimensions sketched above. We hope that our analysis will ultimately be able to shed light on the important general question of the costs and benefits of coordination of local health and economic policies, be it between different sovereign governments, between states in a federal country, or within the European Union.

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A Model Appendix

A.1 Insights from a Two-Period Model

First, we illustrate our key ideas in a simple model with two periods $t \in \{0, 1\}$. There are two countries $k = A, B$. Variables describing consumption, production, or government activity in country $k \in \{A, B\}$ have the superscript k. When discussing a single country, the superscript $-k$ denotes the other country. Each country has a unit mass of agents, with health status s for susceptible and i for infected. Let S^k denote the share of susceptible agents.

Each country has a distinct which we index with subscripts $j = A, B$. Let $c_j^k(h)$ denote the consumption of the good produced in country j by the agent in country k with health status h. We use τ^k to denote the transmission likelihood of country k's susceptible agents. We assume

$$\tau^k(\{c\}) \;=\; \pi_1[c_k^k(s)c_k^k(i) + c_{-k}^k(s)c_{-k}^k(i)](1 - S^k) + \pi_4[c_k^k(s)c_k^{-k}(i) + c_{-k}^k(s)c_{-k}^{-k}(i)](1 - S^{-k});$$

this transmission equation implies that the disease is transmitted both domestically and internationally, in proportion to the product between the susceptible agents' consumption and the infected agents' consumption, as well as to the share of infected agents $1 - S^k$.

We use U^k to denote the utility of country k's agent at time 0. At time 1, susceptible agents have utility $\overline{U}_s^k$ and infected agents have utility $\overline{U}_i^k$.

Government Consider first the centralized problem solved by the government of country k. The objective function is

$$\begin{aligned}\max_{\{c_k^k(h), c_{-k}^k(h)\}} \quad & S^k[U^k(c_k^k(s), c_{-k}^k(s)) + \beta(1-\tau^k)\overline{U}_s^k + \beta\tau^k\overline{U}_i^k] + (1-S^k)[U^k(c_k^k(i), c_{-k}^k(i)) + \beta\overline{U}_i^k] \\ + \quad & p_k(S^{-k}c_k^{-k}(s) + (1-S^{-k})c_k^{-k}(i)) - p_{-k}(S^k c_{-k}^k(s) + (1-S^k)c_{-k}^k(i))\end{aligned}$$

where the good price p_k and p_{-k} are taken as given.

We model the international trade in a simplified setting. From the perspective of a planner in country k, the production cost of domestic goods is 0, but it costs p_{-k} to purchase a unit of the foreign good. Therefore, the optimization problem is equivalent to

$$\begin{aligned}\max_{\{c_k^k(h), c_{-k}^k(h)\}} \quad & S^k[U^k(c_k^k(s), c_{-k}^k(s)) + \beta(1-\tau^k)\Delta\overline{U}^k - p_{-k}c_{-k}^k(s)] \\ & +(1-S^k)[U^k(c_k^k(i), c_{-k}^k(i)) - p_{-k}c_{-k}^k(i)]\end{aligned}$$

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where $\Delta\overline{U}^k = \overline{U}_s^k - \overline{U}_i^k > 0$. Now we assume $U(c_1, c_2) = \alpha \log c_1 + (1-\alpha)\log c_2$. The first-order conditions imply

$$\begin{aligned}
c_k^k(s) &= \frac{\alpha}{\beta(\pi_1 c_k^k(i)(1-S^k) + \pi_4 c_k^{-k}(i)(1-S^{-k}))\Delta\overline{U}^k} \\
c_{-k}^k(s) &= \frac{(1-\alpha)}{\beta(\pi_1 c_{-k}^k(i)(1-S^k) + \pi_4 c_{-k}^{-k}(i)(1-S^{-k}))\Delta\overline{U}^k + p_{-k}} \\
c_k^k(i) &= \frac{\alpha}{\beta(\pi_1 c_k^k(s)S^k)\Delta\overline{U}^k} \\
c_{-k}^k(i) &= \frac{(1-\alpha)}{\beta(\pi_1 c_{-k}^k(s)S^k)\Delta\overline{U}^k + p_{-k}}
\end{aligned}$$

Social Planner Next, we consider the first best from the perspective of a global planner. Let $\hat{c}$ denote the equilibrium allocation:

$$\begin{aligned}
\max_{\{\hat{c}_A^A(h),\hat{c}_B^A(h),\hat{c}_B^B(h),\hat{c}_A^B(h)\}} \quad & S^A[U^A(\hat{c}_A^A(s),\hat{c}_B^A(s)) + \beta(1-\tau^A)\overline{U}_s^A + \beta\tau^A\overline{U}_i^A] \\
& +(1-S^A)[U^A(\hat{c}_A^A(i),\hat{c}_B^A(i)) + \beta\overline{U}_i^A] \\
& +S^B[U^B(\hat{c}_B^B(s),\hat{c}_A^B(s)) + \beta(1-\tau^B)\overline{U}_s^B + \beta\tau^B\overline{U}_i^B] \\
& +(1-S^B)[U^B(\hat{c}_B^B(i),\hat{c}_A^B(i)) + \beta\overline{U}_i^B]
\end{aligned}$$

The first-order conditions imply

$$\begin{aligned}
\hat{c}_k^k(s) &= \frac{\alpha}{\beta(\pi_1 \hat{c}_k^k(i)(1-S^k) + \pi_4 \hat{c}_k^{-k}(i)(1-S^{-k}))\Delta\overline{U}^k} \\
\hat{c}_{-k}^k(s) &= \frac{(1-\alpha)}{\beta(\pi_1 \hat{c}_{-k}^k(i)(1-S^k) + \pi_4 \hat{c}_{-k}^{-k}(i)(1-S^{-k}))\Delta\overline{U}^k} \\
\hat{c}_k^k(i) &= \frac{\alpha}{\beta(\pi_1 \hat{c}_k^k(s)S^k)\Delta\overline{U}^k + \beta(\pi_4 \hat{c}_k^{-k}(s)S^{-k})\Delta\overline{U}^{-k}} \\
\hat{c}_{-k}^k(i) &= \frac{(1-\alpha)}{\beta(\pi_1 \hat{c}_{-k}^k(s)S^k)\Delta\overline{U}^k + \beta(\pi_4 \hat{c}_{-k}^{-k}(s)S^{-k})\Delta\overline{U}^{-k}}
\end{aligned}$$

The difference between the global planner and the local government planner's solutions illustrates two key insights. First, the global planner addresses the externality of international transmission of the pandemic. As a result, the infected agents' consumption has an additional term $\beta(\pi_4 \hat{c}_k^{-k}(s)S^{-k})\Delta\overline{U}^{-k}$ in its denominator. This term lowers the infected agents' consumption, in order to account for its effect to the susceptible agents in country k>

Second, the global planner recognizes that the export price p_{-k} is just a cross-country transfer.

This unnecessarily depresses the consumption of foreign goods, and will therefore be set to 0 using differential tariffs at the optimal global allocation.

A.2 The Static Model

Without pandemics, the model boils down to an essentially static two-country macro model. This is because, in order to focus on the epidemiological dynamics, in (11) we have ruled out economic dynamics. As a benchmark we now provide the basic properties of this simple static model. This analysis is also useful because it directly applies to the choice problems of the infected and the recovered households in the full model, who structurally solve the same static decision problems. The only truly dynamic decisions are made by susceptible households, whose choices influence their future health status.

To simplify notation, we drop country superscripts and time subscripts for the static analysis of households of country k. Denote the wage by w.

The representative consumer of country k (who is not concerned with health) chooses per-period consumption and labor $(c_k, c_{-k}, \ell) \geq 0$ in order to

$$\max v(x) - \frac{1}{2}\kappa\ell^2$$

$$\text{subject to} \quad x = q(c_k, c_{-k}) \tag{42}$$

$$\widehat{p}_k c_k + \widehat{p}_{-k} c_{-k} = w\ell + g \tag{43}$$

where $\widehat{p}_j$ are consumer prices and g is the public transfer. Let λ denote the Lagrange multiplier of the budget constraint. Importantly, λ measures the pre-epidemic willingness to pay for utility, i.e. the "exchange rate between utils and dollars", which is needed to calibrate the model. As noted in Section 2, the solution is characterized by the following first-order constraints:

$$x^{-\rho}\frac{\partial x}{\partial c_k} = \lambda \widehat{p}_k \tag{44}$$

$$x^{-\rho}\frac{\partial x}{\partial c_{-k}} = \lambda \widehat{p}_{-k} \tag{45}$$

$$\kappa\ell = \lambda w \tag{46}$$

Dividing (44) by (45) yields

$$c_{-k} = \left(\frac{1-\alpha}{\alpha}\right)^{\sigma} \left(\frac{\widehat{p}_k}{\widehat{p}_{-k}}\right)^{\sigma} c_k \tag{47}$$

Hence, unsurprisingly, c_k and c_{-k} are linear functions of each other.

Inserting (47) into (42) yields

$$x = \psi^{\frac{\sigma}{\sigma-1}} \left(\alpha \widehat{p}_{-k}\right)^{-\sigma} c_k \tag{48}$$

where

$$\psi = \alpha^{\sigma} \widehat{p}_{-k}^{\sigma-1} + (1-\alpha)^{\sigma} \widehat{p}_{k}^{\sigma-1}$$

Inserting (48) into (44), using (46), yields

$$w\psi^{-\frac{\sigma\rho-1}{\sigma-1}} \left(\alpha \widehat{p}_{-k}\right)^{\sigma\rho} c_k^{-\rho} = \kappa \widehat{p}_k \widehat{p}_{-k} \ell \tag{49}$$

By straightworward calculations, the three equations (43), (47), and (49) yield the following solutions for the three unknowns (c_k, c_{-k}, ℓ). Labor ℓ is given by

$$\ell \left(w\ell + g\right)^{\rho} = \frac{w}{\kappa} \psi^{\frac{1-\rho}{\sigma-1}} \left(\widehat{p}_k \widehat{p}_{-k}\right)^{\rho-1} \tag{50}$$

home consumption c_k by

$$\psi \left(\widehat{p}_k \widehat{p}_{-k}\right)^2 c_k^{\rho+1} - \widehat{p}_k \widehat{p}_{-k} \left(\alpha \widehat{p}_{-k}\right)^{\sigma} g c_k^{\rho} = \frac{w^2}{\kappa} \psi^{-\frac{\sigma\rho-1}{\sigma-1}} \left(\alpha \widehat{p}_{-k}\right)^{\sigma(\rho+1)} \tag{51}$$

and foreign consumption by (47). It is easy to see that (50) and (51) each have a unique positive root. Hence, the household problem has a unique solution.

For the case $\rho = 1$, which we use in the numerical calibration, things are particular simple, as both equations are quadratic. In particular, we have

$$\ell = -\frac{g}{2w} + \frac{1}{2w}\sqrt{g^2 + \frac{4w^2}{\kappa}} \tag{52}$$

which yields the multiplier λ, the "price of utility", by (46), as $\lambda = \frac{\kappa}{w}\ell$.

Optimal domestic consumption is

$$c_k = \frac{g \left(\alpha \widehat{p}_{-k}\right)^{\sigma}}{2\psi \widehat{p}_k \widehat{p}_{-k}} + \frac{\left(\alpha \widehat{p}_{-k}\right)^{\sigma}}{2\psi \widehat{p}_k \widehat{p}_{-k}} \sqrt{g^2 + \frac{4w^2}{\kappa}} \tag{53}$$

and foreign consumption correspondingly.

The above analysis describes the demand side of each of the two economies in the absence of health concerns.

A.2.1 No-Pandemic Equilibria

We re-introduce country superscripts to describe market clearing in economies with no health concerns, be it pre-pandemic or after the arrival of a vaccine. The conditions are

$$w^k = p_k z^k \tag{54}$$

$$z^k \ell^k = c_k^k + c_k^{-k} \tag{55}$$

$k = A, B$, for labor market and product market clearing, respectively.

Social Planner Under a benevolent social planner, government policy in each country will be $(\mu^k, \nu^k) = (0, 0)$: levying taxes on domestic or foreign goods is welfare reducing. Hence, the government collects no taxes, and by the budget constraint (12) transfers are $g = 0$. Consumer prices are undistorted,

$$\widehat{p}_k^k = p_k, \widehat{p}_{-k}^k = p_{-k}$$

and the 4 equations (54) and (55) to are sufficient to determine the 4 prices w^k, p_k, $k = A, B$, by using the solutions of (50), (51), and (47) obtained above. Of course, prices are determined only up to one degree of freedom, and by Walras' Law one of the above equilibrium relations is redundant.

Nash In Nash Equilibrium, $\mu^k = 0$ in each country. Yet, tariffs can be positive, for the standard economic reasons of trade wars discussed more broadly in the main text. Hence, consumer prices are

$$\widehat{p}_k^k = p_k$$

$$\widehat{p}_{-k}^k = (1 + v^k) p_{-k}$$

Public transfers are therefore endogenous even in the static setting,

$$g^k = \nu^k p_{-k} c_{-k}^k \tag{56}$$

Now, for given government policies (ν^A, ν^B), we have the 6 equations (54), (55), and (56) to determine the 6 endogenous variables w^k, p_k, g^k, $k = A, B$.

A.2.2 Demand by Infected or Recovered Households

As noted above, the demand of infected and of recovered households in the full model in Section 2 derives from an essentially static optimization problem. Hence, by letting $w = \phi\overline{w}_t^k$ for the infected households of country k at date t, the household optimization conditions of the full model yield the conditions (50), (51), and (47), appropriately indexed for the i households. Similarly, by letting $w = \overline{w}_t^k$ for the recovered households, the household optimization conditions of the full model lead to (50), (51), and (47), appropriately indexed for the r households.

A.3 Disease Transmission

This subsection provides a microfoundation for the disease transmission dynamics (14) in Section 1.2.

In the basic SIR model (without economic choices) transmission occurs according to

$$T_t = \eta S_t I_t \tag{57}$$

This has the following logic. Let N be size of a given population. Let $N = S + I + R$, where I is the number of infectious, and S that of susceptibles. Let φN be the rate of contacts of a single individual during which the disease can potentially be transmitted.[12] The assumption is that individuals spend a fixed proportion of their time outside the home, where they can transmit or contract the virus. Letting θ denote the probability that a contact leads to an infection,[13] equation (57) can now be derived as follows.[14] One susceptible individual outside his home, per unit of time, on average has φN contacts. This leads to $\varphi N(I/N) = \varphi I$ contacts with infectious individuals. The probability of getting infected in these $k = \varphi I$ contacts is

$$\overline{\tau} = 1 - (1-\theta)^k = \theta \sum_{m=0}^{k-1} \binom{k}{m+1} (-\theta)^m \tag{58}$$

for $k > 0$, and the expected total number of transmissions per unit of time is $\overline{\tau}S$. $\overline{\tau}$ as a function of θ is a polynomial of degree k and strictly concave for $k > 1$. Hence, for small θ (which seems to be the case for Covid-19 under social distancing) $\overline{\tau}$ is smaller than, but approximately equal to

[12]This is the so-called “mass incidence" model which is relevant for Covid-19 (differently from, say, HIV, as analyzed in Greenwood et al. (2019)): one infectious individual can infect a whole (sub-)group, no need for bilateral interaction.

[13]θ clearly depends on the country and its policies. At least in richer countries, θ has decreased dramatically since February 2020.

[14]This is the perspective of susceptibles, which is most relevant for economic incentives. Usually, the derivation takes the perspective of infectious. See standard textbooks such as Brauer (2008).

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$k\theta$. In this case, letting $\eta = \theta\varphi$, the average rate of transmission is approximately equal to

$$\theta k S = \theta\varphi I S = \eta I S$$

as stated in (57). If N is large or the population fragmented (so mass incidence in the form described above is not reasonable), the argument holds by adding up local populations.

A.3.1 The Macro-SIR Model

Eichenbaum et al. (2020) have proposed a particularly simple framework to incorporate economic activity into the above model, by distinguishing transmissions while consuming, at work, and during other activities outside the home. This model does not distinguish between foreign and domestic consumption goods.

To make that precise, dropping the time index for convenience, suppose that individuals spend a fixed fraction $f < 1$ of their time outside neither at work nor consuming. All durations are in terms of the unit of time chosen (which is scaled by φ).[15] To simplify, and different from Brotherhood et al. (2020), we do not distinguish between utility from different types of leisure. Hence, individuals do not derive specific utility from leisure outside the home, and we therefore assume this fraction to be constant.[16] Suppose that individuals of health status h spend a fraction $\ell(h) < 1$ of their time at work, and a fraction $\gamma c(h) < 1$ consuming (shopping, dining, ...), the assumption being that the time spent on consumption is proportional to the quantity bought. We assume that $f + \ell(h) + \gamma c(h) < 1$, the remaining time being leisure alone at home.[17] Then, using the linear approximation of the infection probability $\overline{\tau}$, we have the following infection probabilities for susceptibles and aggregate average transmission rates:

1. During non-work-non-consumption time outside the home,
   - individual proba of becoming infected: $f\eta I$
   - expected total number of transmissions: $f\eta I S$
2. During work,
   - average rate of susceptible contacts with infected: $\varphi L(\ell(i)I/L)$

[15]If this unit is a week and a day has 16 useful hours (e.g. McGrattan, Rogerson et al., 2004), then the individual has $112f$ hours of non-shopping leisure per week outside the home.
[16]See Garibaldi et al. (2020) for work that endogenizes f in a model of occupational choice, abstracting from the work-consumption choice considered here.
[17]We calibrate the parameter values such that the individual time constraints are satisfied in our simulations. Hence, we can ignore the time constraint in the household's optimization problem of (29).

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- individual proba of becoming infected when working: $\ell(s)\eta\ell(i)I$
- expected total number of transmissions at work: $\ell(s)\eta\ell(i)IS$

3. During consumption,

- average rate of contacts with infected: $\varphi\gamma C(\gamma c(i)I/\gamma C)$
- individual proba of becoming infected when consuming $c(s)$: $c(s)\eta\gamma^2 c(i)I$
- expected total number of transmissions from consumption: $\eta\gamma^2 c(s)c(i)IS$

Here,

$$C_t = S_t c_t(s) + I_t c_t(i) + R_t c_t(r)$$

is total consumption, and

$$L_t = S_t \ell_t(s) + I_t \ell_t(i) + R_t \ell_t(r)$$

total labor (hours worked) in the economy.

Hence, an s individual faces the following transition probability to the infected state, if she chooses individual consumption $c(s)$ and labor supply $\ell(s)$:

$$\tau(c(s), \ell(s)) = f\eta I + \ell(s)\eta\ell(i)I + c(s)\eta\gamma^2 c(i)I \quad (59)$$
$$= \eta\left[\gamma^2 c(s)c(i) + \ell(s)\ell(i) + f\right] I \quad (60)$$

This yields the expected total number of transmissions from all activities, now with time indices:

$$T_t = \eta\left(\gamma^2 c_t(s)c_t(i) + \ell_t(s)\ell_t(i) + f\right) I_t S_t \quad (61)$$
$$= \left[\pi_1 c_t(s)c_t(i) + \pi_2 \ell_t(s)\ell_t(i) + \pi_3\right] I_t S_t \quad (62)$$

where

$$\pi_1 = \eta\gamma^2, \pi_2 = \eta, \pi_3 = \eta f$$

A.3.2 International transmission

Again dropping the time index for convenience, we denote individual consumption of good $j = A, B$ in country $k = A, B$ by $c_j^k = c_j^k(h)$. Aggregate consumption of good j in country k is

$$C_j^k = Sc_j^k(s) + Ic_j^k(i) + Rc_j^k(r) \quad (63)$$

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In terms of the notation of (6) and (7) in the main text, we have $C_k^k = H^k$ and $C_{-k}^k = M^k$. As before, suppose individuals of country k and health status h spend a fraction $\ell^k(h)$ of their time at work, a fraction $\gamma c_k^k(h)$ of their time consuming the domestic good, a fraction $\gamma c_{-k}^k(h)$ consuming the foreign good, and a fraction f out of their home for other reasons. When "shopping", an individual is directly exposed to home residents and foreigners. Since the contact intensity for foreign and domestic consumption is likely to differ we assume that the consumer has a contact rate $\varphi^d \gamma(C_k^k + C_{-k}^k)$ with domestic residents and a contact rate $\varphi^f \gamma(C_k^{-k} + C_{-k}^{-k})$ with foreigners. In fact, when consuming the domestic good, an individual in country k meets foreign consumers who consume her domestic good, which leads to a number of contacts per unit of time of $\varphi^f \gamma C_k^{-k}$. And when consuming the foreign good, she meets foreign consumers who consume this good, i.e. their domestic good, which leads to a number of contacts per unit of time of $\varphi^f \gamma C_{-k}^{-k}$. Since the consumption of foreign goods is often intermediated by specialized import/export agents and thus likely to involve fewer direct contacts, we expect $\varphi^f < \varphi^d$.[18]

We assume for simplicity that there are no international encounters in non-work-non-consumption situations, and we also ignore those at the workplace. Hence, the transmission dynamics is unchanged from the previous subsection as regards these two types of encounters, and only changes with respect to the transmission related to consumption. For a susceptible consuming the bundle $(c_k^k(s), c_{-k}^k(s))$, we have:

- average rate of contacts: $\gamma(\varphi^d C_k^k + \varphi^f C_k^{-k}) + \gamma(\varphi^d C_{-k}^k + \varphi^f C_{-k}^{-k})$
- average rate of contacts with infected: $\gamma\varphi^d(c_k^k(i) + c_{-k}^k(i))I^k + \gamma\varphi^f(c_k^{-k}(i) + c_{-k}^{-k}(i))I^{-k}$
- individual proba of becoming infected:

  $c_k^k(s)\theta\gamma^2\left[\varphi^d c_k^k(i)I^k + \varphi^f c_k^{-k}(i)I^{-k}\right] + c_{-k}^k(s)\theta\gamma^2\left[\varphi^d c_{-k}^k(i)I^k + \varphi^f c_{-k}^{-k}(i)I^{-k}\right]$

Adding the infection probabilities shows that a susceptible in country k who chooses $\ell^k(s)$, $c_k^k(s)$, and $c_{-k}^k(s)$ transits to the infectious state with probability

$$
\begin{aligned}
&\tau(c_k^k(s), c_{-k}^k(s), \ell^k(s)) \\
= \; &\left[\theta\gamma^2\varphi^d\left(c_k^k(s)c_k^k(i) + c_{-k}^k(s)c_{-k}^k(i)\right) + \theta\varphi^d\ell^k(s)\ell^k(i) + \theta\varphi^d f\right] I^k \\
&+\theta\gamma^2\varphi^f\left[c_k^k(s)c_k^{-k}(i) + c_{-k}^k(s)c_{-k}^{-k}(i)\right] I^{-k}
\end{aligned}
\tag{64}
$$

[18] An important exception to this logic is tourism. Remember that consumption includes tourism, which is a large component of international trade in several countries (see, e.g., Culiuc, 2014). As in standard foreign trade statistics, holidays abroad therefore count as the domestic purchase of a foreign consumption good. It is likely that this type of import is very contact intensive. Also tourism is not subject to the usual logic of import tariffs. A more general model (not presented here) therefore distinguishes between tourism and other imports/exports.

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This yields the expected total number of transmissions from all activities in country k, now with time indices, as used in Section 1.2:

$$T_t^k = \left[\pi_1(c_{kt}^k(s)c_{kt}^k(i) + c_{-kt}^k(s)c_{-kt}^k(i)) + \pi_2\ell_t^k(s)\ell_t^k(i) + \pi_3\right] I_t^k S_t^k \quad (65)$$

$$+\pi_4\left[c_{kt}^k(s)c_{kt}^{-k}(i) + c_{-kt}^k(s)c_{-kt}^{-k}(i)\right] I_t^{-k} S_t^k \quad (66)$$

where

$$\pi_1 = \theta\gamma^2\varphi^d \quad (67)$$

$$\pi_2 = \theta\varphi^d \quad (68)$$

$$\pi_3 = \theta\varphi^d f \quad (69)$$

$$\pi_4 = \theta\gamma^2\varphi^f \quad (70)$$

The transmission dynamics (65)-(66) generalize those of the single good case (61) - (62). The new terms reflect the transmissions through consumption interactions in exports ($c_{kt}^{-k}(i)$) and imports ($c_{-kt}^k(i)$) and therefore also involve foreign consumption abroad ($c_{-kt}^{-k}(i)$ in the π_4-term).

A.4 Computation Details

The numerical algorithm for solving our model proceeds in a number of steps. We first detail the solution to the model for fixed containment policies and then detail the solution for the optimal coordinated and uncoordinated policies.

Solution for fixed policies. To solve the model for a fixed set of containment taxes, we begin with guesses for the susceptible households' labor and consumption choices in each country and period as well as the relative price of country B's good in each period. Note that we normalize country A prices to 1. Given these guesses, we calculate the implied government tax as well as the labor and consumption of all other household types. We then iterate forward on the SIR equations until the final period of the model, at which point consumption and labor return to their steady state values due to the vaccine's arrival. Next, we iterate backward to derive the present value of lifetime utility for each agent. We then use gradient-based methods to adjust our initial guesses until the susceptible agents' first-order conditions, market clearing conditions, and government budget constraints hold. In this way, we confirm all equilibrium conditions are satisfied.

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Social planner solution. To solve for optimal containment policies from the perspective of a social planner, we nest the solution for fixed policies within another gradient-based optimizer. In this outer loop, we solve for containment policies and tariffs which maximize the present value of total time-0 utility, equally weighted across both countries.

Nash equilibrium solution. To solve for the Nash Equilibrium containment policies we begin with a guess for containment policies and tariffs across both countries. Given a fixed policy for a given country, we use a gradient-based optimizer to find the optimal policy response of the other country that maximizes the welfare of its own households. We then take this policy as fixed and find the optimal policy response of the other country. We iterate on this procedure until both countries' policies are the best responses to each other. We experiment with many different starting values but do not find any differences in the final result, which makes us believe that the identified Nash equilibrium is unique.

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Hang in there: Stock market reactions to withdrawals of COVID-19 stimulus measures[1]

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The COVID-19 pandemic crisis has triggered unprecedented stimulus policy responses by countries worldwide, particularly fiscal stimulus measures. Given the high fiscal costs, some countries have withdrawn such measures, and other countries are contemplating doing so. In this paper, we empirically examine the impact of the withdrawal of fiscal stimulus policies on stock markets using daily data. To this end, we construct a database of withdrawal events and examine the difference between the pre- and post-event stock price returns using event study analysis and cross-country regressions. The results show a significant negative reaction when stimulus is withdrawn prematurely, i.e., when the daily COVID cases were still high relative to the historical pattern, a reaction which can be compounded by social unrest. The results suggest that markets are concerned about the negative impact of early withdrawals of stimulus on the economic recovery prospect, a risk that policymakers have to account for while contemplating the exit strategy from the exceptional crisis-fighting policies.

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I. Introduction

The COVID-19 crisis has triggered unprecedented stimulus policy responses by countries worldwide, particularly fiscal measures such as unemployment benefits, debt moratoria, state guarantees, and furlough schemes. Unsurprisingly, such responses come with large fiscal costs. For example, the U.S. federal budget deficit rose to a record USD 3.1 trillion in the 2020 fiscal year, more than double the previous record deficit of USD 1.4 trillion in 2009. Much of the spending was associated with the USD 2.2 trillion economic relief package the U.S. Congress passed in March 2020 (*New York Times*, October 16, 2020).

Observers have expressed concerns that the exceptional COVID-19-related spending might be unsustainable, concerns that are relevant only for countries with limited fiscal space and high debt, but also for those enjoying adequate fiscal space before the crisis (Balajee, 2020; Creel, 2020; de Jong and Ho, 2020; Hurtgen, 2020). The size of the fiscal policy response has indeed been limited by the available fiscal space, as documented in Alberola and others (2020). Perhaps partly due to these concerns, the US Treasury recently decided not to extend several emergency lending facilities set up by the Federal Reserve at the start of the pandemic (*Financial Times*, November 19, 2020).

However, the early withdrawal of the fiscal stimulus could have negative consequences. For example, it may cut off the lifeline support for the hard-hit households and businesses and threaten the fledging economic recovery, particularly in the presence of the long-lasting scarring effects of the pandemic (Jorda, Singh, and Taylor, 2020; Kozlowski, Veldkamp, and Venkateswaran, 2020, among others).

Withdrawals may also signal to the market that the “firepower” of the government is limited and may be inadequate to support the economy in the future when new waves of COVID-19 outbreaks occur. Aware of these risks, several policymakers and international organizations have recently warned about the potential damaging effects were government support withdrawn too early, as the IMF Managing Director Ms. Georgieva did in October and November 2020.[1]

[1] During Annual Meetings, October 14, 2020 (“Do as much as you can; Do not cut financial lifelines too early”); and during Caixin Summit, November 12, 2020. The ECB President Ms. Lagarde also emphasized that those fiscal measures should stay in place even as the pandemic gradually phases out (*Bloomberg*, October 12, 2020).

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In view of this trade-off, it is worth learning from the recent experience from countries that have withdrawn some COVID-19 stimulus measures. This study moves in that direction and examines how markets assessed the withdrawals of COVID-19-related fiscal stimulus measures. The assessment analyzes the price performance of the large capitalization, medium capitalization, and small capitalization segments of national stock markets before and after the different withdrawal stages of the fiscal stimulus.

The assessment is based on an event study analysis, which finds that stock price returns are generally lower in the aftermath of a stimulus withdrawal event; and on a cross-country regression, which suggests that a country's socio-economic fundamentals explain the magnitude of the stock price return decline. In particular, we find that when a stimulus was withdrawn prematurely (i.e., when the daily COVID cases were still high relative to the historical pattern), stock market reactions were more negative. The results capture quantitively market concerns about insufficient fiscal and monetary policy response compounded by an early withdrawal of the government stimulus (Fitch Solutions, 2020). A prudent exit strategy from the COVID-19 stimulus era should allay these concerns to restore market confidence.

The rest of the paper is structured as follows. Section II reviews related literature; Section III presents the event study analysis; Section IV presents the cross-country regressions; Section V concludes and discusses some policy implications.

II. Literature Review

Our study is related to the literature analyzing the impact of COVID-19 government support measures on the economy and financial markets.[2]

[2] Related to economic analysis of the COVID-19 pandemic, there have been several studies examining the tradeoffs and costs associated with the *lockdown* policy. A large body of studies have analyzed the tradeoff between output losses due to stringency measures and the number of fatalities (Alvarez, Argente, and Lippi, 2020; Eichenbaum, Rebelo, and Trabandt, 2020; Jones, Philippon, and Venkateswaran, 2020; and Hall, Jones, and Klenow, 2020; Sheridan and others, 2020). Highlighting a different trade-off, Acharya, Liu, and Zhao (2020) find that stringency measures appear to boost confidence (as reflected by a decline in forward-looking volatility indices) and thus expedite the medium-term economic recovery, despite causing short-term disruptions.

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Economic models suggest that government intervention could be very effective in reducing COVID-related damage to the economy. For example, using a general equilibrium model, Elenev, Landvoigt, and Van Nieuwerburgh (2020) find that interventions in corporate credit markets (e.g., corporate loan programs) could reduce bankruptcies by about 50 percent and stop a corporate-financial doom loop; furthermore, the program would not incur additional fiscal costs since the costs of financial bailouts would be avoided. The most effective stabilization tool is seemingly unemployment insurance (Faria-e-Castro, 2020). And Casado and others (2020) find that high earning replacement rates supported consumer spending. They estimate that the elimination of the Federal Pandemic Unemployment Compensation supplement could cause local spending to decline by 44 percent.

However, the effectiveness of government support measures depends on the implementation details, a tough challenge due to the urgent need to deploy the measures fast. For example, Céspedes, Chang, and Velasco (2020) show that fiscal transfers need to be large enough to change the behavior and induce people to stay at home; otherwise, the risk of contagion could remain high.

In addition, *empirical* evidence from the U.S. is indicative of the problems a government could face. The Paycheck Protection Program (PPP) consisted of loans designed to provide a direct incentive for small businesses to keep workers on the payroll. However, the geographic distribution of the PPP loans did not address the needs of the country's areas hit the hardest (Granja and others, 2020), and there was evidence that large firms were the main beneficiaries of the PPP loans (Neilson, Humphries, and Ulyssea, 2020). Moreover, despite the positive impact on consumer spending in the U.S., survey data suggest that firms were not optimistic about the efficacy of the fiscal stimulus associated with the CARES Act Loan Program (Bartik and others, 2020). Consumer spending reallocation, with some sectors of the economy impacted more negatively by the pandemic (Barrero, Bloom, and Davis, 2020; Davis, Hansen and Seminario-Amez, 2020), may be partly responsible for the pessimistic views in the survey.

Besides the U.S., empirical evidence from a broader set of countries shows that monetary and fiscal stimulus might have been effective in reducing the harm that containment measures inflicted in the economy (Deb and others, 2020). Nevertheless, the harm to the economy was still substantial: over a 30-day period, industrial production declined by as much as 15 percent.

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Countries that could only provide limited fiscal and monetary policy stimulus recorded losses in industrial production as large as 20 percent.

With regard to asset markets, the announcement of government income support and debt relief measures appear to have had a positive impact on stock price returns (Ashraf, 2020). There is evidence, however, that strict lockdown policies were responsible for large stock price declines once the effects of pandemic severity, workplace mobility, and income support and debt relief measures are accounted for (Davis, Liu, and Sheng, 2020). Arguably, government support may also overshoot. For example, easy monetary policy in the U.S. in the wake of the pandemic appeared to have induced speculation in the housing markets, with the price growth accelerating at a faster pace than in the period prior to the 2007-09 global financial crisis (Zhao, 2020).

This study starts where earlier studies on the impact on financial markets left off. Specifically, it looks at the market reaction to successive withdrawal stages of government fiscal measures. To this end, a broad cross-country analysis based on event study analysis and cross-section regressions allows us to examine the reaction of stock prices to withdrawals in different segments of national stock price indices, and how much fundamental social and economic factors influenced the reaction. The next sections review the data, methodology and results in detail.

III. EVENT STUDY ANALYSIS

Data

The event study uses daily price data obtained from the large-cap, medium-cap, and small-cap stock price indices in U.S. dollars that MSCI constructs for forty-seven (47) economies. The U.S. dollar-denominated indices are used to make stock index returns comparable across countries and to remove local currency effects, i.e., positive local currency returns may be misleading if the country experiences a substantial currency depreciation. The government response (impulse) index is obtained from the Oxford COVID-19 Government Response Tracker. The responses covered by this dataset are COVID-related fiscal measures, including income support for households, debt/contract relief for households, other announced fiscal measures (i.e., economic stimulus spending).

The data sample covers the period from January 1, 2020 to August 28, 2020. The country sample is evenly distributed between advanced economies (24) and emerging market and middle-income economies (23). The advanced economies included are Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hong Kong SAR, Ireland, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Singapore, South Korea, Spain, Sweden, Switzerland, Taiwan POC, and the United Kingdom.

The emerging market economies included are Argentina, Bahrain, Czech Republic (Czechia), Egypt, Hungary, India, Indonesia, Israel, Jordan, Kuwait, Malaysia, Mexico, Morocco, Pakistan, Peru, the Philippines, Poland, Russia, Saudi Arabia, South Africa, Thailand, Turkey, and the United Arab Emirates.

Government withdrawal events: definitions and characteristics

We assess the reaction of stock prices to the withdrawal of government support using event study analysis. First, we define the government withdrawal events as the first date the government response index fell below a certain threshold. Four types of events are considered, the only difference being the event threshold: a 5 percent decline from the peak value of the government response index, a 10 percent decline, a 15 percent decline, and a 20 percent decline.

Table 1 shows the withdrawal dates for the country sample in this study. For comparison purposes, the table also reports countries for which no withdrawal event took place as of end-August 2020. The latter set of countries include Australia, Brazil, China, Chile, Colombia, Oman, Qatar, and the U.S. In a few countries, mainly advanced economies (Bahrain, Canada, Denmark, South Africa, and the United Kingdom), the withdrawal was limited and less than 10 percent of the peak support value. Countries that reined on the pandemics fast during the first wave, such as Germany, Italy, Singapore, and South Korea, withdrew government support fast and by a large amount.

Figure 1 shows the number of days elapsed from the date the government response index reached its maximum value until the date of the withdrawal event.[3] On average, countries withdrew 5 percent of the support after 30 days, 10 percent of the support after 35 days, 15 percent of the

[3] For completeness, the figure also reports important advanced and emerging market economies that did not withdraw government support as of end-August 2020.

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Table 1. Government response index, maximum levels and withdrawal event dates

Country	Government impulse, maximum level	Withdrawal, 5 percent	Withdrawal, 10 percent	Withdrawal, 15 percent	Withdrawal, 20 percent
Argentina	2020-03-25	2020-04-27	NA	NA	NA
Australia	2020-07-08	NA	NA	NA	NA
Austria	2020-03-30	2020-04-23	2020-05-01	2020-05-04	2020-05-11
Bahrain	2020-04-01	2020-07-07	NA	NA	NA
Belgium	2020-05-04	2020-05-11	2020-06-08	2020-06-08	2020-06-08
Brazil	2020-05-25	NA	NA	NA	NA
Canada	2020-04-01	2020-06-22	NA	NA	NA
Chile	2020-07-03	NA	NA	NA	NA
China	2020-05-21	NA	NA	NA	NA
Colombia	2020-04-27	NA	NA	NA	NA
Czech Republic	2020-03-31	2020-04-02	2020-04-20	2020-04-20	2020-04-27
Denmark	2020-05-12	2020-07-08	NA	NA	NA
Egypt	2020-05-31	2020-06-07	2020-06-07	2020-07-01	2020-07-01
Finland	2020-03-28	2020-05-14	2020-05-14	2020-05-29	2020-06-01
France	2020-03-17	2020-05-26	2020-06-02	2020-06-02	2020-06-22
Germany	2020-04-29	2020-05-06	2020-05-07	2020-05-19	2020-05-25
Greece	2020-04-08	2020-05-05	2020-05-05	2020-05-11	2020-06-15
Hong Kong	2020-04-06	2020-05-27	2020-05-29	2020-06-19	2020-06-19
Hungary	2020-04-16	2020-05-04	2020-05-04	2020-06-19	2020-06-19
India	2020-04-09	2020-05-04	2020-05-04	2020-06-01	2020-07-01
Indonesia	2020-04-24	2020-05-03	2020-06-08	2020-06-23	2020-06-23
Ireland	2020-04-06	2020-06-05	2020-06-05	2020-06-26	2020-06-26
Israel	2020-04-08	2020-04-26	2020-05-03	2020-06-08	2020-07-18
Italy	2020-04-12	2020-05-04	2020-05-04	2020-05-04	2020-05-04
Japan	2020-04-16	2020-05-14	2020-05-25	2020-05-25	2020-05-25
Jordan	2020-03-29	2020-04-27	2020-05-04	2020-05-12	2020-06-06
Kuwait	2020-05-10	2020-05-31	2020-05-31	2020-07-17	NA
Malaysia	2020-05-23	2020-06-10	2020-06-10	2020-06-10	2020-06-24
Mexico	2020-04-06	2020-06-01	2020-06-01	NA	NA
Morocco	2020-06-01	2020-06-11	2020-06-11	2020-06-24	2020-06-24
Netherlands	2020-03-31	2020-05-11	2020-05-11	2020-07-01	2020-07-01
New Zealand	2020-04-01	2020-04-28	2020-04-29	2020-05-14	2020-05-14
Norway	2020-04-01	2020-04-20	2020-04-21	2020-05-11	2020-05-14
Oman	2020-07-25	NA	NA	NA	NA
Pakistan	2020-05-01	2020-05-16	2020-06-04	2020-06-04	2020-06-07
Peru	2020-05-01	2020-05-25	2020-07-01	NA	NA
Philippines	2020-04-13	2020-05-06	2020-05-06	2020-05-29	2020-05-29
Poland	2020-04-09	2020-05-30	2020-05-30	2020-05-30	2020-07-09
Portugal	2020-04-10	2020-05-04	2020-05-04	2020-05-17	2020-07-01
Qatar	2020-07-24	NA	NA	NA	NA
Russia	2020-05-01	2020-05-12	2020-06-23	2020-07-15	NA
Saudi Arabia	2020-05-27	2020-05-31	2020-05-31	2020-06-08	NA
Singapore	2020-05-26	2020-06-19	2020-06-19	2020-06-19	2020-06-19
South Africa	2020-05-29	2020-06-08	NA	NA	NA
South Korea	2020-04-06	2020-04-18	2020-04-20	2020-04-20	2020-04-20
Spain	2020-04-05	2020-05-04	2020-05-26	2020-06-01	2020-06-08
Sweden	2020-06-04	2020-06-13	2020-06-15	NA	NA
Switzerland	2020-03-20	2020-05-30	2020-06-01	2020-06-06	2020-06-06
Taiwan	2020-04-21	2020-05-08	2020-05-08	NA	NA
Thailand	2020-04-14	2020-05-18	2020-06-06	2020-06-06	2020-07-01
Turkey	2020-04-19	2020-06-01	2020-07-22	2020-07-22	2020-07-22
United Arab Emirates	2020-04-13	2020-04-29	2020-05-15	2020-06-02	2020-07-03
United Kingdom	2020-06-08	2020-07-06	NA	NA	NA
United States	2020-03-27	NA	NA	NA	NA

Source: Oxford University and authors' calculations.

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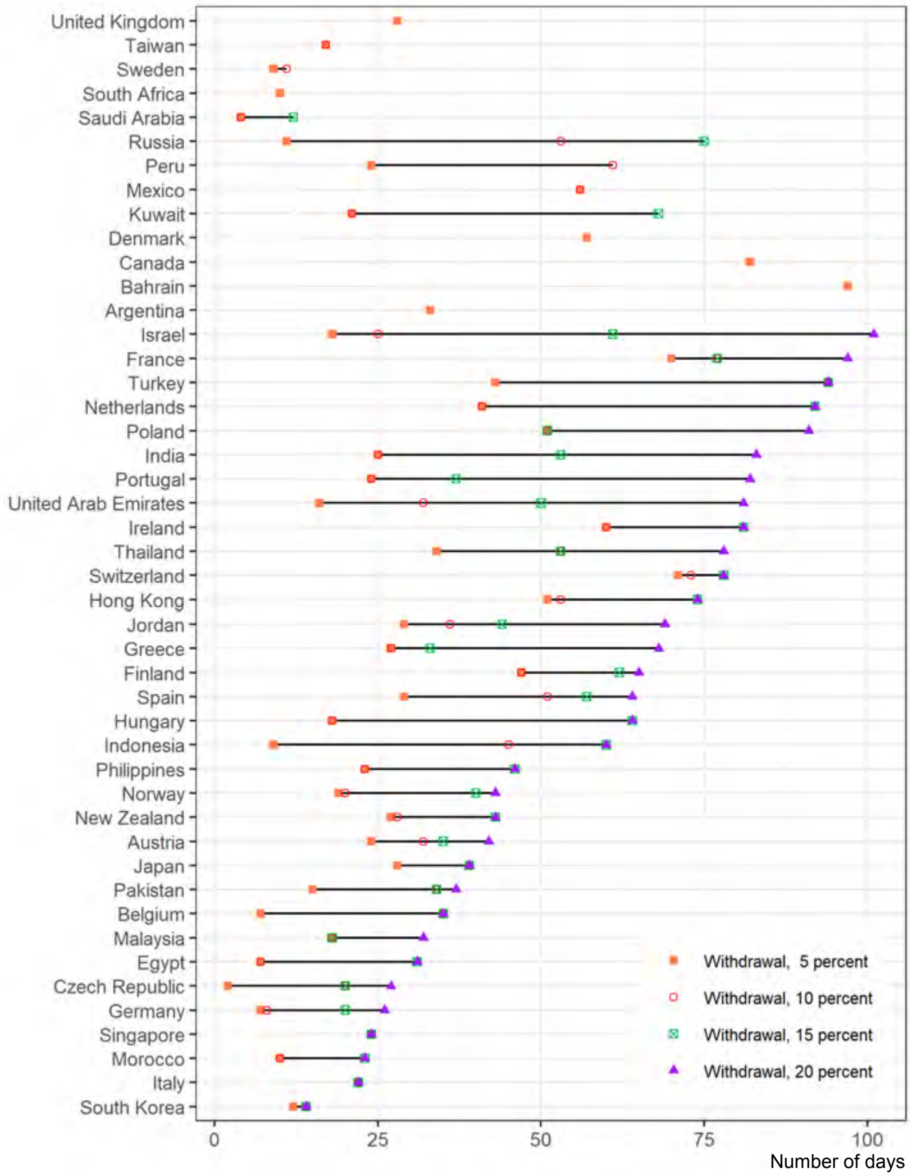
Figure 1. Days elapsed since the date the government impulse reached its maximum value



Note: Number of days from the date the government impulse reached its maximum value until the date of the support withdrawal. Four government withdrawal events are plotted, namely, the first date on which the government support index falls at least by 5 percent, 10 percent, 15 percent, and 20 percent relative to its maximum level.
Source: Oxford University and authors' calculations.

support after 48 days, and 20 percent of the support after 58 days. The average number of days, however, may mask substantial policy differences among countries. For instance, Bahrain and Canada waited more than 75 days to withdraw 5 percent of the maximum government support; Denmark and Mexico waited more than 50 days. On the other hand, in Italy and South Korea, the withdrawal of government support was not gradual; rather, it reduced by more than 20 percent or more on a single day.

Methodology

With the withdrawal events defined above, we proceed to use standard event study analysis to evaluate their impact on the stock prices of large-, medium-, and small-capitalization firms. The event study considers two 5-day windows surrounding the event date T. The pre-event window covers dates T-5, T-4, ..., T-1; and the post-event window covers the dates T+1, $T + 2$, …, $T + 5$. The choice of short pre- and post-event windows aims at mitigating the impact of factors other than the event itself.

Following Brown and Warner (1980, 1985), the constant return model is used to evaluate whether the mean of the distribution of the average post-event daily returns across countries is different from the mean of the distribution of the average pre-event daily returns. Statistical significance is assessed using a paired-sample t-test.

Results

Tables 2-3 and Figure 2 summarize the results of the event study analysis. Regardless of the firm capitalization and the magnitude of the government support withdrawal, the market reaction is negative across countries. The mean difference between post-event window and pre-event window returns is negative, ranging from a minimum of -0.09 percent to a maximum of -0.5 percent. Nevertheless, the paired-sample t-tests suggest that the difference is not statistically significant in most cases. This is evident in Figure 2, which shows that the difference between pre-event and post-event return distributions is mainly concentrated on the tail behavior rather than the central section of the distribution.

Table 2. Mean average daily return differences between post-event and pre-event windows

Event	Withdrawal, gov. impulse, 5 pct			Withdrawal, gov. impulse, 10 pct		
	Large cap	Mid cap	Small cap	Large cap	Mid cap	Small cap
mean difference	-0.400	-0.777	-1.121	-1.741	-0.687	-1.628
t-stat	0.691	0.441	0.268	0.090	0.496	0.111
p-value	-0.091	-0.195	-0.255	-0.470	-0.159	-0.401

Event	Withdrawal, gov. impulse, 15 pct			Withdrawal, gov. impulse, 20 pct		
	Large cap	Mid cap	Small cap	Large cap	Mid cap	Small cap
mean difference	-0.834	-0.412	-0.733	-0.636	-0.698	-0.816
t-stat	0.410	0.683	0.468	0.530	0.490	0.421
p-value	-0.216	-0.088	-0.138	-0.163	-0.156	-0.183

Source: MSCI and authors' calculations.

Table 3, which shows the first four moments of the pre-event and post-event average return distributions, confirms the visual evidence presented in Figure 2. In the post-event distribution, besides the leftwards shift of the mean relative to the pre-event distribution, the distribution mass tends to shift to the right reflecting lower skewness. In addition, the tails of the distribution become thinner, reflecting lower and even negative excess kurtosis.

These results suggest that there are significant differences in the responses of stock market prices to government withdrawal events. Such differences merit further inspections using cross-country regressions, as done in the next section.

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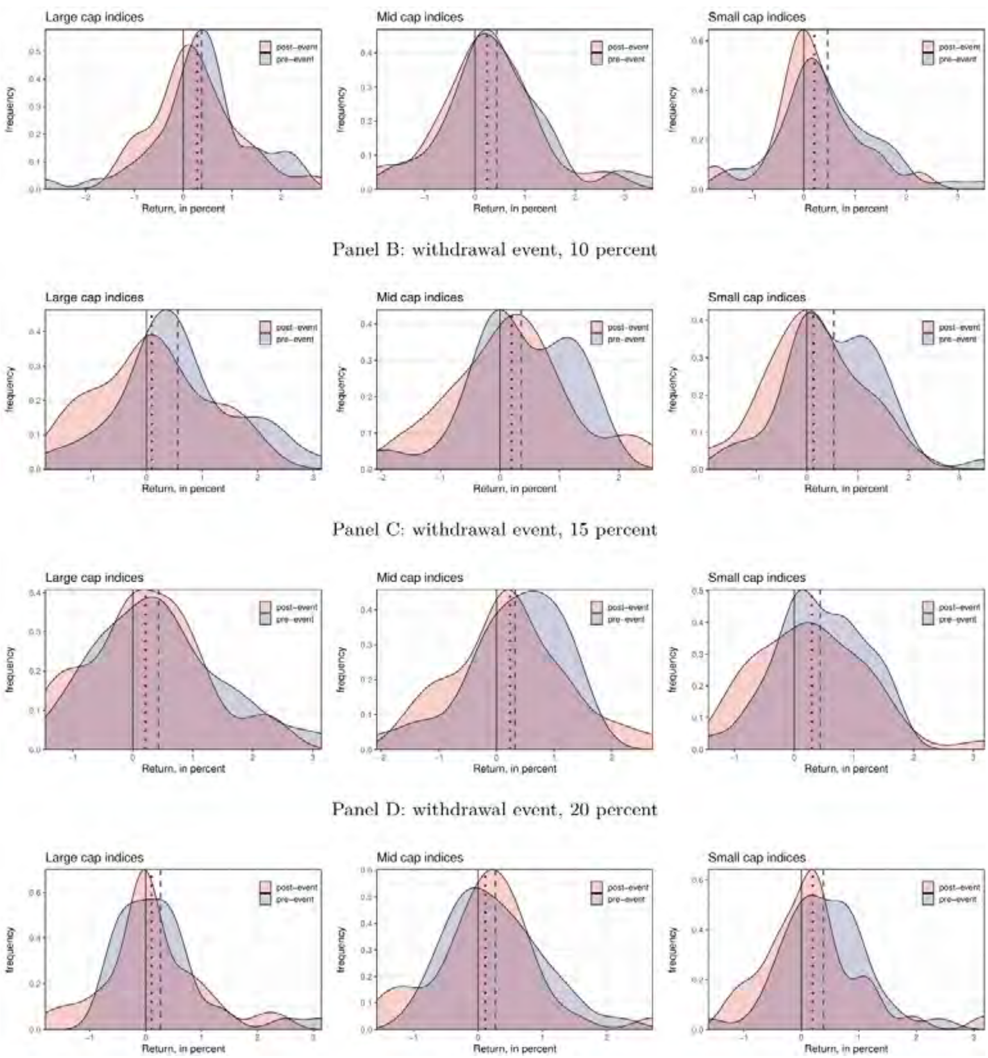
Figure 2. Stock indices, average daily returns in the 5-day pre-event and post-event periods



Note: The figure shows the distributions of the average daily returns of the stock price index in the pre-event (purple) and post-event windows (red) corresponding to large-, medium-, and small-capitalization firms. *Black* vertical line: *zero* return line; dashed *purple* line: mean average daily return during the *pre*-event period; dotted *red* line: mean average daily return during the *post*-event period.

Source: MSCI and authors' calculations.

Table 3. Pre-event and post-event windows, 5-day average daily returns

Event		Withdrawal, gov. impulse, 5 pct			Withdrawal, gov. impulse, 10 pct		
		Large cap	Mid cap	Small cap	Large cap	Mid cap	Small cap
Pre-event	Mean	0.379	0.439	0.464	0.563	0.354	0.529
	Minimum	-2.821	-1.870	-1.614	-1.818	-2.074	-1.614
	Maximum	2.418	3.556	3.519	3.145	1.680	3.490
	Std. dev.	1.027	1.075	0.998	1.076	0.892	0.967
	Skewness	-0.436	0.587	0.595	0.238	-0.646	0.312
	Kurtosis	1.009	0.893	0.901	-0.130	0.191	0.777
Post-event	Mean	0.287	0.244	0.209	0.092	0.195	0.127
	Minimum	-1.324	-1.959	-1.863	-1.740	-1.865	-1.942
	Maximum	2.830	2.789	2.306	2.074	2.571	2.218
	Std. dev.	0.905	0.984	0.867	1.006	1.032	0.931
	Skewness	0.624	0.168	0.047	0.109	0.233	0.036
	Kurtosis	0.336	0.506	0.600	-0.897	-0.205	-0.380

Event		Withdrawal, gov. impulse, 15 pct			Withdrawal, gov. impulse, 20 pct		
		Large cap	Mid cap	Small cap	Large cap	Mid cap	Small cap
Pre-event	Mean	0.429	0.322	0.435	0.268	0.267	0.382
	Minimum	-1.391	-2.074	-1.438	-0.658	-0.930	-1.621
	Maximum	3.145	1.680	1.606	3.145	2.211	2.402
	Std. dev.	1.053	0.857	0.738	0.852	0.712	0.742
	Skewness	0.556	-0.800	-0.261	1.647	0.623	0.056
	Kurtosis	-0.147	0.261	-0.490	2.885	-0.040	0.957
Post-event	Mean	0.213	0.235	0.297	0.105	0.111	0.199
	Minimum	-1.459	-1.568	-1.122	-1.793	-1.568	-1.299
	Maximum	2.407	2.706	3.180	2.407	2.706	3.180
	Std. dev.	0.982	0.986	0.929	0.891	0.844	0.891
	Skewness	0.232	0.304	0.679	0.401	0.430	1.075
	Kurtosis	-0.440	-0.189	0.601	0.528	1.288	1.998

Source: MSCI and authors' calculations.

IV. Cross-Country Regressions

The cross-country regressions examine whether differences in socio-economic fundamentals help explain partly the stock market impact of government support withdrawals. The set of socio-economic fundamentals attempts to capture the strength of the economy before the pandemic started, the ability of the government to deploy an efficient pandemic response, the instability of the social fabric of the country, and the fiscal space available for providing government support.

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Data

Several priors guide our choice of proxies for the socio-economic fundamentals. The average annual GDP growth rate during the 5-year pre-COVID period (2015–2019), calculated using publicly available data from the IMF World Economic Outlook database, serves to capture the pre-COVID strength of the economy. Economies that entered the pandemic on a strong cyclical position may be likely to exit faster and get back to their pre-pandemic growth trajectory with less government support than those caught at a weak cyclical position.

Corruption could prevent a government from deploying the support effectively since it makes more likely that resources are not correctly allocated. Thus, we use the 5-year pre-COVID average value of the Corruption Perception Index (CPI) constructed by Transparency International as a proxy for the efficient allocation and utilization of the government support measures.[4] The index value ranges from zero, the highest corruption level, to 100, the lowest corruption level. The data are downloaded from the World Bank online data repository.

Ceteris paribus, countries enjoying ample fiscal space could afford keeping the government support measures in place longer, although stock market prices may still react negatively if the withdrawal is viewed as *premature*. On the other hand, in countries with little fiscal space, markets may be more forgiving. We approximate the fiscal space variable with the 5-year pre-COVID average primary fiscal balance-to-GDP ratio. The data are sourced from the IMF World Economic Outlook public database.

Our last socio-economic fundamental variable is social unrest. Arguably, support withdrawal in a country where the social unrest climate is high and public protests are numerous could lead to a escalation of social conflict and violence, which could have large negative impact on markets. In a peaceful society, the stock market impact would be more subdued, all else being equal. To measure social unrest, we use the Reported Social Unrest Index (RSUI) by Barrett and others (2020) to construct a social unrest count variable. The variable records the number of major

[4] The CPI is a composite index combining data from 13 surveys and the most widely used indicator of corruption worldwide.

unrest events that have occurred in a country since 2000,[5] where the major events are country-month observations satisfying the multiple criteria laid out in Barrett and others (2020).[6]

In addition to socio-economic fundamental variables, we also include a measure of how large the adjustment was at the time of the withdrawal event. Recall that the withdrawal event is measured as the first time the government response index falls below certain threshold values, i.e., 5 percent, 10 percent, 15 percent, and 20 percent. The withdrawal may be sudden and large at the time of the event, or it could have been gradual, extending over several days or weeks. In the former case there would be a larger impact on stock prices if no advanced notice of the withdrawal was available. We capture the event-related withdrawal adjustment as the percentage change of government response index during the post-event period relative to the pre-event period.

Finally, our last explanatory variable is related to the severity of the pandemic at the time of the withdrawals. Withholding or reducing government support when the pandemic is raging would have a very different impact on markets than when the pandemic is receding. We capture the severity of the pandemic by the ratio of the 7-day backward moving average increase in COVID cases at the time of the withdrawal event to the 7-day moving average of the highest daily increase experienced up to the event date. Importantly, a higher ratio indicates a premature withdrawal of stimulus in the sense that it means the COVID outbreak was still severe when the stimulus policies were withdrawn.

Table 4 presents the summary descriptive statistics of the explanatory variables as well as the stock price returns of the large cap, medium cap, and small cap segments of the national stock market indices. Panels A, B, C, and D correspond respectively to the withdrawal events of 5 percent, 10 percent, 15 percent, and 20 percent. The number of countries included in the regression is less than in the event study analysis since data for all the explanatory variables is not available. Also, the number of countries decreases as the threshold of withdrawal increases

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[5] We use 2000 as a cutoff year after balancing the number of events (i.e., to avoid too few events) with timeliness (i.e., to avoid looking too far back and being subject to fundamental changes in the socio-economic structures).

[6] Barrett and others (2020) recommend using this event count instead of the social unrest index itself for cross-country comparison studies. The index is normalized to 100 in each country regardless of the number of events, and thus its use in cross-country studies is questionable.

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Table 4. Summary statistics for data in cross-country regressions

Variable	Obs.	Mean	Median	Minimum	Maximum	Std. dev.
Panel A: withdrawal of government impulse, 5 percent						
Large cap return	37	-0.595	-0.507	-3.981	2.493	1.600
Mid cap return	37	-0.110	-0.264	-3.243	3.673	1.577
Small cap return	38	-0.267	-0.281	-3.404	4.920	1.771
Covid-19 acceleration	38	0.350	0.234	0.007	0.928	0.293
Withdrawal adjustment	38	0.904	0.915	0.752	0.948	0.040
Real GDP growth	38	2.857	2.446	-0.237	10.333	2.005
Corruption	38	59.342	57.600	30.200	88.800	19.536
Social unrest	38	3.132	3.000	0.000	7.000	2.095
Primary Balance to GDP	38	-0.502	0.085	-12.026	3.697	2.828
Panel B: withdrawal of government impulse, 10 percent						
Large cap return	32	-0.667	-0.585	-3.981	2.493	1.560
Mid cap return	32	-0.091	-0.201	-2.697	3.673	1.535
Small cap return	33	-0.277	-0.308	-2.839	4.920	1.763
Covid-19 acceleration	33	0.321	0.222	0.013	0.909	0.288
Withdrawal adjustment	33	0.861	0.876	0.731	0.899	0.047
Real GDP growth	33	3.093	2.682	0.096	10.333	2.019
Corruption	33	58.267	56.600	30.200	88.200	19.064
Social unrest	33	3.182	3.000	0.000	7.000	2.157
Primary Balance to GDP	33	-0.431	0.421	-12.026	3.697	2.984
Panel C: withdrawal of government impulse, 15 percent						
Large cap return	29	-0.672	-0.507	-3.981	2.493	1.469
Mid cap return	29	-0.208	-0.264	-2.598	3.673	1.297
Small cap return	30	-0.334	-0.519	-2.644	4.920	1.625
Covid-19 acceleration	30	0.275	0.133	0.006	0.880	0.283
Withdrawal adjustment	30	0.789	0.816	0.532	0.850	0.071
Real GDP growth	30	3.147	2.750	0.096	10.333	2.107
Corruption	30	59.020	57.600	31.800	88.200	18.138
Social unrest	30	3.067	3.000	0.000	7.000	2.132
Primary Balance to GDP	30	-0.493	0.259	-12.026	3.697	3.114
Panel D: withdrawal of government impulse, 20 percent						
Large cap return	27	-0.756	-0.662	-3.981	2.493	1.490
Mid cap return	27	-0.212	-0.264	-2.598	3.673	1.337
Small cap return	28	-0.365	-0.747	-2.644	4.920	1.680
Covid-19 acceleration	28	0.243	0.132	0.006	0.928	0.277
Withdrawal adjustment	28	0.738	0.756	0.532	0.797	0.059
Real GDP growth	28	3.313	2.911	0.936	10.333	2.074
Corruption	28	59.957	59.500	31.800	88.200	18.400
Social unrest	28	3.071	3.000	0.000	7.000	2.210
Primary Balance to GDP	28	0.204	0.460	-2.717	3.697	1.621

Sources: IMF, MSCI, Oxford University, World Bank, and authors' calculations.

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Table 5. Cross-country regression samples

Country	sample	Country	sample	Country	sample	Country	sample
Argentina	a	India	a, b, c, d	Morocco	a, b, c, d	South Africa	a
Austria	a, b, c, d	Indonesia	a, b, c, d	Netherlands	a, b, c, d	Spain	a, b, c, d
Belgium	a, b, c, d	Ireland	a, b, c, d	New Zealand	a, b, c, d	Sweden	a, b
Canada	a	Israel	a, b, c, d	Norway	a, b, c, d	Switzerland	a, b, c, d
Czech Republic	a, b, c, d	Italy	a, b, c, d	Pakistan	a, b, c, d	Thailand	a, b, c, d
Denmark	a	Japan	a, b, c, d	Peru	a, b	Turkey	a, b, c, d
Finland	a, b, c, d	Jordan	a, b, c, d	Philippines	a, b, c, d	United Arab Emirates	a, b, c, d
Germany	a, b, c, d	Kuwait	a, b, c	Poland	a, b, c, d	United Kingdom	a
Greece	a, b, c, d	Malaysia	a, b, c, d	Portugal	a, b, c, d		
Hungary	a, b, c, d	Mexico	a, b	Saudi Arabia	a, b, c		

Note: a: 5 percent withdrawal sample; b: 10 percent withdrawal sample; c: 15 percent withdrawal sample; d: 20 percent withdrawal sample.
Source: Authors' calculations.

(fewer countries committed to larger withdrawals). Depending on the event, the number of countries in the regression ranges from as high as 38 to as low as 28 (Table 5).

Following a withdrawal, the average stock price return falls in all three segments of the market, regardless of the size of the withdrawal. Larger withdrawals tend to be associated with larger stock price return declines although, as noted also in the previous section, the differences between the pre-event and post-event returns are not all statistically significant.

Methodology and Results

To examine in more detail what drives stock price returns lower following a withdrawal, we conducted a simple cross-country analysis by regressing the change in the stock return (i.e., the post-event return minus the pre-event return) on the pandemic severity, magnitude of withdrawal, and socio-economic fundamental variables. Table 6 presents the results of the cross-country regressions for the withdrawal events of 5 percent, 10 percent, 15 percent and 20 percent in the three market segments of national stock markets (large, medium, and small-cap markets).

Our main variable of interest is the COVID acceleration variable, which proxies for the pandemic severity at the time of the withdrawal event (with a higher value indicating an "earlier" or premature withdrawal). As shown in Table 6, the sign of this variable is generally negative,

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Table 6. Cross-country regressions

	Market segment					
	Large cap	Medium cap	Small cap	Large cap	Medium cap	Small cap
	Withdrawal, gov.impulse, 5 percent			Withdrawal, gov.impulse, 10 percent		
Covid-19 acceleration	-1.129	0.164	-0.499	-1.375	-0.882	-0.678
	(0.216)	(0.872)	(0.641)	(0.166)	(0.446)	(0.573)
Withdrawal adjustment	7.582	11.949*	7.839	4.404	9.521	3.854
	(0.192)	(0.072)	(0.256)	(0.394)	(0.124)	(0.548)
Real GDP growth	0.205*	0.125	0.260*	0.271**	0.154	0.328**
	(0.083)	(0.342)	(0.066)	(0.034)	(0.290)	(0.040)
Corruption	-0.057***	-0.042**	-0.050**	-0.044**	-0.025	-0.033
	(0.002)	(0.031)	(0.016)	(0.017)	(0.227)	(0.137)
Social unrest	-0.280**	-0.265*	-0.424***	-0.195	-0.161	-0.331*
	(0.037)	(0.077)	(0.009)	(0.157)	(0.319)	(0.061)
Primary Balance to GDP	-0.144	0.005	-0.061	-0.165*	-0.042	-0.085
	(0.110)	(0.957)	(0.561)	(0.071)	(0.688)	(0.448)
Constant	-3.428	-7.998	-3.685	-1.711	-6.512	-1.431
	(0.504)	(0.171)	(0.546)	(0.702)	(0.224)	(0.798)
Observations	37	37	38	32	32	33
R-squared	0.428	0.253	0.331	0.447	0.204	0.307
	Withdrawal, gov.impulse, 15 percent			Withdrawal, gov.impulse, 20 percent		
Covid-19 acceleration	-2.584**	-1.478	-1.577	-1.970*	-0.902	-1.406
	(0.025)	(0.228)	(0.238)	(0.080)	(0.453)	(0.264)
Withdrawal adjustment	-2.428	2.582	-1.593	-5.108	3.119	-0.578
	(0.486)	(0.506)	(0.713)	(0.242)	(0.512)	(0.911)
Real GDP growth	0.356***	0.345**	0.448***	0.340**	0.327**	0.479***
	(0.006)	(0.014)	(0.005)	(0.012)	(0.026)	(0.004)
Corruption	-0.040**	0.009	-0.013	-0.035*	0.014	-0.006
	(0.036)	(0.663)	(0.556)	(0.083)	(0.528)	(0.797)
Social unrest	-0.166	-0.181	-0.311**	-0.138	-0.129	-0.272*
	(0.179)	(0.188)	(0.048)	(0.294)	(0.373)	(0.094)
Primary Balance to GDP	-0.278***	-0.153	-0.204*	-0.303*	-0.104	-0.220
	(0.003)	(0.115)	(0.060)	(0.061)	(0.543)	(0.247)
Constant	3.572	-2.987	1.584	4.973	-3.800	0.063
	(0.317)	(0.450)	(0.719)	(0.239)	(0.409)	(0.990)
Observations	29	29	30	27	27	28
R-squared	0.577	0.327	0.457	0.535	0.301	0.457

Note: *** 1 percent, ** 5 percent, * 10 percent significance.
Source: Authors' calculations.

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which indicates that early withdrawals are received negatively when infection rates are high. Moreover, the absolute value of the coefficients increases as the withdrawal becomes larger.

The coefficients of this variable are statistically significant only at the higher threshold levels of 15 percent and 20 percent. This is intuitive because markets may not notice small withdrawals (i.e., those in the range of 5-10 percent) or consider them large enough to affect the overall level of government support. Despite the different significance levels for the COVID acceleration variable under different threshold levels, our regression results are still robust in the sense that all other variables (including GDP growth, corruption, social unrest, and primary balance-to-GDP ratio) have the same signs and mostly the same significance levels across all threshold levels (see below).

In addition, the coefficients are statistically significant only in the large-cap segment of the market, which provides some suggestive evidence that large-cap companies benefit more from the stimulus. Of course, we do not control for other factors such as industry composition, so this result is only indirect evidence for the hypothesis.

The size of the withdrawal adjustment appears not to matter much. An examination of Figure 1 suggests a plausible explanation: in most countries in the sample, withdrawals have been gradual, which is reflected by the small variability of the variable summary statistics shown in Table 4.

The cyclical position of the economy prior to the pandemic, proxied by the average real GDP growth, has a positive effect, reducing the gap between pre-event and post-event returns. With the economy growing at a strong pace, corporations have had room to build strong profits and buffers and should be more resilient both to the pandemic shock and to the withdrawal of the stimulus.

Higher levels of corruption, especially at the lower threshold levels, contribute to the widening of the stock return gap. Arguably, one explanation is that in more corrupted economies, firms are more dependent on government support. This, in turn, tends to be awarded to firms better connected with the authorities. And as the firms are more dependent on government support, the market believes that they would fare worse once the support is withdrawn.

Social unrest appears to hurt firms in the small-cap segment the most, as evident by the magnitudes and signs of the coefficients. Arguably, due to their local and small-scale operations, small businesses are more affected by the business disruptions and worsened security associated with social unrest; with the impact softened by the availability of government support. Reduced government support could worsen social unrest and lower output in the medium and long-term (Hlatshwayo and Redl, Forthcoming; Sedik and Xu, 2020).

Lastly, the results corresponding to the fiscal space variable, the primary balance to GDP ratio, appear puzzling at first glance. The coefficients suggest that a country enjoying more fiscal space may experience a larger drop in the stock return of large-cap companies after the stimulus is withdrawn. One possible explanation is that market participants were disappointed when the government withdrew support while there was still ample fiscal space; they may question whether the government has made the right decision, and further question the soundness of the overall COVID-19 response strategy. Through this channel, economies with larger fiscal space tend to experience larger drops in stock returns compared with countries with restricted fiscal space. Recent surveys support the plausibility of this explanation (Fitch Solutions, 2020).

V. Conclusions and Policy Implications

In the time of COVID-19, extending the exceptional government support measures would lead to higher fiscal costs and increase the risk that the debt burden becomes unsustainable. Yet, unwinding the measures too early may disrupt the normalization of economic activities and damage the incipient economic recovery. This analysis attempts to quantify the market views on the trade-off using a combination of event studies and cross-country regressions.

The results show that markets, as proxied by the behavior of stock price returns, react negatively when government stimulus was withdrawn prematurely, that is, when the number of daily COVID-19 cases were still high relative to the recent past. In addition, we find that social unrest hurts smaller firms the most, and the problem could be compounded if reduced government support further fuels social tensions.

Future studies can further enhance our event study methodology. One option is to explicitly account for other driving forces and model the counterfactual stock returns more rigorously through time series models, similar to the methodology used in Acharya, Liu, and Zhao (2020).

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The cleanest way is probably to model the counterfactuals country by country, although this may be computation-intensive.

Despite the need for further work, hereby we still lay out some policy implications to stimulate more discussions. First, it may not be wise to withdraw the fiscal support measures when the economy is not "out of the woods" yet. The pandemic experience so far, based on countries following diverse health and pandemic prevention policies, is that there could be successive infection waves as social distancing and mobility restriction measures are lifted so caution is warranted. In addition, even if policymakers are confident that there is no new COVID waves, the presence of long-lasting scarring effects would also prevent the economy from a quick recovery if the support measures were withdrawn too early.

Second, a "blanket" withdrawal of the support measures (and forced re-use of the COVID fiscal support in case a new wave hits) may not work. Therefore, it is of utmost importance to design a clear contingency plan and communicate it clearly before announcing the withdrawal. The plan should clearly communicate that the reason why the government is withdrawing the exceptional fiscal support measures now is to restore fiscal prudence and ensure debt sustainability; but that the government stands ready to step in and resume support measures in case the pandemic situation deteriorates or the economic recovery falters. Compared with a blanket withdrawal, implementing such a contingency plan would anchor expectations and achieve a better balance among prudence, agility, and credibility of the fiscal policy framework.

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Family ties and the pandemic: Some evidence from Sars-CoV-2

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This paper provides an empirical analysis of the relationship between the strength of family ties and the spread of Sars-CoV-2. The dataset is constructed for a cross-section of 63 countries combining different data sources, to cover seven dimensions: the spread of the virus, family ties, trust and religion, policies implemented to stop the outbreak, status of the economy, geography, demography. We observe a robust positive relationship between family ties and the contagion rate across the world; in particular, the attitude of parents towards the wellbeing for their children is the main force that drives the positive correlation with the contagion. Instead, the respect toward parents (the variable love-parents) seems to be a component of the family ties which negatively correlates with the diffusion of Sars-CoV-2, leading to the final quadratic relationship between the overall family ties strength and the spread of the virus. As conclusive evidence, we observe that the death rate, as well as the recovery rate, are not affected by the strength of family ties and other social capital variables. What matters, in this case, are structural variables like GPD, number of hospital beds per capita, life expectance, median age and geographical location.

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1 Introduction

The spread of Sars-CoV-2 around the globe has seriously affected the lives of most people. After an initial outbreak in China, the virus has incredibly spread worldwide and mostly affected all European countries and then the USA, India, and South America. Some papers have tried to understand the path of the virus transmission and the main determinants of the disease diffusion. There are many possible variables: apart from the epidemiological nature of the virus, the efficiency of the health system, the intensity of lockdown and isolation policies enforced by many countries, masks wearing, the number of hospital beds and intensive care units to end with the role of preventive medicine and territorial health structure. In general, not appropriate attention has been paid to the role of other structural variables, such as the social, family and demographic structure of different nations and geographical area.

We believe that to get a good explanation of the different virus transmission across the globe we need to adequately consider, foremost, epidemiological factors, health variables and containment policies enforced by governments; but also to address the demography of the different populations and the social structure of various countries; in particular, the role of family ties in each area and relationships among generations existing in each country.

In this paper, after a brief recall of the literature on virus transmission, in the third paragraph, we address the issue of the role of family ties in explaining many social phenomena, in particular the spread of the coronavirus. We discuss the reasons why the family structure (and relationships within families) may be a key factor if one wants to understand differences in the Covid-19 cases and the number of deaths across countries. In the fourth paragraph, we describe our original dataset based on data taken from World Values Survey (WVS), John Hopkins' Covid data archive and GlobalEconomy.com. In the fifth one, we present our econometric estimates which show that family ties are a key variable, able to explain a large part of the different distribution of Covid-19 cases and deaths across the world. This outcome can be very useful to several governments in defining and implementing what may be an effective policy to address the virus transmission.

A good policy to address the Sars-CoV-2 should be based not only on medical factors or containment policies, but also on regulating social and family behaviours of different population – for example, by enforcing social distancing within the families, or keeping kids away from grandparents or limiting their relation, or simply asking relatives to take adequate precaution when they meet, as wearing masks and gloves, keeping distance, etc. – and giving the proper attention to school as a channel for the virus transmission. Family and social dimensions may be in the end successful in containing the virus diffusion as health prevention and medical treatment.

2 What do we know on virus transmission and containment policies

The literature on virus transmission with some exceptions is very recent. There are some few papers which address the determinants, the health economics and the effects of the pandemic that have affected the globe between 1918 and 1920. Barro (2020), Barro -Ursùa-Weng (2020) and Aasve et al. (2020) show that the pandemic of the Nineteenth century had very different geographical patterns and that social distancing measures were very effective in preventing the spread of the virus. In the same time, the degree of trust – the trust that people have with respect to other people and governments – and social capital have clearly emerged as one of the key variables for the success of the containment policies enforced by public authorities and limiting the virus diffusion.

The number of infected people and deaths in the 1918-1920 pandemic was very high and terrible. Between the Autumn of 1918 and the spring of 1919, the influenza pandemic was able to cause a death toll of almost 50 millions of people – there is a degree of uncertainty on this magnitude, also given the limited way of tracing and accounting deaths linked to the pandemic at that time – while the number of estimated cases was at least four times the number of people who died. The key aspect which contributed to the virus spread was the end of the First World War that originated an incredible movement of people across Europe – soldiers were going back home from the battlefield. At that time, however, the virus circulated relatively slowly and essentially was brought by soldiers, who were looking to get back to their home – travelling and commuting were very limited at that time. This in part explains why there were three major waves in the 1918-1919 pandemic (some authors also considered a fourth minor wave at the beginning of 1920). Of course, the health technology and the knowledge at the virus diffusion at that time were quite limited, as the way of communicating and exchanging key information among countries.

In the 2020 pandemic, the virus transmission has been much quicker, since travel opportunities, the role of airplane flights, movements of people linked to touristic activities, shipping of goods worldwide, and many other means of moving around the globe are now incredibly more significant. One interesting question is whether, given the different health and social conditions of the other pandemics in history, we have to expect major waves following this winter 2020 and in the early spring of 2021[1]. At this moment, we are not sure of the trend of contagion in the next few months and if we have to live with the virus for some period of time; if our epidemiology technologies and infections controlling capabilities are strong enough to prevent new diffusion; if people will have to keep going in adopting social distancing and mask wearing; or if and when finally the vaccine will be discovered and its distribution to most of the human being living on the earth accomplished.

The history of pandemics shows that most of the virus tend to remain for a certain period – two or more waves, which is linked to the specific virus epidemiology and to the speed of public authorities' response and the responsible behaviour of population. The current main

[1] When this work was closed (end of October) is clear that a major second wave, bigger than the first one, is currently under way.

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challenge is whether with our epidemiological techniques, we will be able to moderate and flatten the next probable curves in virus transmission. However, these months after the onset of the pandemic have already taught us some key factors in addressing this pandemic which is useful to briefly assess. One of the key factors is how the virus tends to spread across time: a recent analysis[2] clearly shows that the epidemiological curve not necessarily follows the path of an exponential curve, but rather tends to rise rapidly, peak and then to flatten. The initial phase, in the very first two-four weeks, is exponential[3] but then, given the government response and the change in the behaviour of the population, the curve tends to smooth and slowly decrease. In these last two months (September and October) we have experienced a clear upsurge of the pandemic, which seems evidently related to a certain relaxation of the social isolation measures which took place during the summer holiday. This is crucial for the understanding of pandemic mechanics and its evolution and the definition of accurate public policies to address the pandemic diffusion.

One first important aspect is the different reaction across the various countries in adopting lockdown measures, such as self-isolation, wearing masks and tools of protection. Given that we do not have yet a good medical solution to Sars-CoV-2, the current policy to address the virus has to be based on social distancing and enforcing good practices in human behaviour[4]. There is clear evidence that in regions and states where the lockdown measures were stronger and more intense, the death rate and the number of infected people were considerably lower. Based on a sample of 11 European countries among which Italy, Spain, UK, France and Germany, Flaxman et. al. (2020) found that the adoption of major non-pharmaceutical measures like national lockdowns, closure of schools, ban of public events and social gathering, have had a big effect in reducing transmission, diminishing the Reproduction Index below 1 for all the observed countries.

However, this is generally true only when people largely trust others and the government – when the quality of institutions is high and people follow the norms and show a high level of social capital – and therefore the severity of measures is followed by people and leads to a significant geographical restriction on the movement of individuals[5]. Along the same line, Scala et al (2020) show the importance of the right timing of restriction policies and mobility limitations: "while an early lockdown shifts the contagion in time, beyond a critical value of lockdown strength, the pandemic tends to restart after lifting the restrictions". Hsiang et al. (2020) show that even if closing schools and restriction of the movement of the population tend to produce high and very significant economic effects (on GDP and employment), the anti-contagion measures have been quite successful in slowing down the exponential growth of the virus in the initial phase, therefore saving in economic terms and human lives a considerable amount of money. Aksoy et al. (2020) focus on the role of public attention in

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[2] Baldwin (2020).

[3] We checked the data for many countries, even with a different starting point in time – Italy was, after China, the first Western country to experience the start of the pandemic at the end of February, followed then by Germany, Spain and France. After a period of incredible growth, which lasted more than a month, the number of infected people clearly dropped in a couple of months.

[4] See on this Van Bavel et al (2020), Baldwin-Weder di Mauro (2020) and Batscher et al (2000).

[5] See on this the data and the analysis made by Flaxman et al. (2020).

the reaction of governments. Countries with high institutional quality, in which public attention to Covid-19 (measured as the share of daily Google searches in a country related to Covid-19) increased fast after the first case, rapidly introduced non-pharmaceutical measures. Countries with high institutional quality but low public attention waited more time before introducing any anti-contagion measures. These slow responses appear to have increased consequent death tolls.

The recent data on virus diffusion clearly show that in Brazil, US, India, Iran and Israel, for some different reasons, the slowness to adopt stricter measures against the infection – social distancing, use of masks, etc. – have caused a considerable increase of the virus diffusion. During this summer, the relaxation of many containment measures and the increase in travelling and movement of people, connected to summer vacations in some European and Western countries, are provoking clear signs of a new upsurge.

Going to the data on Covid diffusion, some studies show that social distancing is one of the main crucial variables in determining the different scores on Covid cases and the number of deaths. Greenstone-Nigam (2020) prove that physical isolation was very effective when adopted for containing the virus' spread. In countries where social distancing has been adopted, and especially in the early stage of the Covid diffusion, the reduction in the number of infections and deaths have been very strong and well-defined. According to Old and Scott (2020), as mortality rates of COVID-19 increase strongly with age, social distancing, especially for older and at-risk groups, becomes an important variable. In this regard, comparing the age and longevity structure of the United States in 1920, with the current one, the value of social distancing today is more than three times higher than the corresponding value of 1920.

Some papers have addressed the complex issue of whether the weather condition, mainly the temperature (Celsius degree) and percentage of humidity that characterized some specific geographic area, may have affected the number of cases and in general the transmission of the virus. While some evidence show that there is a clear correlation with the degree of humidity, the level of air pollution and the average temperature, the epidemiology studies showed that especially after the Covid diffusion in very warm countries in May-July 2020 – such as India, South Africa and other African and Central America countries – this relation tends to be not so robust, if not fully weak.

As regards the degree of humidity, Ward et al. (2020) found a negative correlation with the number of Covid-19 cases in Australia: a 1% decrease in relative humidity increases the number of cases of 7-8%. Similar findings have been found for China (Hubei Province) by Qi et al. (2020). The fact that the two studies have been carried out in different hemispheres and in different seasons (Autumn in Australia, Winter/Spring in China) suggests the universality of a negative correlation between the degree of humidity and the magnitude of the pandemic.

Coker et al. (2020) addressed the role of air pollution in the Corona outbreak. A polluted environment may threaten the respiratory system, increasing the severity of Sars virus consequences for patients. They highlight a positive link between ambient PM2.5

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concentration on excess mortality rate in Northern Italian Regions, the area of the country most badly affected by the pandemic.

The degree of people's mobility and the intensity of travelling and commuting are another obvious variable that may explain the different data of Covid cases and the spread of the virus. Bonaccorsi et al (2020) and Scala et al. (2020) show that the intense restriction in mobility (measured by the telephone traffic), as a consequence of lockdown measures taken after the virus outbreak, was quite effective in containing the virus diffusion and flatten the curve.

Another interesting variable that shows a clear correlation with virus transmission is the degree of economic development of various nations. Countries with a higher Gdp (per capita) have scored better, meaning an obvious ability to detect better the infection, a superior reaction and effectiveness in promoting containment policies. This is also due of course to the fact that wealthier countries also tend to have better and more effective health systems. The same picture also emerges from other data that are strictly connected with the countries' level of Gdp, such as the degree of trade openness and exchange of good and services. We should also expect that the effectiveness and efficiency of the various national health services, e.g., the number of hospitals, the number of bed and the size of intensive units, are the other crucial variables that may explain a low virus diffusion and a limited number of deaths.

Countries have also shown a different ability in tracing and introducing some forms of early warning that partially also explains the different results of various countries. For example, China has shown a robust ability to react to the virus diffusion, enforcing very strict lockdown measures. The same also seems true for Korea, Singapore and some other Asian countries. Of course, it is self-evident that authoritarian regimes and countries with weaker democratic institutions may be facilitated in enforcing social isolation measures and quickly to implement a fully lockdown policy, as compared to democratic regimes[6].

Social, psychological and behavioural attitude and response by people is another crucial factor that explains the performance of health systems and the number of people infected across countries. Van Babel et al (2020) highlights that the perception of threat plays a crucial role. Like other animals, human beings can perceive emotions and the feeling of danger that can be very effective in the virus containment, since it motivates people to adopt good practices and change unhealthy behaviour. However, as the last months of this summer are showing, people very often "exhibit an 'optimistic bias': the belief that bad things are less likely to befall oneself than others" – the importance of handwashing or wearing a mask have been partially abandoned and in many holidays spots in Europe, the touristic season has brought negligent behaviours. This bias can be very dangerous since it "can lead people to underestimate their likelihood of contracting" the virus and therefore to disregard health

[6] See Frey-Chen- Presidente (2020). The number of swabs and the ability to perform early tracing mechanism are other important variables in the Covid spread.

warnings, health general rules and guidelines suggested by the government. Of course, as we will see in a moment, this bias is much frequent when social capital is low, rules of law are less shared and followed, people do not respect social norms, the degree of trust is low – people have a low trust on other people and the government.

The intensity of social distancing has been quite different in various countries; the same is true for people's compliance to governments' decisions. Measures of social distancing have been gradually adopted during the initial phase – in the months of March and April – by most countries, even if there have been some surprising exceptions – Brazil, the same US, and in particular, Sweden and the UK – however, in the last country, the decision to leave everything opened before the end of March has been fully reversed.

The degree of compliance to more or less broad lockdown measures taken by various governments seems very interestingly to be essentially related to the degree of trust and social capital existing in various countries[7]. Trusting the government and other people is a key variable in shaping people behavior and there are individuals who behave better when they know other people will do the same. For example, Aasve at al. (2020) show that the pandemic had permanent effects on individuals' social trust. Borgonovi and Andrieu (2020) show that in the Us, the enforcement of social distancing and policies of containment (namely, the reduction in people's mobility) have been much larger in counties with high levels of social capital. In the same vein, Frey-Chen-Presidente (2020) show that – contrary to the initial feelings – the response of collectivist and democratic governments has been superior and more effective than authoritarian governments.

In a very interesting paper, Bartsher et al. (2020) explore the role of social capital in some European countries: in the initial phase of the pandemic, is more probable that areas with higher social capital tend to be the areas with more virus diffusion – since this area are also more socially active. After the initial phase, however, countries with high social capital show a clear reduction in the number of infections and positive cases – and this is true before the moment when the government decided to enforce a more or less full lockdown policy. Their estimates show that a one-standard deviation increase in social capital tends to produce between 12% and 32% fewer Covid cases per capita, from mid-March to mid-May. The area with higher social capital shows lower excess mortality and a stronger decline in mobility. The data also show that the main mechanism through which social capital may affect the number of infections is individual mobility. However, social capital reveals to be crucial not only in the pre-lockdown period but also when the drastic measure of social distancing and isolation are taken. Along the same line, Durante-Guiso-Gulino (2020) and Sapienza and Zingales (2020) show that the indicators of social capital and trust are clearly correlated with the number of people infected and the size of the contagion: areas with higher social capital have shown a sharper drop in mobility and infected people; and that, after partial reopening in some countries, social distancing measures remained more prevalent in areas with higher social capital.

[7] See on this Bartscher et al (2020), Ciminelli-Mandico (2020), Durante-Guiso-Gulino (2020), Borgonovi-Andrieu (2020), Barrios-Benmelech-Hochberg-Sapienza-Zingales (2020), Greenstone-Nigam (2020).

Finally, some papers showed that the nature of the political regime and the political colour of different areas had affected the Sars-CoV-2 diffusion. Interestingly, in the same vein, Painter-Qu (2020) show that in the Us, political colour and political preference may have affected social distancing enforcement and containment policies: people living in Republican counties are 'less likely to completely stay at home after a state order has been implemented relative to those in Democratic counties'.

3 The importance of family ties for trust, public morale and the transmission of social values

To explain the differences among countries in Covid-19 cases, we think that a crucial role has been played by family ties and social capital – which we know is strongly correlated to the family structure. Our key hint is the following: in the context where family ties are important, people tend to live more together; where grandparents, sons and nephews live all together, this may affect the different diffusion rates experienced by many countries.

In the last decade, some papers have tried to address the importance of family ties. The family ties and family structure matter a lot in explaining the level of trust, the growth rate of an economy, the social capital and many people's economic and political behaviour.

The first author who clearly described the importance of family ties was Edward Banfield in 1958[8]. The author depicts the family as "*amoral familism*", a situation in which there is "inability of the villagers to act together for their common good or, indeed, for any end transcending the immediate, material interest of the nuclear family. This inability to concert activity beyond the immediate family arises from an ethos – that of 'amoral familism (…) (according to which people) maximize the material, short-run advantage of the nuclear family; and assume that all others will do likewise" (p. 9).

Therefore, "in a society of amoral familism, no one will further the interest of the group or community except as it is to his private advantage to do so" (p. 83). In this society, it is tough to build and maintain public organizations, given the selfish attitude of individuals who rely exclusively on the family. This aspect is not new, unique, or so surprising, since in many other countries and among other people, "where legal authority is weak and the law is resented and resisted, the safety and welfare of the individual are mainly assured by the family"[9]. This characteristic of family ties is the key core of many countries in Southern Europe and Asia and has attracted some studies and research projects over the last 50 years.

Bisin and Topa (2002), Bisin and Verdier (1998, 2000, 2010) have highlighted the role of cultural transmission, in particular the transmission of social status and cultural traits: children are influenced by their family ('vertical transmission'), and then with the population at large

[8] Banfield (1958).
[9] Barzini (1968).

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and the environment in which they live with (e.g. teachers, schools, etc. ('oblique transmission').

Therefore, one may assume that moral values and social capital (e.g., social civicness and trust in institutions) may be essentially transmitted (although not exclusively) by families to their heirs, and that, these values tend to remain stable across a certain period of time. The persistence of moral values, the degree of civicness and social capital in most of the developed countries, and in particular in some Italian regions, as first proved by Putnam (1996) to extend across least six centuries, confirm the stability of moral value within the members of various families, and in some specific social and economic contexts. Family matters and matters a lot. Recently Sgroi et al. (2020) show that cultural traits in Italy are very persistent and tend to mimic those of their maternal grandmother. Family shapes the moral values of individual members; in particular, the values and the cultural traits of the youngest, in the end, affecting overall public ethics and tax morale. Therefore, the transmission of cultural values within the same family along different periods of time would also inevitably imply some, more or less pronounced, the stability of public morale, social capital, and trustworthiness.

Apart from the vertical transmission, there is also some, more or less intense, form of oblique transmission, where the social context (e.g., school, neighbourliness, etc.) helps to share moral values. In general, we observe substantial homogeneity among the various communities, and people's choice to reside in areas where other individuals live that share the same values. We also observe a strong persistence of cultural traits, attitudes, values, and lifestyles among various communities, with some pronounced resilience of cultural traits and heterogeneous values. For example, Orthodox Jewish communities in the United States, but also elsewhere in the world, are a clear example of cultural persistence. Outside the USA, we have the well-known case of Corsicans, Catalans, Irish Catholics, and Italians, especially in Northern Europe.

Guiso-Sapienza and Zingales (2006, 2007, 2010) and Butler et al. (2009) show that in Italy social capital tends to persist over the long-term (more than five centuries) and explains its stability since the experience of free-city-state in the Middle Age. Tabellini (2008, 2010), by using an approach based on instrumental variables, links cross-country variation in measures of trust to the quality of political institutions in the nineteenth century and attributes the persistence of institutions to indicators of individual values and beliefs, such as trust and respect for others. Of course, the finding of some significant statistical correlations does not imply causal relationships; endogeneity needs to be addressed.

Francis Fukuyama (1995) argues that "though it may seem a stretch to compare Italy with the Confucian culture of Hong-Kong and Taiwan, the nature of social capital is similar in certain respects. In parts of Italy and in the Chinese cases, family bonds tend to be stronger than other kinds of social bonds not based on kinship, while the strength and number of intermediate associations between state and individual have been relatively low, reflecting a pervasive distrust of people outside the family. The consequences for the industrial structure are similar: private sector firms tend to be relatively small and family-controlled, while large-scale enterprises need the support of the state to be viable."

The key finding is, therefore, that amoral familism tends to produce a special and stable social equilibrium, in which people exclusively trust and care about their immediate family: "expect everybody else to behave in that way, and therefore (rationally) do not trust non-family members and do not expect to be trusted outside the family" (Alesina-Giuliano, 2010, 2011) and Alesina et al. (2018). The 'power of the family' on individuals tends to affect their degree of political participation; therefore, resulting in low civic engagement and low generalized trust, confidence in public life, and the quality of political institutions. This kind of familism is predicted to hinder the development of high-quality political institutions, the pursuit of the common good, and participation in public affairs. In the same time, social capital strongly affects economic performances and that trust, and civic norms are stronger in countries with higher and more equal incomes, and better-educated and ethnically homogeneous population.

The importance of the family and the key role of family ties have been already emphasized as a key factor to explain many economic, political and social dimensions, such as the quality of democracy, the political participation, the economic growth, and the quality and the intensity of social capital – and we may add the compliance to containment policies in the case of a pandemic outbreak. We are not willing to say that family ties are always bad… "Strong or weak family ties are neither "bad" nor "good" but they lead to different organizations of the family"[10] and have different economic, moral, and social implications. Of course, a strong correlation does not necessarily imply causality: "do political institutions flourish only where the family is weak or is it the other way around? Does the family become self-sufficient only where the political institutions are not strong enough?"[11].

By summarizing, there is sound evidence that:

a) when the role of the family is strong, civic duty tends to be low, so is the social capital, tax morale and tax compliance. When family ties are weak, on the other hand, trust in the public sector tends to result in higher public morale and greater civic duty, and also tax evasion tends to be lower[12].
b) In Southern European countries, the role of the family is very important; however, this is also true in many other developed and less developed countries;
c) studies have demonstrated that countries where family matters tend to show less social capital, less participation, weaker political involvement, and a lower degree of trust;
d) Societies that rely heavily on families tend to have a lesser degree of trustworthiness and confidence in public institutions;
e) Family ties are often associated with negative economic performance, reduced rate of investment and growth.

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[10] Alesina-Giuliano (2011).
[11] Barzini (1978).
[12] See on this Schneider (2012), Alm (2012, 2014), Marè-Motroni-Porcelli (2020).

In this paper we investigate whether family ties and the power of the family affect the size of the virus' spread, the number of deaths and other variables related to the recent pandemic. To the best of our knowledge, this is the first study that attempts to address this issue.

4 Our Dataset

We build our dataset by merging different types of data at the country level. Information on COVID-19 outbreak, our dependent variables, have been collected from the Center for Systems Science and Engineering (CSSE) of the Johns Hopkins University. Data include, for 187 countries, the number of confirmed cases, the number of deaths and the number of recovered from the January 22 up to September 12, the day we closed the estimation (data are updated on a daily basis).

Information on the composition of the population, on the status of the economy, the policy response to the pandemic and other general structural characteristics of each country (including also information on the health care system), have been collected from "GlobalEconomy.com" and from "ourworldindata.org", two web repositories that combine official statistics and research data sources on almost all world countries of the world. In particular, regarding the status of the economy, we consider the following variables: GDP per capita, Trade openness, Globalization index, Gini income inequality index, the Human development index, Health spending per capita, the number of hospital beds per capita and Infant death. Regarding the structure of the population, we have included: Population size, Percent urban and rural population, Population ages above 65, Population ages 0-14, median age and life expectancy. The health care conditions have been measured considering the diabetes prevalence rate and the cardiovascular death rate. We took the following general variables to measure another relevant general characteristic of each country: Rule of law index, Corruption Perceptions Index, Fragile state index, Civil liberties index, Social globalization index, Student-teacher ratio primary school, Carbon dioxide emissions, Degree of transport and telecommunication infrastructure. In order to measure the policy response to the pandemic we collected the Government Response Stringency Index published daily on ourworldindata.org, this is a composite measure based on nine response indicators including school closures, workplace closures, and travel bans, rescaled to a value from 0 to 100 (100 = strictest). Finally, we also considered the following geographical characteristics: latitude and hemisphere.

Information on trust, attitude toward religion and composition of the family, especially to monitor the rate of older people living in the family, have been collected from the latest available World Value Survey (WWS) editions at the time of closing the estimations. In particular, we have extracted the following variables collapsed at country level in terms of averages: Trust people (people can be trusted? 1=agree, 2=disagree), Trust church ("how much confidence do you have in church" (1=a great deal, 4=none at all), Religious person ("are you a religious person", 1=religious person, 3=convinced atheist), Cohabitation with parents ("do you live with your parents", 1 = yes).

In conclusion, the strength of family ties, that represents our primary variable of interest, have been computed using the same data, and following the same procedure, proposed in Marè-Motroni-Porcelli (2020). The strength of the family ties can be measured considering three WVS variables. First of all, the variable that denotes directly the importance of the family (importance of family), which collects opinions about the importance of the family from 1, indicating high importance to 4 indicating less importance. The two other variables, instead, capture the strength of the family ties indirectly and from different angles: the relevance of love and respect for one's parents (love parents), and the duties and responsibilities of parents towards children (help child). In particular, the variable "love parents" measures how the respondent agrees with one of two statements: a) "Regardless of what the qualities and faults of one's parents are, one must always love and respect them;" or b) "One does not have the duty to respect and love parents who have not earned it". The variable "help child" captures to what extent the respondent agrees with one of the two statements: a) "It is the parents' duty to do their best for their children even at the expense of their wellbeing;" or b) "Parents have a life of their own and should not be asked to sacrifice their wellbeing for the sake of their children." The first option for both questions takes the value of 1, while the second alternative takes the value of 2. As suggested in Marè, Motroni, Porcelli (2020) in the empirical analysis, the strength of family ties is considered computing the principal component of the variable's importance of "family", "love parents" and "help child".

Table 1 and Table 2 that follow display, respectively, the detailed description and the descriptive statistics considering the regression sample of 63 countries. The variables reported in the tables have been divided into seven groups that correspond to the dimensions of our analysis: Covid-19 variables (dependent variables), Family ties, Trust and religion, Policy Economy, Geography, Demography. Finally, the variables reported are a restricted set of those collected, since we focus the attention only the variables used in the final specification of the empirical model in order to maximize the number of countries included in the analysis.[13]

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[13]The regression sample includes the following 63 countries, for which we could collect the main block of variables without missing values: Albania, Azerbaijan, Argentina, Austria, Bangladesh, Armenia, Belgium, Brazil, Bulgaria, Belarus, Canada, Chile, China, Croatia, Czechia, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Guatemala, Hungary, Iceland, India, Indonesia, Ireland, Italy, Japan, Jordan, Korea, South, Latvia, Lithuania, Luxembourg, Malta, Mexico, Moldova, Morocco, Netherlands, New Zealand, Norway, Peru, Philippines, Poland, Portugal, Romania, Russia, Saudi Arabia, Singapore, Slovakia, Slovenia, South Africa, Zimbabwe, Spain, Sweden, Switzerland, Turkey, Ukraine, Egypt, United Kingdom, Tanzania, USA.

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Table 1. Description, source, and availability of variables

Variables	Description	Source
Covid-19 variables (dependent variables)		
Covid cases per 10000 inhab.	Number of registered cases per capita since January 22 up to September 12 per 10000 inhabitants (daily average)	COVID-19 Data Repository Johns Hopkins University
Covid deaths per 10000 inhab.	Number of deaths registered since January 22 up to September 14 per 10000 inhabitants (daily average)	
Covid death ratio %	% of deaths over registered cases since January 22 up to September 14 (daily average)	
Covid recovery ratio %	% of recovered over registered cases since January 22 up to September 14 (daily average)	
Family ties		
Principal component	Principal component among "family," "loveparents", and "helpchild"	World Values Survey and European Values Study
Importance of family	"how important is family in your life" (1=very important, 4=not at all important)	
Love parents	"love and respect parents" (1=agree, 2=disagree)	
Help child	"parents should sacrifice own wellbeing for their children" (1=agree, 2=disagree)	
Trust and religion		
Religious person	"how important is religion in your life" (1=very important, 4=not at all important)	World Values Survey and European Values Study
Trust church	"are you a religious person" (1=religious person, 3=convinced atheist)	
Trust people	"how much confidence do you have in church" (1=a great deal, 4=none at all)	
Rule of law	"people can be trusted" (1=agree, 2=disagree)	

Variables	Description	Source
	Policy	
COVID measures stringency index	Composite indicator measuring the policy response of the governments to the spread of the COVID-19 outbreak over nine dimensions (school closures; workplace closures; cancellation of public events; restrictions on public gatherings; closures of public transport; stay-at-home requirements; public information campaigns; restrictions on internal movements; and international travel controls	Our World in Data
	Economy	
GDP	GDP per capita Purchasing Power Parity (average 2008-2018)	Our World in Data and The Global Economy repository
Human development index	Composite index that measures key dimensions of human development: life expectancy, literacy, educational enrolment and per capita GDP (year 2015)	
Health expenditure % GDP	Health spending (% of GDP) (average 2008-2018)	
No. of beds per 1000 inhab.	Hospital beds include inpatient beds available in public, private, general, and specialized hospitals and rehabilitation centers. In most cases beds for both acute and chronic care are included (year 2018).	
	Geography	
Latitude	Distance from the equator	COVID-19 Data Repository
North hemisphere	Dummy = 1 if the country is in the north hemisphere	
	Demography	
Age (median)	year 2015	Our World in Data and The Global Economy repository
Life expectancy in years	Life expectancy in years (average 2008-2018)	
Diabetes prevalence	Percentage of people ages 20-79 who have type 1 or type 2 diabetes (year 2017)	
Cardiovasc death rate	Number of deaths of cardiovascular disease per 100,000 individuals (year 2017)	

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Table 2. Descriptive statistics (regression sample)*

Variables	Obs.	Mean	Std. Dev.	Min	Max
Covid-19 variables (dependent variables)					
Covid cases per 10000 inhab.	63	19.8683	19.5229	0.0640	85.3092
Covid deaths per 10000 inhab.	63	0.8906	1.2172	0.0026	5.4686
Covid death ratio %	63	4.2134	3.5307	0.0607	14.2558
Covid recovery ratio %	63	63.4387	20.7174	0.0000	88.6117
Family ties					
Principal component	63	0.3542	0.9955	-2.1650	1.9461
Importance of family	63	1.2954	0.1718	1.0549	1.8619
Love parents	63	1.1337	0.0879	1.0158	1.4212
Help child	63	1.2206	0.1688	1.0270	1.7321
Trust and religion					
Religious person	62	1.3502	0.2471	1.0297	1.9614
Trust church	62	2.1904	0.5278	1.1151	3.3897
Trust people	63	1.6971	0.1719	1.2396	1.9358
Rule of law	63	0.5659	0.9958	-1.5645	1.9964
Policy					
COVID measures stringency index	63	51.88	19.84	0.00	92.67
Economy					
GDP	63	27385	18760	2268	93007
Human development index	61	0.822	0.104	0.535	0.953
Health expenditure % GDP	62	6.111	4.160	0.862	16.928
No. of beds per 1000 inhab.	61	4.232	2.794	0.530	13.050
Geography					
Latitude	63	38.4167	16.0184	0.7893	64.9631
North hemisphere	63	0.8571	0.3527	0.0000	1.0000
Demography					
Age (median)	61	37.69	7.48	17.70	48.20
Life expectancy in years	63	76.15	5.79	54.95	83.28
Diabetes prevalence	61	7.1	2.9	1.8	17.7
Cardiovasc death rate	61	231.3	130.0	79.4	559.8

(*) The number of observations is restricted to countries with no missing values in all variables.

5 The empirical model and the econometric results

Figure 1 and 2 reports a preliminary view of the main variables of our analysis. In particular, figure 1 shows the intensity of the Covid-19 outbreak across the 63 countries included in our analysis. In the cartograms, we report the number of cases and deaths per capita together with the death and recovery ratios, all in terms of daily average over the 235 days covered in the dataset. Figure 2 report, for the same number of countries, the intensity of the family ties measured with our three variables: help-child, the importance of the family, love-parents and the principal component constructed over the three variables.

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Figure 1 – Covid-19 outbreak data for the 63 countries included in the analysis

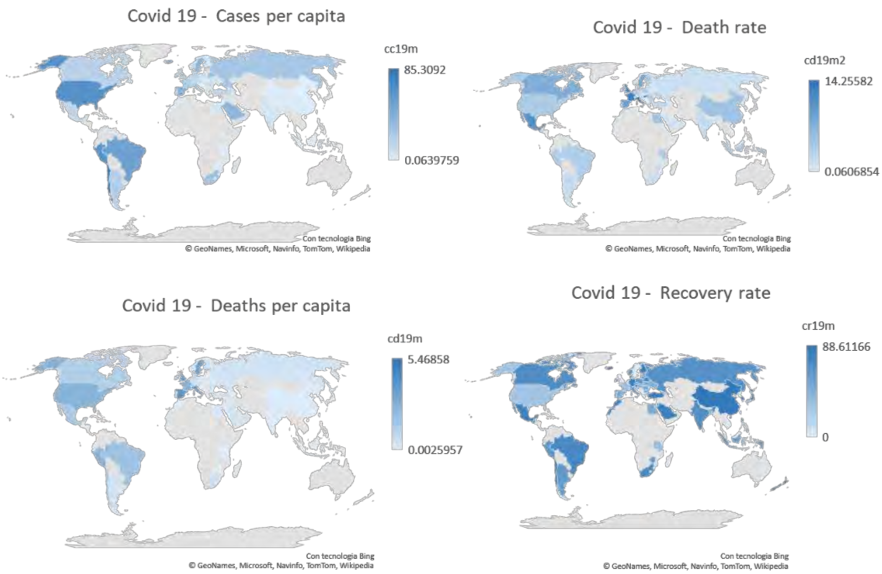
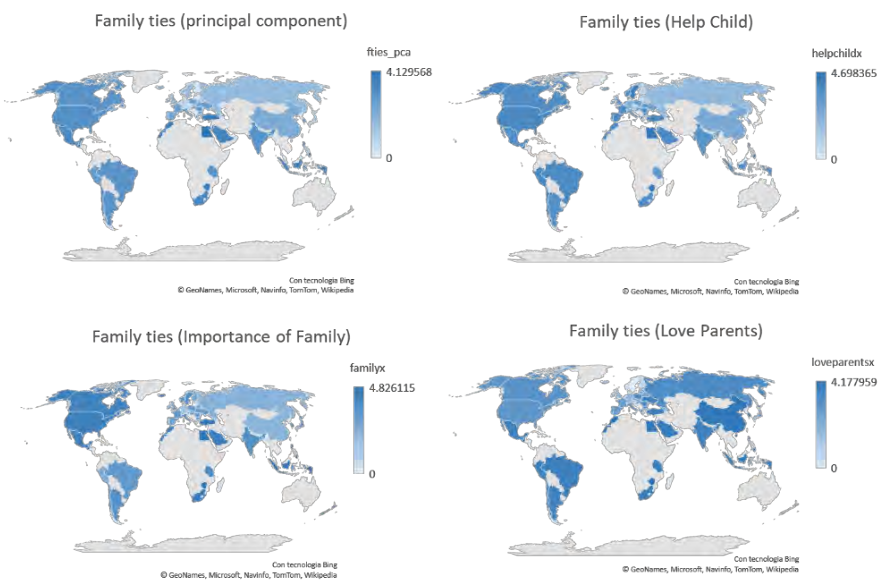


Figure 2 – Family Ties data for the 63 countries included in the analysis



Notes: original variables have been standardized and reversed to show a positive polarity

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The analysis of the raw data shows a clear nonlinear relationship between the strength of family ties and the impact of the COVID-19 outbreak. In particular, Figures 3, 4 and 5 show a set of scatterplots where, on the horizontal axis, we measure the intensity of the family ties in terms of the principal component and in terms of the original three variables, instead, on the vertical axis we report our dependent variables: the number of COVID-19 cases per 10000 inhabitants, the death rate and the recovery rate.

Clearly, in Figure 3 we observe a quadratic relationship between the strength of the family ties and the number of Covid-19 cases per 10,000 inhabitants. This preliminary evidence shows that the intensity of the family ties may play an essential role in the transmission of the virus, suggesting that where the importance of the family is substantial, the probability of contagious becomes higher. However, when we decompose the overall effect measured through the principal component into the three original variables, we obtain further interesting evidence. It seems that the attitude of parents towards the wellbeing for their children (the variable help-child), together with the variable that captures the importance of the family, are the elements of the family ties that correlate positively with the contagion. Instead, the respect toward parents (the variable love-parents) seems to be a component of the family ties which negatively correlates with the diffusion of Covid-19, leading to the final quadratic relationship between the overall family ties strength and the spread of the virus.

Figure 3 – Covid-19 cases vs family ties variables

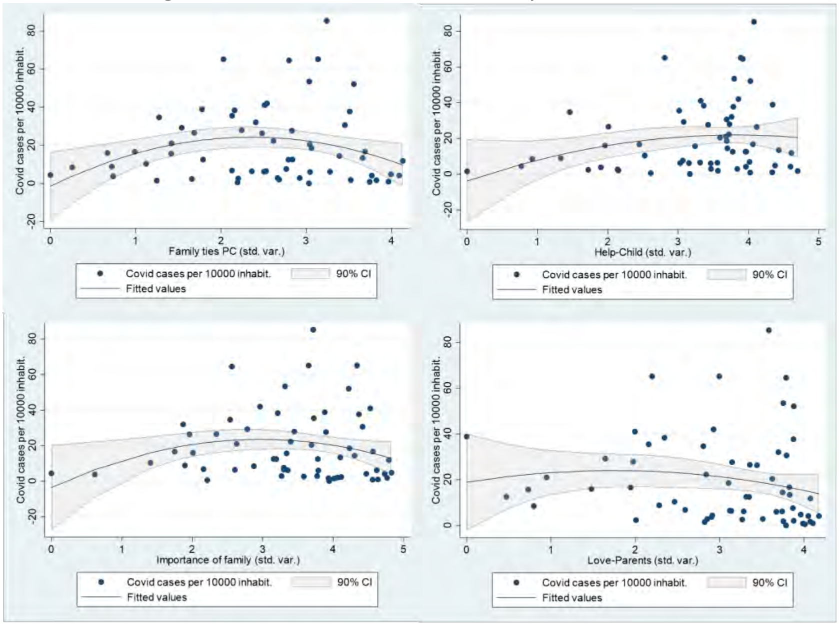

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Figure 4 – Covid-19 death rate vs family ties variables

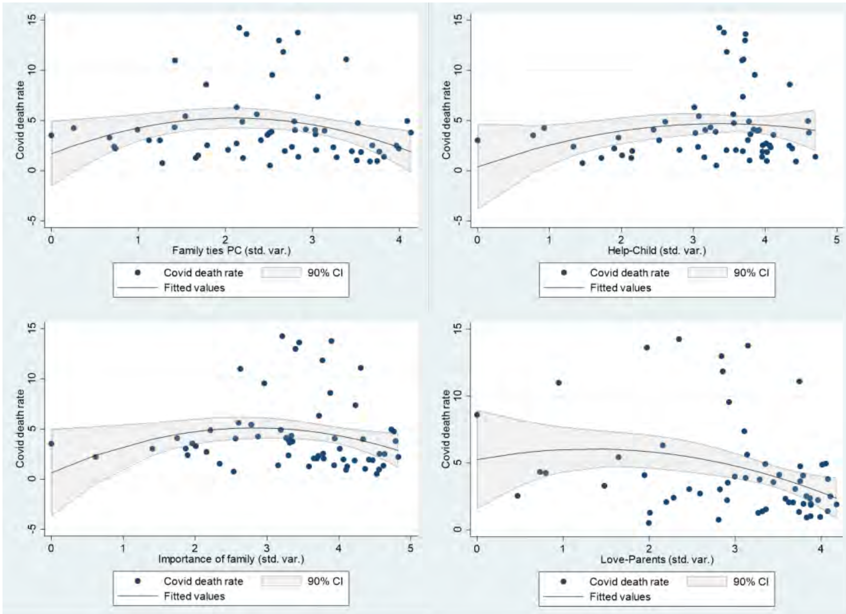
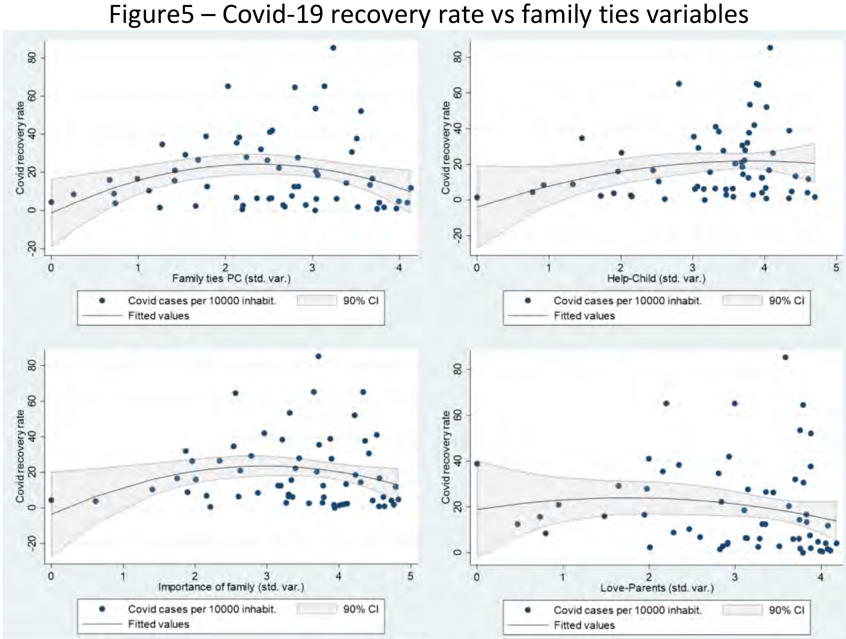


Figure5 – Covid-19 recovery rate vs family ties variables



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Figures 4, instead, visualizes the relationship between family ties variables and the death rate providing a very similar pattern to the one concerning the number of cases. Finally figure 5 reports the relationship between family ties variables and the recovery rate, in this case, the pattern of the relationship is inverted as expected.

To obtain a more robust analysis of the relationship existing between the strength of the family ties and the intensity of the virus diffusion, we specify the following linear model:

$$Y_i = \beta_0 + \beta_1 F_i + \beta_2 F_i^2 + \beta_3' \boldsymbol{T}_i + \beta_4 P_i + \beta_5' \boldsymbol{E}_i + \beta_6' \boldsymbol{G}_i + \beta_7' \boldsymbol{D}_i + \varepsilon_i \qquad (1)$$

where

- Y_i measures the intensity of the COVID-19 outbreak in terms of number of cases, number of deaths, death rate and recovery rate, these variables have been considered in terms of daily averages over the 235 days period covered in the dataset;
- F_i measures the strength of the family ties in terms of the principal component of the three original variables *(family, help child and love parents as reported)* and enter into the model with a quadratic structure;
- $\boldsymbol{T}_i$ is a matrix of social capital variables, including trust, religiosity and rule of law.
- P_i is the Government Stringency Index measuring the policy response of the governments over nine dimensions *(school closures; workplace closures; cancellation of public events; restrictions on public gatherings; closures of public transport; stay-at-home requirements; public information campaigns; restrictions on internal movements; and international travel controls)*
- $\boldsymbol{E}_i$ is a matrix of economic variables, including GPD, Human development index, Health expenditure, no. of hospital beds per capita;
- $\boldsymbol{G}_i$ is a matrix of geographic characteristics, including latitude and hemisphere;
- $\boldsymbol{D}_i$ is a matrix of demographic characteristics, including median age, life expectancy and health status.
- ε_i is the stochastic component of the model.

The coefficients have been estimated through the OLS estimator using robust standard errors to correct for heteroscedasticity, in the regression analysis, all variables have been standardized (with mean 0 and standard deviation 1) in order to make the results of the point estimates comparable across the betas and to identify, at the same time, what are the variables that exert the most substantial impact.

Our estimate is based on a cross-section approach. One may ask whether a panel structure may produce better results. Some authors use a day-by-day approach data on virus cases and deaths, from the beginning of March to the end of May (see for example Bartscher et al. (2020) that use regressions with the daily log cumulative Covid-19 cases on a measure of social capital and some daily fixed effects). We are not fully persuaded of the usefulness of such approach, since putting together daily data with variables with small variability across time may increase the number of observations but not to add much significance to the coefficients' econometric estimates. However, as a robustness check – see table A1 in the appendix – we have specified the same model as a daily panel without averaging the dependent variables. In this case, the

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coefficients have been estimated using a Feasible GLS estimator, leading to a set of results statistically identical to the one obtained with the cross-sectional approach.

The results of the point estimates of the relationship between family ties and covid-19 cases, based on our cross-sectional approach, are reported in Table 3, where each column corresponds to a different specification of the model. In column 1) we consider the full model, in columns form 2) to 9) we consider separately the other groups of variables included in the final specification.

Table 3. OLS point estimates of the impact of family ties on COVID-19 cases per capita

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
					Y = Covid cases per capita				
Famility ties PC	**0.454**	**0.756**							
	[0.046]**	**[0.001]*****							
Famility ties PC square	**-0.0997**	**-0.157**							
	[0.204]	**[0.003]*****							
Religious person	**-0.62**		0.142						
	[0.041]**		[0.529]						
Trust church	**0.585**		-0.0830						
	[0.010]***		[0.719]						
Trust people	**-0.406**		-0.0692						
	[0.003]***		[0.613]						
Rule of law index	**-0.500**		0.219						
	[0.083]*		[0.174]						
COVID measures stringency index	-0.109			-0.0457					
	[0.513]			[0.654]					
GDP per capita Purchasing Power Parity	**0.485**				**0.364**				
	[0.000]***				**[0.027]****				
Human development index	0.267				-0.0953				
	[0.300]				[0.456]				
Health spending % GDP	**0.244**					**0.168**			
	[0.085]*					**[0.009]*****			
No. of beds per 1000 inhab.	**-0.174**					-0.119			
	[0.084]*					[0.146]			
Latitude	0.0366						0.0558		
	[0.770]						[0.604]		
North hemisphere	-0.734						-0.443		
	[0.223]						[0.279]		
Median age in years	-0.163							0.0332	
	[0.371]							[0.658]	
Life expectancy in years	0.346								0.0755
	[0.357]								[0.532]
Constant	0.066	-0.623	0.00385	0.129	-0.0289	0.0148	0.466	0.119	0.0761
	[0.887]	[0.001]***	[0.973]	[0.153]	[0.814]	[0.879]	[0.215]	[0.193]	[0.501]
Observations	61	63	62	63	61	61	63	61	61
R-squared	0.475	0.069	0.065	0.004	0.133	0.112	0.041	0.002	0.111

*Notes: all variables are standardized, p-values in brackets , robust standard errors, * p<0.10, ** p<0.05, *** p<0.01"*

As shown in column 1) and 2) of Table 3, family ties exert a strong quadratic impact on the number of COIVD-19 cases as also reported in visual terms in Figure 3. Moreover, also other variables present a strong correlation with the number of COVID-19 cases leading to an R2 index of 47%.

As reported in table 3, we have interesting evidence stemming from social capital variables: trust in other people and religiosity are negatively correlated with the number of cases, instead trust in the church shows a positive correlation. The role of religion in shaping and affecting trust and public morale has attracted many scholars and researches in the last year (see among others Torgler 2006). The conclusions are in general ambiguous and the effect of religion on trust and the sense of civicness is not clear. We have some evidence that people who declare themselves as a very religious people then tend to obey to the rules of law and belief in common value, showing a high degree of trust and social capital; otherwise, there are other estimates where the belief in church and God tend to negatively affect the trust and public morale. In our case, we may presume that the degree of religiosity may have encouraged more compliant behaviour with social distancing and measures of physical limitation – wearing masks, keeping distance with other people and so on. It is not clear how to explain why trust in the church has positively affected the number of cases – one simple hypothesis may be that these people have resulted in increased attendance of churches and religious functions – and for that way to have had more chances to be infected.

The fight of the pandemic has been conducted, especially in the surge phase, through the adoption of the lockdowns and/or measures to limit the movements of people to the maximum extent possible. Both measures imply an extreme restriction of personal freedom, and for being successful, they need people to obey the rule of law strictly. It is reasonable to assume that a high attitude towards the respect of the rule of law and a high level of trust on the government and on other people have a positive impact in curbing the outbreak of the Coronavirus pandemic. In general, the assumption is confirmed with the various dependent variables, however, the magnitude of the effect is not very meaningful. Interestingly, the variable rule of law exhibits an opposite (negative) sign than family ties (positive sign, linear model), indirectly confirming the role of the family ties in the spreading of the virus.

Moreover, table 3, shows that GDP and health expenditure exhibit a robust positive correlation which was quite surprising at first sight. *Prima facie*, one should expect lower virus transmission in countries with higher GDP and higher health expenditure, which should imply a better and more efficient health system. One initial possible explanation is that this result is an effect of the efficiency of data collection. More developed countries were able to detect more cases than poorer ones. The number of swabs is positively correlated with the level of a country's health system. It is plausible therefore to assume that the more advanced countries have been able to discover, detect and therefore register, a greater number of cases. As a result, the number of deaths to be linked to the virus also becomes greater. The non-significance of the coefficient of health expenditure variable in regressions with the mortality and recovery rate can be seen as a confirmation of this hypothesis. The more advanced countries were able to detect more cases, but, also due to the lack of knowledge on COVID-19, they have not shown a greater ability to treat it. Another possible plausible explanation could be that most of the infections have originated in nursing homes and hospitals, which are more widespread in more developed countries which have historically greater investments in healthcare, a larger public health expenditure, and a more developed and efficient health system.

In table 4 we report the results of the same model specified with the three variables used to measure the strength of family ties in substitution of the principal component. The econometric analysis shows that the attitude of parents towards the wellbeing for their children (the variable help-child) is the family ties component that mainly generates a positive

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impact on the spread of covid-109. Therefore, we confirm the graphical analysis provided in figure 3.

Table 4. OLS point estimates of the impact of family ties on COVID-19 cases per capita, segmentation of different family ties variables

	(1)	(2)
	Y = Covid cases per capita	
Help Child	0.224	0.209
	[0.085]*	[0.007]***
Importance of family	-0.103	-0.0377
	[0.360]	[0.629]
Love Parents	0.0209	-0.124
	[0.896]	[0.098]*
Religious person	-0.628	
	[0.039]**	
Trust church	0.555	
	[0.027]**	
Trust people	-0.326	
	[0.017]**	
Rule of law index	-0.472	
	[0.091]*	
COVID measures stringency index	-0.12	
	[0.481]	
GDP per capita Purchasing Power Parity	0.538	
	[0.000]***	
Human development index	0.133	
	[0.625]	
Health spending % GDP	0.206	
	[0.215]	
No. of beds per 1000 inhab.	-0.0254	
	[0.858]	
Latitude	0.0688	
	[0.589]	
North hemisphere	-0.884	
	[0.101]	
Median age in years	-0.203	
	[0.268]	
Life expectancy in years	0.446	
	[0.257]	
Constant	0.0512	-0.0558
	[0.947]	[0.836]
Observations	61	63
R-squared	0.496	0.079

*Notes: all variables are standardized, p-values in brackets , robust standard errors, * p<0.10, ** p<0.05, *** p<0.01"*

In table 5, following the same structure of table 3, we report the results of the relationship between our variables and covid-19 death rate. Different evidence emerges now, the death rate is not correlated with family ties and social capital variables; what seems to matter now are structural and demographic variables. We observe a negative relationship with the number of hospital beds and life expectancy. Instead, a positive relationship emerges with the dummy "north hemisphere" and the median age and a negative relationship with the distance from the equator.

The empirical estimates highlight the crucial role of the age structure of various societies in the outbreak of Covid-19. It is reasonable to expect that where the share of those over 65 is higher, the Covid-19 cases and deaths increase. Finally, life expectancy exhibits a negative correlation with death rate meaning that in countries where people live longer the chance to recover is higher.

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Table 5. OLS point estimates of the impact of family ties on COVID-19 death rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
					Y = Covid death rate				
Famility ties PC	0.519	1.029							
	[0.282]	[0.017]**							
Famility ties PC square	-0.0851	-0.250							
	[0.457]	[0.010]**							
Religious person	-0.0397		0.599						
	[0.922]		[0.017]**						
Trust church	-0.51		-0.864						
	[0.226]		[0.003]***						
Trust people	-0.01		0.0965						
	[0.952]		[0.489]						
Rule of law index	-0.285		0.0462						
	[0.433]		[0.743]						
COVID measures stringency index	0.041			0.101					
	[0.749]			[0.270]					
GDP per capita Purchasing Power Parity	-0.216				-0.00538				
	[0.211]				[0.980]				
Human development index	**0.698**				**0.322**				
	[0.085]*				**[0.089]***				
Health spending % GDP	0.147					**0.329**			
	[0.396]					**[0.003]*****			
No. of beds per 1000 inhab.	**-0.535**					-0.116			
	[0.002]***					[0.231]			
Latitude	**-0.658**						-0.180		
	[0.000]***						[0.340]		
North hemisphere	**1.309**						**0.649**		
	[0.002]***						**[0.043]****		
Median age in years	0.407							**0.293**	
	[0.314]							**[0.012]****	
Life expectancy in years	**-0.772**								**0.268**
	[0.018]**								**[0.038]****
Constant	-0.326	-0.419	0.351	0.338	0.367	0.161	-0.0780	0.365	0.213
	[0.661]	[0.241]	[0.019]**	[0.014]**	[0.024]**	[0.147]	[0.322]	[0.008]***	[0.057]*
Observations	61	63	62	63	61	61	63	61	61
R-squared	0.532	0.083	0.197	0.009	0.089	0.158	0.043	0.076	0.173

*Notes: all variables are standardized, p-values in brackets , robust standard errors, * p<0.10, ** p<0.05, *** p<0.01"*

To conclude the set of empirical analysis, table 6 reports the results of the relationship estimated between our variables and covid-19 recovery rate. In line with the evidence emerged with the death rate analysis, social capital variables, and family ties exert a feeble impact on the recovery rate. Again, structural variables play the most important role here. We observe a strong positive impact generated by the number of hospital beds and life expectancy. Finally, geographical variables, probably associated with climate conditions, exert a strong effect on the recovery rate. Countries located in the northern hemisphere and closer to the equator show a lower recovery rate.

Table 6. OLS point estimates of the impact of family ties on COVID-19 recovery rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
					Y = Covid recovery rate				
Familiy ties PC	**-0.988**	**-0.873**							
	[0.069]*	**[0.040]****							
Familiy ties PC square	**0.229**	**0.182**							
	[0.072]*	**[0.066]***							
Religious person	-0.493		-0.565						
	[0.349]		[0.089]*						
Trust church	0.654		0.613						
	[0.109]		[0.059]*						
Trust people	-0.0339		-0.108						
	[0.870]		[0.609]						
Rule of law index	-0.148		0.0496						
	[0.591]		[0.769]						
COVID measures stringency index	0.0584			-0.0172					
	[0.692]			[0.859]					
GDP per capita Purchasing Power Parity	**0.351**				-0.0204				
	[0.029]**				[0.932]				
Human development index	-0.701				-0.00688				
	[0.133]				[0.976]				
Health spending % GDP	-0.247					-0.172			
	[0.226]					[0.217]			
No. of beds per 1000 inhab.	**0.372**					0.139			
	[0.029]**					[0.194]			
Latitude	**0.772**						0.295		
	[0.002]***						[0.117]		
North hemisphere	**-1.397**						-0.507		
	[0.005]***						[0.164]		
Median age in years	-0.0847							-0.0440	
	[0.796]							[0.714]	
Life expectancy in years	**1.025**								0.0424
	[0.014]**								[0.831]
Constant	0.867	0.877	-0.0605	0.0109	0.0118	0.110	0.216	0.00348	-0.0206
	[0.305]	[0.030]**	[0.666]	[0.937]	[0.939]	[0.299]	[0.352]	[0.980]	[0.884]
Observations	61	63	62	63	61	61	63	61	61
R-squared	0.42	0.040	0.052	0.000	0.001	0.052	0.059	0.002	0.038

*Notes: all variables are standardized, p-values in brackets , robust standard errors, * p<0.10, ** p<0.05, *** p<0.01"*

6 Concluding remarks

Our data show that family ties, among other factors, are a key variable in explaining the different diffusion of the Sars-CoV-2 pandemic in various countries. Countries where family ties matter, show a higher number of infections and deaths. These results are also confirmed when religion, trust (that affect public morale and the degree of people's civicness) and social capital are considered.

We get some surprising results with the role of national health systems: countries with larger health expenditures show more cases, and this may be due to the increased capacity of detection (the number of swabs) and monitoring of more developed countries, which are characterized by higher expenditure on health. However, as expected, health care systems with higher capacity in terms of the number of hospital beds per capita can reduce the number of deaths sensibly increasing, at the same time, the recovery rate.

Our results suggest a nonlinear impact of family ties on the spread of the virus. As family ties grow, there is an initial positive impact on the spread of contagion and mortality, with a subsequent reduction in the number of cases. This result and Figures 3-5 suggest that family

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ties and especially those that go from parents to their children tend to reduce the compliance to the compulsory measure of social distancing. Still, when such relationship between the members of the family becomes very strong, the need to safeguard the health of relatives, especially their parents, emphasizes the importance to keep the correct distance within the family.

There are some clear possible policy implications of our exercise. Given the different age structure of the population, and the different way of living within the families in various countries – with more frequent contact between parents, grandparents and children – we have evidence that countries where family ties are strong and more important, tend to show also a larger virus diffusion. Therefore, one key factor in preventing the virus circulation may be to find an acceptable and sociable way to limit contacts between the youngest and oldest. Social isolation, policies of limited lockdown, or even measures that prevent close contacts between the different members of families – especially the ones that go from parents to their children – seems to be a good tool for the restraint of the virus – at least in the initial phase of the pandemic diffusion, or when the number of infected people risks of getting out of control. Given the larger probability, the younger population has of being infected – most of the time even with very mild symptoms and no serious consequences – actions that temporarily isolate family members and protect people with different age structure may be quite effective in controlling the spread of the pandemic.

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Appendix

Table A1 - Impact of family ties on COVID-19 cases per capita, Death rate and Recovery rate. Daily panel, random effect model, estimated through F-GFLS.

	Cases		*Death Rate*		*Recovery Rate*	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Familiy ties PC	**0.242**	**0.494**	0.180	**0.492**	-0.234	-0.234
	[0.035]**	**[0.000]*****	[0.461]	**[0.072]***	[0.225]	[0.234]
Familiy ties PC square	-0.0550	**-0.102**	0.00506	-0.105	0.0500	0.0254
	[0.192]	**[0.002]*****	[0.934]	[0.115]	[0.300]	[0.590]
Religious person	**-0.331**		-0.100		-0.268	
	[0.034]**		[0.630]		[0.243]	
Trust church	**0.365**		**-0.363**		0.254	
	[0.004]***		**[0.077]***		[0.103]	
Trust people	**-0.240**		0.00333		-0.0176	
	[0.001]***		[0.965]		[0.865]	
Rule of law index	-0.240		-0.254		-0.0295	
	[0.138]		[0.170]		[0.818]	
COVID measures stringency index	0.00609		-0.00271		-0.00639	
	[0.343]		[0.277]		[0.401]	
GDP per capita Purchasing Power Parity	**0.320**		-0.106		0.116	
	[0.000]***		[0.292]		[0.123]	
Human development index	0.124		0.415		-0.287	
	[0.387]		[0.019]**		[0.155]	
Health spending % GDP	**0.141**		**0.138**		-0.123	
	[0.075]*		**[0.097]***		[0.137]	
No. of beds per 1000 inhab.	-0.0530		**-0.355**		0.105	
	[0.457]		**[0.000]*****		[0.135]	
Latitude	0.0572		**-0.523**		**0.321**	
	[0.443]		**[0.000]*****		**[0.002]*****	
North hemisphere	-0.501		**0.930**		**-0.463**	
	[0.116]		**[0.000]*****		**[0.013]****	
Median age in years	-0.0973		0.235		-0.0519	
	[0.385]		[0.268]		[0.721]	
Life expectancy in years	0.255		**-0.510**		**0.482**	
	[0.209]		**[0.007]*****		**[0.009]*****	
Constant	0.803	-0.883	-0.373	-0.996	0.857	-1.327
	[0.014]**	[0.000]***	[0.350]	[0.000]***	[0.013]**	[0.001]***
Day fixed effect	yes	yes	yes	yes	yes	yes
Country Random effect	yes	yes	yes	yes	yes	yes
Observations	14152	14152	14152	14152	14152	14152
R-squared	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

*Notes: all variables are standardized, p-values in brackets , robust standard errors clustered at country level, * p<0.10, ** p<0.05, *** p<0.01"*

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Centralisation, voter perception, and the sense of government unpreparedness during the COVID-19 pandemic in Italy[1]

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In this article, we rely on a periodic public opinion poll indicator of the performance of the mayor, collected for 103 large cities in Italy and in three waves (2015, 2017, and 2020), to examine whether and to what extent the exogenous shift in policy-making decisions induced by the COVID-19 pandemic has affected citizens' perceptions regarding attributions of responsibility. We leverage the variation in political alignment between central and local governments and implement a difference-in-differences research design, finding that when decisions are fully centralised (during the lockdown), the voter approval for the mayor of an aligned city decreases by of around 7%. Further analyses suggest that our results are more marked (i) during pre-electoral years as compared to other years of a term and (ii) in cities with a lower level of social capital. Lastly, we document that the decrease in the approval ratings of mayors observed in aligned cities reflects a sense of 'punishment' for the lack of central government preparedness against the pandemic.

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1 The scientific output expressed does not imply a policy position of the European Commission. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use which might be made of this publication.

2 European Commission, Joint Research Centre (JRC).
3 European Commission, Joint Research Centre (JRC).

1. Introduction

Municipalities are at the heart of the Italian decentralised system of government. As in most other countries, they are responsible for important public programs in the fields of welfare services, territorial development, local transport, infant schools, sports and cultural facilities, local police services, as well as infrastructural spending. These activities are easily recognised by citizens, who since 1993 are also entitled to directly vote for the mayor and municipal council members. It then follows that citizens often assign a decisive policy role to the mayor as she represents the first point of reference for pursuing their interests or addressing their issues (Sancino and Castellani, 2016), hence enhancing the citizens' capacity to attribute policy responsibilities to the right level of government. Nonetheless, on January 31st, 2020, the Italian central government proclaimed a national state of emergency, which entitled it to take any relevant measure to solve the crisis brought about by the COVID-19 pandemic. Since then, leveraging its increased centralised authority and in order to control the reproduction rate of the new coronavirus, the government progressively announced several measures that closed schools and universities, public spaces, non-essential businesses, and economic activities, along with restricting the movement of individuals (colloquially referred to as 'lockdown').

While it is widely recognised in the literature that under crisis a centralised decision-making system is more efficient than a multi-level political architecture of governance (Boin and 't Hart, 2003; 't Hart et al., 1993) because centralised decisions allow prompt and urgent responses to be taken (Bronner, 1982; Cohen, 1979; Perrow, 1967), the consequences of sharp changes in voters' ability to attribute policy-making responsibilities to the correct level of government have not been deeply explored yet.

The public economics literature suggests that the fragmentation of power should enhance clarity of responsibility and accountability (Powell, 2000) since the assignment of public functions to lower levels of government can discipline and control politicians.[1] Within this framework, scholars of comparative electoral behaviour suggest that voters are perfectly able to attribute responsibility for policy making (see, among others, Bowler et al., 2020; Duch and Stevenson, 2008; Fortunato et al., 2020; Kedar, 2005). In contrast, a critical view of decentralisation claims that in decentralised systems there are information problems that prevent accountability from being an effective control mechanism as incomplete information

[1] Voters must be able to distinguish who is responsible for what by establishing a causal link between outcomes and politicians' past actions (Ferejohn, 1986; Key, 1966).

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prevents individuals from establishing a causal link between outcomes and politicians' actions (Anderson, 2000; Anderson, 2006; Duch and Stevenson, 2008; Leyden and Borrelli, 1995; Lowry et al., 1998; Powell and Whitten, 1993; Royed et al. 2000; Treismann, 2007).[2] Basically, the decentralisation of authority to lower levels of government might increase the complexity of the system (Bagehot, 1867; Downs, 1957; Sartori, 1994), and therefore voters cannot possibly understand the policy-making process in sufficient detail to accurately attribute responsibility for its outcomes.[3] Along these lines, Malandrino and Demichelis (2020) investigate the reaction of policymakers to the COVID-19 pandemic in Italy by analysing the sequence of rapid reforms implemented in the legal system. They conclude that the high frequency of these measures, which differentially attributed powers along the governmental central–local chain, has produced conflict in decision making, uncertainty in the attribution of responsibilities between central and local authorities and, ultimately, variation in the public administration outcomes offered to citizens.

Evidently, complex mechanisms behind voters' attributions of policy-making influence are in place, but intuition would suggest that the clarity of responsibility is a key aspect and, therefore, that government architecture is an important determinant—the point here being that voters' perceptions of policy-making influence can be affected by the architecture of governance. Indeed, upon realising the effect of a policy, voters cannot be entirely sure that it has been enacted by a specific government level, and this might become particularly difficult when a decision-making process changes sharply, as occurred during the first wave of the COVID-19 outbreak.

It is this issue that we deal with here. In particular, we ask: How do voters respond to a sharp change in the policy-making decision system? Of course, one cannot hope to find an unambiguous answer to this central question, which has been the subject of a significant literature; one can, however, hope to find robust evidence and clarify some of the deeper forces at work regarding the causal link between policy-making decisions and voters' attribution, by overcoming some empirical limitations detected in earlier studies and

[2] In addition, the existence of asymmetrical information in decentralised systems creates incentives for politicians either to blame other levels of government for poor performance, or through credit-taking (Barreiro, 1999; Maravall, 1999; McGraw, 1990; McGraw et al., 1993; Weaver, 1986).

[3] Scholars refer to uninformed voters and those lacking an organised belief system of political attitudes as 'myopic' (Campbell et al., 1960; Converse, 1964). Subsequent research has illustrated that voters lack political knowledge (Delli Carpini and Keeter, 1996), possess misinformation (Kuklinski et al., 2000), and often make seemingly irrational electoral decisions (Bartels, 2008; Caplan, 2007; Lau and Redlawsk, 2006).

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primarily related to lack of 'causality' (see Healy and Malhotra, 2013 for a discussion of these limitations).

In this work, we exploit the change in the decision-making system induced by the pandemic to study voters' attributions of policy-making influence. Specifically, we rely on a panel of 103 large cities in Italy (all provincial capitals) observed in three waves (2015, 2017, and 2020) to examine whether and to what extent the exogenous shift in the policy-making system affected citizens' perceptions regarding attributions of responsibility. To identify this effect, we take advantage of the political alignment of the city council to the central government, and we implement a difference-in-differences research design. We posit that politically aligned cities are expected to be more influenced by the change in the decision-making process, as voters in these cities might find it more difficult to separate and clearly identify the attribution of activities and responsibilities between the central and local governments, seeing as they share the same ruling party. Conversely, for voters in non-aligned cities, such responsibilities might be easier to separate.

To proxy the policy-making influence that each voter expects each mayor/municipal council to exert, we adopt the governance pool indicator, a periodic public opinion poll on the approval ratings of mayors (and the municipal councils). This indicator represents a local measure of 'political' performance as citizens evaluate mayors—and councils—not based on their perceptions of local conditions but according to actual local performance indicators. Therefore, we compare the difference in the governance poll score between aligned and non-aligned cities before the pandemic, when policy outcomes were unambiguously attributed to the local policy maker, with the same difference during the COVID-19 outbreak, when decisions were fully centralised.

Our results indicate that when decisions are in the hands of the local governments, the attribution of responsibility is not affected by their alignment status, thus revealing that citizens are perfectly able to punish or reward politicians at different levels of government for their actions (Fortunato et al., 2020). Conversely, the governance score achieved by an aligned city during the lockdown, when decisions were fully centralised, is 7% lower compared to what it would have been in the absence of the lockdown, i.e. when policy decisions are in the local government's own hands. Our main results survive a number of robustness checks. Further analyses suggest that our findings are more marked (i) during pre-electoral years as compared to other years in a term and (ii) in cities with a lower level of

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social capital, whereas we do not find a more pronounced effect in cities guided by mayors supported by large majorities. Finally, we document that voter perceptions of local government performance in aligned municipalities decrease not because citizens have 'blind spots' that cause them to misattribute policy responsibility; rather, such a decrease seems to be driven by a sort of 'punishment' directed towards the central government. This last finding resembles the 'disillusion' effect detected by Daniele et al. (2020) and might be interpreted as a perception of a lack of government preparedness against the pandemic. Since during a crisis, citizens always overwhelm governing institutions to some degree, they may have had higher expectations for the government's management and tackling of the pandemic.[4]

While contributing to the literature on retrospective voting, our article is most closely related to work focusing on approval ratings observed at regular intervals throughout a mayor's time in office (Fortunato et al., 2020), rather than electoral outcomes (see Healy and Malhotra, 2013 for a comprehensive review). By leveraging variation stemming from a stochastic and unpredictable event, the COVID-19 outbreak, we also contribute to the literature that investigates government responses to natural disasters to identify the relationship between policy action and voter responses (e.g. Achen and Bartels, 2004; Bechtel and Hainmueller, 2011; Gasper and Reeves, 2011; Healy and Malhotra, 2009; Malhotra and Kuo, 2008). Furthermore, we contribute to the literature related to the effects of alignment—here referring to incumbents of sub-national governments belonging to the same political party as the national one—on several policy outcomes, including grants and or spending programmes (Ansolabehere and Snyder, 2006; Arulampalam et al., 2009; Brollo and Nannicini, 2012; Simpser et al., 2016; Fouirnaies and Mutlu-Eren, 2015; Larcinese et al., 2006; Solé-Ollé and Sorribas-Navarro, 2008), bureaucratic performance (Rivera, 2020), and public services (Callen at al., 2020). Our focus also overlaps with the small yet growing strand of papers looking into the effect of the COVID-19 outbreak on political attitudes (Amat et al., 2020; Bruck et al., 2020; Bol et al., 2020; Bækgaard et al., 2020). We differ from most studies that are primarily based on correlations by providing more robust evidence grounded in a quasi-natural experimental approach. A notable exception is Daniele et al. (2020), who provide experimental evidence on a comprehensive set of socio-political attitudes by means of online surveys run at the country level. We therefore complement their analysis by relying on a

[4] An alternative and countervailing argument might be that citizens are easily united around a common cause precisely because a crisis represents a situation that is out of the ordinary. This mechanism is known in the literature as 'rally around the flag'. See, among others, Ariely (2017), Gibler et al. (2012), and Hetherington and Nelson (2003), and the literature therein.

more fine-grained indicator of voter perception at the local level. Our work is eventually close to the literature documenting dissatisfaction with the political establishment during crises (Margalit, 2019), including in the US (Stevenson and Wolfers, 2011) and Europe (Hernandez and Kriesi, 2016). Lastly, our research also ties into the emerging literature tackling the challenges of the COVID-19 outbreak in different areas of economics and political science (Brodeur et al., 2020, and the literature therein).

The remainder of this work is structured as follows. Section 2 illustrates the institutional context, Section 3 describes the data, while the econometric strategy is presented in Section 4. Findings and robustness tests are discussed in Sections 5 and 6, respectively. Heterogeneous effects are analysed in Section 7, while Section 8 further investigates the mechanism behind our findings. The last section offers some concluding remarks.

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2. Institutional setting

2.1 Municipal decentralisation in Italy

The Italian Constitution defines four administrative layers of government: the central government, regions, provinces, and municipalities. While most regions and provinces are ruled by ordinary statutes, some of them—the autonomous regions and provinces—are ruled by special statutes.[5] Furthermore, Italy counts 107 provinces, which have been reformed by law 56/2014 that reduced their public competences and eliminated the possibility of direct election of their own representatives. Finally, municipalities are the smallest level of jurisdiction and number around 8,000; the average size is around 6,400 inhabitants, and most have fewer than 15,000 inhabitants (approximately 90%).

Italian municipalities are responsible for a large array of important public programmes in the fields of welfare services, territorial development, local transport, infant schools, sports and cultural facilities, local police services, as well as infrastructure spending. As a share of the general government budget, in the timespan covered by our empirical analysis (2015–2020), municipalities account on average for about 8.5% of total public expenditure, which corresponds to €66 billion per year.

[5] Italy has five autonomous regions (Sicily and Sardinia, which are insular territories, and Valle d'Aosta, Trentino-Alto Adige, and Friuli-Venezia Giulia, which are northern boundary territories) and two autonomous provinces (Trento and Bolzano).

On the revenue side, municipalities can rely on transfers from upper levels of government (mainly central and regional governments) and, as a result of a lengthy process of fiscal devolution, on their own revenue sources. The main municipal tax—introduced in 1992—is the ICI (*Imposta Comunale sugli Immobili*, renamed IMU, *Imposta Municipale Unica,* in 2011), due yearly from real-estate owners to the municipality where the property is located. The tax base is the cadastral income, which does not vary over time unless a quite rare nation-wide uniform increase in all cadastral values is established by law. Another important feature is that the range of tax rates applicable to main residences (the dwellings where owners have their residence) is smaller than that applicable to additional residences (rented properties, secondary properties used for holidays, and so on). Moreover, tax credits (conditional, for instance, on having children in the household) are allowed for main residences but not for additional residences. Other revenue sources for Italian municipalities are the duties due for waste collection (until 2013, a tax named TARSU; since 2014, a charge named TARI), the surtax on the central government personal income tax (*Addizionale Comunale all'Irpef*), various types of fees (for parking permits, occupation of public areas, use of billboards, and so on), and charges for the use of municipal services (e.g. infant schools, sports facilities).

2.2 The COVID-19 outbreak and the role of institutions

On January 31st, 2020, through a resolution of the Council of Ministers,[6] the Italian government declared a state of national emergency (*stato di emergenza nazionale*) as a result of the health risk associated with the outbreak of the first two Italian cases of COVID-19. This temporary emergency condition was originally introduced for six months (up to the end of July 2020), then was renewed for over two months (up to October 15th, 2020), and finally was further extended to January 31st, 2021.[7] The emergency condition provides the national government and the Civil Protection with 'extraordinary' or 'special' powers. In particular, it allows the government to act in derogation on many aspects by the issuance of DPCMs (Decrees of the President of the Council of Ministers), legal acts that are directly emanated by the President of the Council without the approval of Parliament and which can only be issued

[6] See http://www.governo.it/node/13937.

[7] We should acknowledge that by law (Codice della Protezione Civile—Legislative Decree n. 1, January 2nd, 2018), the national emergency state may be declared for a maximum of 12 months, which can be extended up to another 12 months. Therefore, in principle, it may be further prorogated up to January 31st, 2022, under critical circumstances.

in case of a state of emergency.[8] Indeed, Article 120 of the Italian Constitution foresees that the government can exercise 'substitute powers' over local authorities such as regions, provinces, and municipalities in case of serious danger to public safety and security. Although the same article recognizes that the substitute powers should be exercised in compliance with the principles of subsidiarity and loyal collaboration between central and local authorities, the emergency measure establishes that local acts can be issued only subject to the issue of national acts. Consequently, a DPCM, once issued, prevails over any other local act (Baldini, 2020). Hence, overall, the national government—and the President of the Council of Ministers in particular—plays a central role in defining the policy options to combat the pandemic, while the local authorities see their executive powers temporarily reduced, or even cancelled. In practice, during the pandemic all powers—including decisions on local taxes and the allocation of expenditures—rest in the hands of the central government.[9]

2.3 The local electoral system

As for the municipal-level electoral system, since 1993 Italy has opted for a mayor–council system: the municipal council members and the mayor are separately and directly elected by citizens in elections normally held every 5 years. The mechanism of direct election implies that the mayor is endowed with strong powers over municipal politics (a basic feature of presidential government), even though the council retains the power to dismiss the mayor by means of a vote of no confidence (a basic feature of parliamentary government). Another interesting feature of the local electoral system is that the election mechanism is differentiated according to the demographic size of the municipality. Voters in municipalities with more than 15,000 inhabitants elect their mayors following a double-ballot plurality rule system, whereas municipalities with fewer than 15,000 inhabitants elect their mayors through a single-ballot plurality rule. It then follows that in small municipalities, the electoral system is quite simple: each mayoral candidate is associated with a list of candidates for the city council. Voters are entitled to vote for a mayoral candidate and may cast, if they wish, a

[8] Given the prolonged extraordinary circumstances, after a first preliminary phase the President of the Council was asked to present the contents of DPCMs to the Italian Parliament before their approval.
[9] Along these lines, see for example the '*Decreto Rilancio*' (Relaunch Decree), one the major interventions by the government to tackle the economic consequences of the COVID-19 emergency, which—among other interventions—exempted citizens from the payment of local taxes such as the IMU, TOSAP, and the regional tax on productive activities (IRAP). Details can be found here: https://www.mef.gov.it/en/inevidenza/Relaunch-Decree-155-billion-for-Phase-two-of-the-Economy-00001/.

preference vote for a specific candidate for member of the city council. The mayoral candidate who gains the largest number of votes is elected mayor. In contrast, a double-ballot majoritarian electoral mechanism is applied in the case of large municipalities. Each mayoral candidate is associated with one list, or a coalition of lists, of candidates for the post of councillor; in the first ballot, voters are entitled to vote for a mayoral candidate and, if they wish, for one list associated—or not—with said candidate (that is, a split vote is permitted). Each mayoral candidate must officially declare her affiliation to one or more lists running for election to the council. This declaration shall only be deemed valid if it coincides with similar declarations made by the candidates featured on the lists in question. In other words, electors may vote for one of the coalitions of parties listed for the elections. The mayoral candidate who receives the absolute majority of votes is elected mayor in the first ballot. If none of the mayoral candidates receive the absolute majority of votes in the first ballot, then a second ballot is held between the two candidates who have collected the largest number of votes in the first round. During the second ballot, voters are entitled to vote for the mayoral candidate only, as council members are those elected in the first round. The candidate who ultimately obtains the absolute majority of votes is elected mayor.

3. Data

The empirical analysis is based on a dataset of Italian municipalities resulting from a combination of different archives publicly available from the Italian Ministry of the Interior, the Italian Ministry of the Economy, the Italian Statistical Office (ISTAT), the National Association of Italian Municipalities (ANCI), and *Il Sole 24 ore*, the major Italian economic newspaper. The dataset contains a full range of information for each municipality, organized into three sections: (1) data on the local public opinion poll; (2) electoral data, including the party affiliation of the mayors elected during the period covered by the dataset; (3) demographic and socioeconomic data.

As previously mentioned, Italian municipalities differ along several dimensions and are also affected by many legislative thresholds based on population. To begin with, municipalities that are also provincial capitals normally provide a much wider range of services. Moreover, the salaries of the mayor, of the members of the executive committee, and of the councillors, the size of the city council and of the executive committee, the electoral rule, whether or not a municipality can have additional elective bodies in its districts, and whether or not a municipality can host hospital facilities or organize a healthcare district are all policy assignments that vary with population size (Gagliarducci and Nannicini, 2013). In addition, vertical transfers from the central government vary proportionally with population size (Law 504/1992). Furthermore, municipalities below 5,000 inhabitants are exempted from having to comply with a set of rules imposed on municipalities by the national government in order to improve their fiscal discipline (based on the Domestic Stability Pact). Finally, the large majority of votes at the local level in Italy are cast in favour of independent lists (*liste civiche*), for which it is not possible to associate any political colour. As shown by Bracco et al. (2015), more than 65% of Italian municipalities cannot be classified as left or right. For this reason, they strongly recommend relying only on large municipalities to avoid biased estimates (ibidem, p. 83).

In light of these concerns, and with the aim of clearly identifying our effect, we restrict our sample to municipalities that are the capital of a province. Such restrictions ensure that there are no other policy changes, structural reforms, or different institutional settings that are relevant for the municipalities in the sample, thus making possible unbiased comparisons. With these restrictions, we are left with almost the entire universe of cities that are capitals of a province, consisting of 103 municipalities and including 304 observations for the years 2015, 2017, and 2020.[10]

Looking at the political coalitions supporting the mayors, Table 1 documents that the absolute majority belongs to the centre–left wing (58%), while approximately one third (30%) can be attributed to the centre–right. As expected, the presence of independent lists is strongly reduced since we look at sufficiently large municipalities (provincial capitals). Indeed, only 7% of elected mayors are supported by *liste civiche*, with zero cases emerging in the case of regional capitals. The remaining councils (4%) are assigned to the Five Star Movement (*Movimento 5 Stelle,* M5S), a post-ideological party (Bordignon and Ceccarini, 2015) not directly attributable to more traditional political schemes.

[10] Our sample does not include all 107 capitals of provinces due to constraints on the dependent variable, discussed in the following section.

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Table 1: Political coalition supporting the mayor by (category of) municipality

Coalition	All municipalities		Regional capitals (*capoluoghi di regione*)		Provincial capitals (*capoluoghi di provincia*)	
	Number	%	Number	%	Number	%
Centre–left	178	58%	37	62%	141	57%
Centre–right	93	30%	16	27%	77	31%
M5S	11	4%	5	8%	6	2%
Independent (*lista civica*)	21	7%	0	0%	21	8%
Others	1	0%	0	0%	1	0%
Missing	5	2%	2	3%	3	1%
Total	309	100%	60	100%	249	100%

Note: The table reports statistics on mayors' coalition affiliation in the years of the poll (i.e. 2015, 2017, and 2020). The category 'Others' includes one Centre coalition.

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3.1 Dependent variable

Our dependent variable is the approval rating of the mayor, expressed by the residents of the municipality. This information is retrieved from a periodic public opinion poll (called the 'Governance Poll'), conducted by IPR Marketing, an Italian institute specialized in surveys, and published by the principal Italian daily financial newspaper, *Il Sole 24 ore*. We collected this data for the last three years in which the survey was completed, i.e. 2015, 2017, and 2020. It is worth mentioning that in 2020, the Governance Poll was conducted in June, when the first wave of the pandemic had ended and, therefore, when citizens had already formed an opinion on how the COVID-19 outbreak was managed by the central and local governments.

The poll is conducted on all the municipalities that are capitals of a province.[11] Based on the IPR Marketing declaration, in each municipality the sample is composed of between 600 and 1,000 citizens and is representative of the adult population with respect to gender, age, and residence area. The interviews were conducted using a mixed system including (*i*) computer-assisted telephone interviewing (CATI) and (*ii*) computer-assisted web interviewing (CAWI).

[11] The poll was not conducted on 107 capitals of provinces for different contingent reasons (e.g. the election for mayor was too close in time to the survey period. In our case, two municipalities were excluded in 2020 (Andria and Carbonia) and three in 2017 (Carbonia, Lodi, and Padova). To allow comparability between at least one data point during (2020) and before (2017) the COVID-19 pandemic, we limited the analysis to the subset of municipalities for which the poll is available in both periods. Therefore, our database covers 103 out of a total of 107 municipalities acting as capitals of provinces. We should also acknowledge that information for 2015 is limited to 98 of our 103 target municipalities.

The respondents answered the following question:

> 'I would like to ask your overall opinion on the work of the mayor. If municipal elections were held tomorrow, would you vote in favour of or against the incumbent mayor?'[12]

The indicator is then built as the percentage of respondents who expressed their potential intention to vote in favour of the incumbent mayor over the overall respondents; therefore, it is a continuous variable ranging between 0 and 100. According to our sample, the average value of our dependent variable is approximately 53.6%, with a minimum score of 38.1%, a maximum of 69.9%, and a standard deviation of approximately 4.9%.[13]

The key aspect of this variable is that it captures citizen perceptions regarding the attribution of responsibility to the mayor and the municipal council. Stated differently, we can estimate the policy-making influence that each respondent expects each mayor/municipal council to exert under two different systems: one characterized by a high level of decentralisation (before the COVID-19 outbreak), where policy outcomes are unambiguously attributed to the local policy maker, and the other being substantially fully centralised (during the pandemic).

3.2 Aligned cities

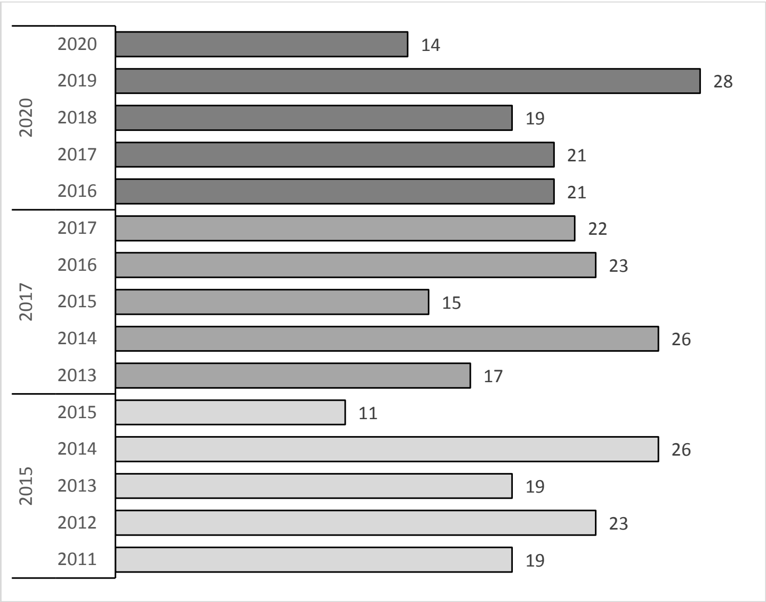
Our treatment variable is given by the political alignment of the city council with the central government. For this purpose, we define the alignment variable, *Aligned*, as equal to 1 if the mayor's party/coalition is the same as that in power at the central level at the time the poll was conducted and zero otherwise.

It is worth noting that there are two sources of variation in the city-alignment status. First, the city council might share the same political coalition as the central government as a consequence of local elections. Along these lines, as already mentioned, municipal elections are normally held every 5 years between April and June, but the timing is not the same for all municipalities. The staggering of electoral dates is the result of local governments having to resign before the end of their term because of not being able to form a majority in the city council supporting the local government or because of political scandals or judicial impeachment. It then follows that the staggered timing of the Italian municipal elections

[12] The question was asked in Italian, the language of the respondents, as follows: 'Le chiedo un giudizio complessivo sull'operato del sindaco. Se domani ci fossero le elezioni comunali, lei voterebbe a favore o contro l'attuale sindaco?'
[13] The summary statistics for all variables used in the analysis are available upon request.

determines a sort of random assignment of the political cycle of municipalities, and therefore of the alignment status. That is to say, the position in the term of a single municipality—and its relative majority—in a given year can be considered as good as randomly assigned (Coviello and Gagliarducci, 2017; Ferraresi, 2020), especially with respect to the timing of the pandemic hitting Italy. Figure 1 demonstrates that municipalities indeed follow different election schedules. Specifically, of the 103 municipalities surveyed in 2020, 21 (20%) voted four or three years before the poll (i.e. in 2016 and 2017), 19 (18%) two years before, 28 (27%) the year before, and the remaining 14 (14%) voted in the same year of the poll but after the date it was conducted. The same applies for 22 municipalities surveyed in 2017 and for 11 surveyed in 2015. [14]

Figure 1: Number of elections by year of the poll and date of elections



Note: This figure shows the number of municipalities by date of polling (i.e. 2015, 2017, and 2020), distributed across the date of the previous elections.

On the other hand, a municipality might become aligned as a result of national elections. Along the timespan of our analysis, a general election was held in 2018, with an additional governmental reshuffle in 2019, thus leading to three different governmental coalitions. In

[14] Specifically, 2020 elections were held in October, while the 2020 Governance Poll was conducted in June. In 2017, elections were held in June, while the 2017 Governance Poll was conducted in November–December 2016, and the 2015 elections were held in May, while the 2015 Governance Poll was conducted in March–April 2015.

particular, until the general elections of 2018, the majority of the national government was guided by a left-wing coalition. After the election, and up to September 4th, 2019, the national government was guided by the Five Star Movement (*Movimento 5 Stelle*) and the Northern League (*Lega Nord*), a far-right party. Following the governmental reshuffle, in September 2019 the majority was taken by a left-wing coalition composed of the Five Star Movement, the Democratic Party (*Partito Democratico*), and some other minor centre–left parties.[15]

Table 2 presents information on the number of elections by year and by winning coalition for aligned and non-aligned governments. It is interesting to note that the sample is not equally split between aligned and non-aligned municipalities, as the former group of municipalities (182 observations) is slightly larger than the latter (122 observations).

Table 2: Distribution of elections by aligned and non-aligned municipalities

Year of the poll	Aligned					Not Aligned					Total poll
	Centre-right	*Centre-left*	*M5S*	*Others*	*Total*	*Centre-right*	*Centre-left*	*M5S*	*Others*	*Total*	
2015	0	73	0	0	73	19	0	3	3	25	98
2017	0	67	0	0	67	22	0	4	10	36	103
2020	0	38	4	0	42	52	0	0	9	61	103
Total	0	178	4	0	182	93	0	7	22	122	304

Note: The category 'Others' includes 21 independent lists ('liste civiche') and one Centre coalition. Data on polls are not available for five municipalities in 2015.

3.3 Control variable

The dataset also includes some time-varying control variables that account for differences among municipalities in their population structure and economic conditions. The demographic controls include total population (*population*) and population density (*density*), expressed by population per square kilometre of municipal territory; these variables can capture the presence of scale economies in the provision of public goods. We also include the share of population aged between 0 and 5 (*child*), the share of population over 65 (*aged*), and the share of foreign population (*migrants*) to account for some specific age-related public needs such as nursery schools and nursing homes.

[15] The government also included *Italia Viva* (guided by Matteo Renzi, former Secretary of the Democratic Party) and *Liberi e Uguali* (a party of the left).

Before moving to the empirical investigation, as a preliminary piece of evidence it is worth noting that before the pandemic, the average value of the municipal governance poll score obtained by aligned cities (54.029) was higher than that of non-aligned ones (52.869), with a difference equal to 1.160. Since the COVID-19 outbreak, when policy decisions became centralised, the same difference has become negative (–1.914). It then follows that the difference in the differences (–3.074 = –1.914 – 1.160) is statistically significant at the 5% level, suggesting that during emergency times the perception of the local government actions drastically reduces when central and local governments are nested, that is, when they belong to the same party coalition.

4. Empirical strategy

Since we are interested in understanding how and to what extent voters' attributions of policy-making influence can be affected when decisions mainly rest in the hand of the central government, we consider politically aligned cities as treated and non-aligned cities as controls. We then exploit the change in policy decisions induced by the pandemic that led to a centralised decision-making system. The exogenous change allows us to compare the difference in the governance poll score index between aligned and non-aligned cities before the pandemic, when municipalities could enjoy the usual discretion in setting policy decisions, with the same difference after the COVID-19 outbreak, when decisions were centralised.

The difference in differences (DiD) model estimated in this study is specified as follows:

$$Governance\ poll\ score_{it} = \alpha + \beta Aligned_{it} + \lambda Post_t + \gamma Aligned_{it} \times Post_t + f_t + f_i + u_{it},$$

where $Governance\ poll\ score_{it}$ is the (log) of the governance poll score for city i at time t, where $t = 2015, 2017, 2020$. $Aligned_{it}$ is a dummy variable that takes the value of one if the coalition of the mayor coincides with the coalition in power at the central level and zero otherwise; $Post_t$ is a binary variable that is equal to one for the poll conducted in 2020, as a consequence of the COVID-19 pandemic; f_i is an unobserved municipal specific effect; f_t are poll-year fixed effects that capture shocks common to every city in the year the survey was conducted; and u_{tr} is the error term, clustered at the city level.

It is important to note at the outset that in this estimating framework, the coefficient β accounts for the impact of being aligned on the government poll score before the COVID-19 outbreak, while γ captures the differential effect, with respect to β, of being aligned after the outbreak. It then follows that the estimate of the combination of $\beta + \gamma$ accounts for the difference in the government poll between aligned and non-aligned teams after the lockdown.

A few more empirical choices merit further explanation. First, as local elections for some cities originally scheduled in May/June 2020 were postponed to September/October 2020, the pandemic could not have influenced the alignment status in these cities, and hence, it can be considered as truly exogenous. Second, since Italian regions are involved in the decision-making process of some relevant public functions, i.e. health, education, and assistance, one might argue that there could be some other unobservable characteristics related to the specific region that might influence people's perceptions through time, thus affecting the municipal governance score. For this reason, in further specifications we augment model (1) by including an interaction of region-by-year fixed effects. In addition, our framework allows three types of municipalities to be included: (i) always aligned; (ii) never aligned; and (iii) switchers. While a key trait of our identification strategy exploits the municipal variation in the aligned status due to the result of the electoral competition (both at the national and at the local level), one might argue that, in practice, we do not observe the same city (aligned or non-aligned) before and after the COVID-19 outbreak, as one would in the standard DiD approach. Therefore, to mitigate such a concern, we split the data into two periods, one before the pandemic (2015 or 2017) and one during the pandemic (2020), and we rely only on municipalities that have been either always or never aligned. In this way, it is possible to compare our outcome variable in the same group of aligned municipalities before and after the pandemic with the difference in the same group of non-aligned ones, thereby eliminating any source of bias in the comparison.

5. Findings

The first round of results is shown in Table 3. Each of the nine columns correspond to different specifications of Equation (1). The baseline specification, which includes municipal and year fixed effects, is reported in column (1). The model in column (2) factors in all demographic factors described in Section 3.3 to control for characteristics of the

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municipalities varying across time and space that are potentially correlated to the alignment status and the governance indicator. Column (3) includes a set of region-by-year fixed effects to account for unobservable characteristics related to the specificity of region that vary over time.

As was already alluded to, the status of aligned municipalities is not constant over time. Indeed, there are cities that become aligned with the central government and others that lose this status. Despite the fact that the alignment status is determined by the result of the electoral competition and is not influenced by the pandemic, in the classical difference-in-differences setting one would like to compare the outcome variable for a given aligned city before and after the COVID-19 outbreak with the same outcome of a non-aligned city before and during the pandemic. It follows that the estimates in columns 4 through 9 replicate the previous set of regressions but are obtained by restricting the analysis to subsamples of municipalities. Consistently, results reported in columns 4, 5, and 6 use information only on municipalities that are either always or never aligned in 2017 and 2020. In contrast, in columns 7, 8, and 9 we rely on municipalities that are always or never aligned in 2015 and 2020. This approach allows us to control for any potential bias due to the fact that the municipalities in the treatment and control groups differ from one year to another.

The results in Table 3 show that the coefficient associated with $Aligned_{it}$ is positive, albeit not statistically significant, thus indicating that before the lockdown, when decisions were in the hands of the local governments, voters' perceptions regarding attributions of responsibility were not affected by the alignment status. These findings corroborate the recent results of Fortunato et al. (2020) revealing that citizens are able to punish or reward politicians at different levels of government for their actions, thus hampering citizens' control and effective democratic government.

Central to the issue at hand is, however, the coefficient of $Aligned_{it} \times Post_t$, which captures the differential effect of being politically aligned during the pandemic with respect to not being aligned. The coefficient turns out to be negative, remarkably similar in magnitude (ranging from –0.068 to –0.141), and statistically robust along all specifications. It is also interesting to point out that the comparison of the estimates in columns (3) through (6) and in columns (7) through (9) indicates that results are not affected by the different composition of aligned and non-aligned municipalities over time, as the coefficients of $Aligned_{it} \times Post_t$ are similar in magnitude. In terms of point estimates, following column 1 it emerges that the

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governance score of an aligned city, when decisions are fully centralised, is 7% lower compared to the score it would have obtained in the absence of a lockdown, when policy decisions are under its own responsibility.

What all of this seems to point to is that under a centralised decision-making system, citizens of aligned municipalities seem to be less able to identify who to blame or praise for policy outcomes. There is, of course, an alternative explanation for this result, one that relies on the fact that citizens perfectly identify policy responsibilities across levels of government, but in aligned municipalities the observed decrease in the governance score might simply reflect negative perceptions of the policies adopted by the central government during the pandemic. This is what we further explore in Section 8.

6. Robustness tests

In this section, the validity of the previous results is confirmed by a battery of robustness tests that are intended to address possible issues related to the research design that could bias the baseline estimates. First, the classical placebo test is performed. Then, we move to a falsification exercise to prove that the estimated effects do not ensue from other municipal shocks. Lastly, after controlling for city and poll fixed effects, we test for the potential presence of remaining sources of bias by performing balancing regressions.

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Table 3: Baseline results

Dep. Variable	(Log of) governance poll score								
	Full sample			Sample 2017–2020			Sample 2015–2020		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Aligned × Post	-0.068**	-0.070**	-0.088**	-0.071**	-0.085**	-0.113*	-0.106**	-0.102**	-0.142*
	(0.029)	(0.030)	(0.041)	(0.030)	(0.033)	(0.058)	(0.040)	(0.050)	(0.081)
Aligned	0.007	0.010	0.022						
	(0.024)	(0.024)	(0.029)						
Post	0.018	0.016	0.060						
	(0.020)	(0.039)	(0.064)						
Observations	304	304	304	124	124	124	95	95	95
Adjusted R-squared	0.033	0.026	0.023	0.071	0.102	0.081	0.158	0.178	0.427
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Poll FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Region × Poll	No	No	Yes	No	No	Yes	No	No	Yes

Note: *Aligned* is a dummy variable that takes the value one if the political party of the mayor belongs to the same political sphere as the national government and zero otherwise. *Post* is a dummy variable that takes the value of one for the 2020 poll (during the pandemic) and zero otherwise. Control variables are population, children, aged, population density, and foreigners. Standard errors, clustered at the municipality level, are shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

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6.1 Placebo test

A common way to conduct a placebo test in the context of DiD analysis is to focus on the span prior to the shock, that is, to simulate what would have happened to the governance poll score in aligned municipalities if a fake year were used for the pandemic. In our framework, we replicate the baseline model by supposing that the COVID-19 outbreak had occurred in 2017. In other words, we create a (*Fake*)*Post* dummy variable equal to one for the polls conducted in 2017 and zero otherwise, and we interact it with the aligned indicator.

Were the coefficient associated with $Aligned_{it} \times (Fake)Post_t$ negative and significant, it would suggest that before the true year of the *de facto* centralised decision-making system experienced by Italian municipalities during the COVID-19 outbreak, aligned municipalities were already experiencing a lower governance score as compared to non-aligned ones, thus casting doubt on the validity of the previous results.

Reassuringly, the placebo exercise does not lead to any statistically significant effect on our main outcome variable as the γ coefficient turns out to be indistinguishable from zero in all specifications (Table 4).

Table 4: Fake treatment results

Dep. Variable	(Log of) governance poll score		
	(1)	(2)	(3)
Aligned × Fake (Post)	-0.017	-0.012	-0.029
	(0.022)	(0.022)	(0.020)
Aligned	-0.047	-0.046	-0.056*
	(0.036)	(0.033)	(0.031)
Fake (Post)	-0.003	-0.008	0.032
	(0.020)	(0.024)	(0.030)
Observations	201	201	201
Adjusted R-squared	0.066	0.102	0.293
Municipality FE	Yes	Yes	Yes
Poll FE	Yes	Yes	Yes
Controls	No	Yes	Yes
Region × Poll	No	No	Yes

Note: *Aligned* is a dummy variable that takes the value of one if the political party of the mayor belongs to the same political sphere as the national government and zero otherwise. *Fake Post* is a dummy variable that takes the value of one for the 2017 poll and zero otherwise. Control variables are population, children, aged, population density, and foreigners. Standard errors, clustered at the municipality level, are shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

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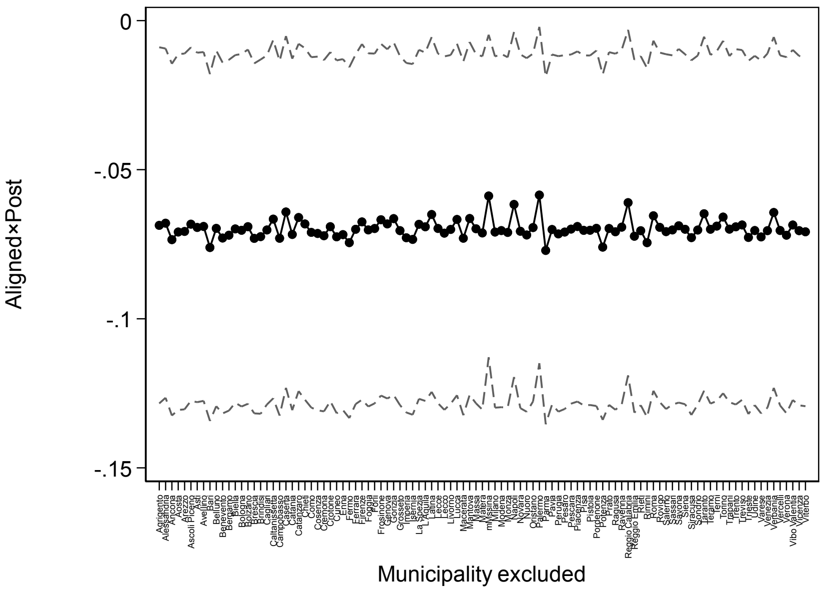
6.2 City outliers

It is also important to test whether our main findings are sensitive to the exclusion of a single city, given their relatively low number in our sample. For this reason, we have estimated Equation (1) dropping one city at a time. The result of the estimated coefficient, γ, and its 95% confidence interval, are shown in Figure 2 and the results are very similar to those obtained in our baseline specification. Hence, it can be concluded that our main results are not driven by a particular city and are thus generalizable.

Figure 2: Municipality excluded



6.3 Balancing test

While in the baseline estimates we control for time-invariant unobserved determinants of the city governance score by including municipal fixed effects, there still might potentially be some remaining sources of bias due to unobserved confounders. The usual way to overcome this issue is to add variables as controls on the right-hand side of the regression. In this case, if the presence of unobserved effects were relevant, the coefficient of interest would be sensitive to the inclusion of these controls. As the comparison of the estimates in the columns (1 and 2; 4 and 5; 7 and 8) of Table 3 shows, adding controls to the baseline specification hardly changes any of the results. However, these demographic, socioeconomic variables might be poorly measured proxies of the confounders. As recently shown by Pei et al. (2018), a more sensitive test consists of including individual controls as dependent variables on the left-hand side of the regression equation. Table 5 shows that of these balancing regressions for various demographic and socioeconomic controls, none yields significant effects. These results help to rule out the possibility that any correlation between the aligned variable and other time-varying characteristics of cities is driving the results.

To sum up, the analyses carried out in this section have strengthened the evidence of a negative relationship between municipality alignment and governance score during the pandemic, namely, when the policy decision process is entirely in the hands of the central government. In addition, the results indicate that it is very likely that such an effect is due to the shock caused by the COVID-19 outbreak, as no other plausible explanations that clearly hold as arguments against a causal interpretation of this relationship are found.

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Table 5: Balancing test

Dep. Variable	Population (1)	Children (2)	Aged (3)	Density (4)	Foreigners (5)
Aligned × Post	-0.001	0.001	-0.003	0.001	-0.114
	(0.001)	(0.007)	(0.005)	(0.001)	(0.431)
Aligned	0.000	-0.005	0.001	-0.000	-0.285
	(0.001)	(0.005)	(0.003)	(0.000)	(0.389)
Post	0.003	-0.086**	0.016**	-0.001	0.158
	(0.002)	(0.007)	(0.007)	(0.001)	(0.770)
Observations	309	309	309	309	309
Adjusted R-squared	0.874	0.860	0.746	0.854	0.198
Municipality FE	Yes	Yes	Yes	Yes	Yes
Poll FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes

Note: *Aligned* is a dummy variable that takes the value of one if the political party of the mayor belongs to the same political sphere as the national government, and zero otherwise. *Post* is a dummy variable that takes the value of one for the 2020 poll (during the pandemic) and zero otherwise. Control variables are population, children, aged, population density, foreigners, and exclude the dependent variable. Standard errors, clustered at the municipality level, are shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

7. Heterogeneous effects

To investigate whether there is evidence of a heterogeneous response across cities, we analyse how the effect varies along several dimensions. We find that our findings are more marked (i) during pre-electoral years as compared to other years of the term and (ii) in cities with a lower level of social capital, while we do not find a more pronounced effect in cities guided by mayors supported by large majorities (more visible). All of these results are available upon request.

8. Citizen blind spots or disapproval of the central government

So far, we have shown that once the decision-making process is centralised, the governance pool indicator declines more in aligned municipalities as compared to non-aligned ones. Nevertheless, it is not clear yet whether such a decrease is due to the fact that citizens are temporarily unable to accurately attribute responsibility for policy outcomes, given the new institutional framework experienced during the pandemic or, instead, if the drop in the governance indicator reflects a negative perception of the policies adopted by the central government during the COVID-19 outbreak. Along these lines, when consequences of government's actions or inactions are perceived to be deleterious, voters tend to be 'disaffected', especially during crises (Gregory, 2003, pp. 557–558).

To test the plausibility of these assumptions, we collect information on the party affiliation of the regional council over the period of 2015–2020 and we create two distinct variables of political alignment. On the one hand, we re-define our aligned variable as a dummy variable that is equal to 1 if the mayor's coalition is the same as the coalition in power at the central level but not at the regional government level, and zero otherwise ($Aligned_{Gov}$). On the other hand, we build a dummy variable that is equal to 1 if the mayor's coalition is the same as the coalition in power at the regional level but not at the national government level, and zero otherwise ($Aligned_{Reg}$). These variables are then interacted with *Post* in the following model:

$$Governance\ poll\ score_{it} = \alpha + \beta AlignedGov_{it} + \lambda Post_t + \gamma AlignedGov_{it} \times Post_t + \lambda AlignedReg_{it} + \delta Post_{it} \times AlignedReg_{it} + f_t + f_i + u_{it}. \quad (2)$$

While the government decision-making process became highly centralised during the pandemic, regions were entitled to set additional (and more restrictive) measures. Therefore,

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the split of the aligned coefficient would allow us to understand which of the two effects prevails. On the one hand, if the centralisation of policy-making decisions triggered by the pandemic brought about citizen confusion regarding policy responsibilities between different levels of government, we would expect both the coefficients γ and δ to be negative and statistically significant. On the other hand, if the decline of the governance indicator observed in aligned cities captures negative perceptions of the policies adopted by the central government, including measures that restrict the movement of individuals (e.g. the 'lockdown'), we would observe a negative and significant coefficient associated with municipalities aligned only with the government (γ), and no effect for cities aligned with the regional council (δ).

Results of this analysis are shown in columns 1 through 3 of Table 6 and indicate that the 'punishment' channel is likely to be the most plausible explanation of the decline in the governance pool indicator. Indeed, the coefficient associated with $AlignedGov_{it} \times Post_t$, which accounts for the differential effect of being under a centralised decision system for municipalities aligned only with the central government, turns out to be negative (ranging from –0.069 to –0.103) and statistically significant at the 5% level. Conversely, the coefficient δ, which captures the differential effect of being under a centralised decision system for municipalities aligned only with the regional government, is close to zero and not statistically significant in all specifications.

What emerges, therefore, is that in a pandemic, when the policy-decision process is mainly exercised by the central government, the citizens' approval rate of the mayor in aligned municipalities is significantly lower compared to that in non-aligned ones. Strikingly, this is not because citizens suffer from 'blind spots' that cause them to misattribute policy responsibility; rather, such a decrease seems to be driven by a sort of 'punishment' for the policy decisions of the central government, which might reflect a sense of a lack of government preparedness against the pandemic. It is very likely that citizens might have had higher expectations regarding the policy responses of the government to the pandemic, and the decline in the governance pool indicators precisely in those cities politically aligned with the government reveals that such expectations were not met.

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Table 6: Government and regional alignment

Dep. Variable	(Log of) governance poll score		
	(1)	(2)	(3)
$Aligned_{Gov}$ × Post	-0.069**	-0.069**	-0.103**
	(0.034)	(0.035)	(0.044)
$Aligned_{Reg}$ × Post	0.002	0.003	-0.051
	(0.051)	(0.052)	(0.076)
$Aligned_{Gov}$	0.006	0.009	0.021
	(0.026)	(0.027)	(0.034)
$Aligned_{Reg}$	-0.006	-0.003	0.013
	(0.048)	(0.047)	(0.065)
Post	0.020	0.015	0.099
	(0.027)	(0.048)	(0.084)
Observations	304	304	304
Adjusted R-squared	0.026	0.019	0.021
Municipality FE	Yes	Yes	Yes
Poll FE	Yes	Yes	Yes
Controls	No	Yes	Yes
Region × Poll	No	No	Yes

Note: $Aligned_{Gov}$ is a dummy variable that takes the value of one if the political party of the mayor belongs to the same political sphere as the national government and zero otherwise. *Post* is a dummy variable that takes the value of one for the 2020 poll (during the pandemic) and zero otherwise. $Aligned_{Reg}$ is a dummy variable that takes the value of one if the political party of the mayor belongs to the same political sphere as the regional government and zero otherwise. Control variables are population, children, aged, population density, and foreigners. Standard errors, clustered at the municipality level, are shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

9. Conclusions

In this paper, we investigated how and to what extent voters' attributions of policy-making influence are affected by the structure of the government. To induce a source of plausible exogenous variation, we exploited the fact that during the first wave of the COVID-19 pandemic the government decision-making process became highly centralized. The unprecedented nature of this event has allowed us to compare the governance score, capturing the level of citizen satisfaction with the work of the mayor and of the municipal council, between politically aligned and non-aligned cities before the pandemic, when the mayor and the city council could enjoy the usual discretion in setting policy decisions, with the same difference during the COVID-19 outbreak, when policy decisions were centralised.

Our findings indicate that the governance score of an aligned municipality when decisions are centralised is 7% lower compared to what it would have been in the absence of a lockdown, when policy decisions are in its own hands. All results survive a battery of robustness tests. Further investigations suggest that our findings are more marked (i) during pre-electoral years as compared to other years of a term and (ii) in cities with lower levels of social capital, while we do not find more a pronounced effect in cities guided by mayors supported by large majorities. Moreover, we document that voter perception of local governance in aligned municipalities decreased not because citizens misattributed policy responsibility to different government layers, but rather because they were 'punishing' policy decisions underpinned by the central government.

Although our results are based on a robust indicator of citizen perceptions, it is possible that voter responses could represent a better and more objective indicator of voter attributions of responsibility. Along these lines, a natural extension of this analysis is to explore whether similar effects are observed when using electoral outcomes. In this regard, we conducted a preliminary exploration of this question by collecting data on the results of electoral competitions in the 16 cities that held elections in September/October 2020, i.e. during the pandemic. Among these 16 cities, 8 were led by a mayor politically aligned with the central government. It is interesting to observe that two cities experienced a swing from the left- to the right-wing coalition and were therefore no longer aligned with the central government. In three cases, cities continued to be aligned with the central government, but the share of votes cast for the ruling coalition decreased by approximately 3 percentage points as compared to the previous election, while in the remaining three cases the share of votes for the ruling (aligned) party was unchanged. Future research, when more electoral results become available for a larger sample of cities, could therefore apply our empirical strategy and investigate whether and to what extent voting decisions are affected by the sharp changes in the decision process induced by the COVID-19 outbreak.

Despite this limitation, these findings suggest that politically aligned cities appear to be more affected by citizens' perceptions of the government's response to a crisis. More specifically, if policies adopted by the central government are unpopular or if there is an impression of a lack of government preparedness against the pandemic, such a (negative) perception is exacerbated in cities whose mayor shares the same political affiliation as the central government. This last finding calls for extra attention on how the government will handle subsequent waves of the pandemic. Finally, while our findings are based on information related to Italian cities, they are also in line with those recently documented by both Daniele et al. (2020) and Herrera et al. (2020) for the European countries. Indeed, their analyses, carried out across Europe, suggest that the pandemic has conducted to severe drops in institutional trust (Daniele et al., 2020), and that the political approval of governments has declined when Covid-19 infections were accelerating (Herrera et al., 2020).

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Local economies amidst the COVID-19 crisis in Italy: A tale of diverging trajectories[1]

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Impact evaluations of the microeconomic effects of the COVID-19 upheavals are essential but nonetheless highly challenging. Data scarcity and identification issues, due to the ubiquitous nature of the exogenous shock, account for the current dearth of counterfactual studies. To fill this gap, we combine up-to-date quarterly local labor markets (LLMs) data, collected from the Business Register kept by the Union of the Italian Chambers of Commerce, with the machine learning control method for counterfactual building. This allows us to shed light on the pandemic's impact on the local economic dynamics of one of the hardest-hit countries, Italy. We document that the shock has already caused a moderate drop in employment and firm exit and an abrupt decrease in firm entry at the country level. More importantly, these effects have been dramatically uneven across the Italian territory and spatially uncorrelated with the epidemiological pattern of the first wave. We then use the estimated individual treatment effects to investigate the main predictors of such unbalanced trajectories, finding that the heterogeneity of impacts is primarily associated with interactions among the exposure of economic activities to high social aggregation risks and pre-existing labor market fragilities. These results call for immediate place- and sector-based policy responses.

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1. Introduction

With over 56,000 deaths and more than 1,600,000 cases (as of December 2, 2020), Italy ranks among the worst-hit countries by COVID-19.[1] The Italian government was the first in Europe to declare, on March 9, an unprecedented national lockdown that paralyzed the country. From March 25, productive activities were shut down, except for those deemed 'essential' for the functioning of the country's economic system. On May 4, lockdown rules started to be lifted, and, from June 15, almost all economic activities were finally allowed to re-open, albeit under strict safety protocols. The suspension of restrictive measures continued throughout the summer until the impressive resurgence of the contagion in the fall of 2020 forced the government and regional authorities to issue new social distancing policies, including the reintroduction of restrictive measures targeting economic activities.

The repercussions of this remarkable series of disruptive events on the Italian economy are enormous, and the Italian government tried to attenuate these impacts via the adoption of several emergency measures and fiscal packages.[2] In order to increase workers' protection, the government also issued an *ad hoc* Decree-Law on March 17, which introduced two labor market policies: a special COVID-19 short-time work retroactive compensation scheme and a freezing of layoffs[3] (Casarico & Lattanzio, 2020). The layoff freeze measure has been extended several times, and it is currently in effect until March 2021.

Despite the implementation of a wide range of policy interventions, annual forecasts by the Bank of Italy (July 2020) pointed to a 9.5% GDP fall, a reduction of 11.8% in the number of hours worked and a decrease of 4.5% in the number of persons employed, while more recent estimates (October 2020) by the International Monetary Fund (IMF), suggest an even larger annual GDP drop at 10.6%.[4]

However, credible *ex-post* quantifications of microeconomic and local impacts are still missing. Such a vacuum is hardly surprising as real-time microdata is scarce. On top of data scarcity, rigorous evaluation of the crisis effects is challenging for econometric issues: the COVID-19 exogenous shock

[1] See https://www.worldometers.info/coronavirus/country/italy/.

[2] For a database of fiscal policy responses to COVID-19 in Italy (as well as many other countries), please refer to https://www.imf.org/en/Topics/imf-and-covid19/Fiscal-Policies-Database-in-Response-to-COVID-19.

[3] The layoff freeze could also be applied retroactively to layoffs pending from February 23.

[4] See here: https://www.bancaditalia.it/pubblicazioni/proiezioni-macroeconomiche/2020/en-estratto-boleco-3-2020.pdf?language_id=1 and here https://www.imf.org/en/Publications/WEO/Issues/2020/09/30/world-economic-outlook-october-2020.

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virtually left no part of the world unaffected. In econometric jargon, this means that it is hard to find a control group because the treatment affected all units simultaneously or with short lags.[5] As noted by Chudik et al. (2020), this implies that in most cases, standard evaluation techniques, such as difference-in-difference or the synthetic control method (SCM), are not applicable.[6] This is probably the reason why, although micro literature on the pandemic is flourishing (Adams-Prassl et al., 2020; Baker et al., 2020; Bartik et al., 2020; Benedetti et al., 2020; Bick & Blandin, 2020; Blundell et al., 2020; Buchheim et al., 2020; Cajner et al., 2020; Carvalho et al., 2020; Forsythe et al., 2020; Gourinchas et al., 2020; Von Gaudecker et al., 2020), that almost all these policy-relevant works are not based on counterfactual impact evaluation methodologies. A notable exception is the study by Chetty et al. (2020), who employ private real-time anonymized data and an evaluation strategy which exploits between-state heterogeneity in the reopening's timing to document the granular impact of the pandemic and the related policy responses on various economic outcomes in the United States.

Concerning Italy, Ascani et al. (2020) provide evidence of a close relationship between COVID-19 disease patterns and local economies' characteristics. Pini and Rinaldi (2020) show that over 30,000 people missed out on employment opportunities during the two months of lockdown, mainly because of a pronounced decrease in business births. Casarico and Lattanzio (2020) focus on how different categories of workers were affected by the pandemic in the short-term and carry out a first evaluation of the policy responses implemented. Using a linear probability model, they find that workers already in disadvantaged conditions before the shock (young, low-skilled, and seasonal workers) have substantially higher risks of losing their jobs.

These studies underline important local and sectoral components of the impacts of the crisis in Italy. Indeed, in Europe as elsewhere, the current crisis is undoubtedly a regional one, because the economic impacts are unfolding unevenly at the local level, so regional perspectives are essential to understand

[5] There are some exceptions: in countries and areas where no total lockdowns were implemented, one might exploit staggered or heterogenous policy responses to generate a counterfactual scenario (see the study by Chetty et al. (2020) mentioned below). This is not the case of Italy. Yet, one could argue that since the spread of the contagion, especially in the first wave, was highly heterogeneous and predominantly affected Northern Italian regions, it would be possible to use the Southern regions as a control group or to consider the shock as 'continuous' treatment with different intensity levels. However, we disagree with the premise. The national lockdown implemented during the first wave, and the shutdown of entire sectors, involved the entire country.

[6] To make up for this, Chudik et al. (2020) develop a cross-country econometric model in which the Covid-19 shock is identified using the IMF's GDP growth forecast revisions between January and April 2020, under the assumption that Covid-19 was the main driver of these forecast revisions. In this way, they use the difference in the forecasts as a counterfactual strategy to quantify the economic impact of the shock.

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the unequal impacts of the pandemic (Bailey et al., 2020). At least in the Italian context, however, we are not aware of any paper showing *ex-post* counterfactual evidence on the local microeconomic effects of the COVID-19 disruption on labor and firm outcomes.

This article quantifies the heterogeneous impacts of COVID-19 on employment and business demography for all 610 Italian local labor markets (LLMs)[7] and investigates the main territorial features of such unevenness. To this end, we leverage up-to-date quarterly LLMs data, collected from the Business Register kept by the Union of the Italian Chambers of Commerce, combined with the newly developed machine learning control method (MLCM). MLCM draws on the predictive ability of machine learning (ML) algorithms to generate a no-COVID counterfactual scenario (i.e. a 'business-as-usual' scenario) in such a peculiar econometric setting. The use of the MLCM is made possible by constructing a comprehensive time-series cross-sectional database on LLMs.

Thanks to this counterfactual approach, we document that at the end of the third quarter of 2020, the shock has not only already caused a steep decrease in firm entry and a moderate drop in employment and firm exit at the aggregate level but, more importantly, that the effects have been markedly heterogeneous across the Italian territory. In the following step, we use a regression tree to identify the features that matter the most in explaining the heterogeneity of the outcome variable, i.e. the estimated treatment effect of employment change. We find that the features more significantly associated with employment effects are the share of workers in sectors characterized by a high social aggregation risk and pre-existing labor market fragilities.

The remainder of this paper proceeds as follows. Section 2 describes the data. Section 3 introduces the econometric methodologies. Section 4 reports the treatment effects resulting from the counterfactual analysis, while the subsequent section investigates the main predictors of the estimated impacts. Section 6 concludes.

2. Data

Our primary dependent variable is the log of overall employment. In addition, we also split employment between manufacturing and services, and investigate the impact of COVID-19 on the number of new business registrations (births) and cessations of trading (deaths). All these variables come from the Business Register kept by the Union of the Italian Chambers of Commerce (*Unioncamere*). The Business Register is based on administrative data on the Italian companies gathered by the provincial Chambers of Commerce. It contains information on the registration data

[7] The criteria used to determine Italian LLMs are similar to those used to define Metropolitan Statistical Areas in the US or Travel to Work Areas in the UK.

of the universe of Italian private non-financial sector firms. The Business Register quarterly data on local employment have been made available by the Italian Social Security Institute (INPS) since the third trimester of 2014.

To estimate the impact of COVID-19 on each LLM, we build a comprehensive, balanced panel of all 610 Italian LLMs from 2014 Q3 to 2020 Q3 and employ the random forest algorithm described in Section 3. The counterfactual is estimated by controlling for the industrial structure of each LLM. To this end, we exploit the classification by the Italian National Institute of Statistics (Istat), which splits the Italian LLMs into four classes: without specialization, non-manufacturing, made in Italy,[8] and other manufacturing. Furthermore, in light of the expected plunge in tourism-related employment, we split the non-manufacturing class into touristic and non-touristic. We then control for LLM size, geographical dummies, population density, unemployment rate, activity rate, yearly and quarterly fixed effects, and trends in employment, business births, and business deaths. For each of the latter three variables, we control for two lags of the same quarter, the lags of the four preceding quarters, and four lags of the yearly averages. The total number of features included in the counterfactual analysis is 54.

In the second phase of the empirical analysis, the association analysis uses the estimated COVID-19 impact on employment for all LLMs as the outcome of interest to uncover its primary predictors. For this analysis, we collected variables potentially correlated with the employment change due to COVID-19. We use the dependency ratio to control for the population structure and its implications for the productive part of the population. As a measure of the spread of COVID-19, we use the excess mortality estimates provided by Cerqua et al. (2020), updated to 31 August 2020.[9] We also employ two variables which capture the criticality of the tasks performed by employees, the possibility of exposure to the virus and physical proximity to the workplace, all highlighted as relevant factors in the literature (see Barbieri et al., 2020): the share of jobs having a high risk of social aggregation and the share of jobs having a high 'integrated' risk. These variables were created on the basis of the work conducted by an *ad hoc* task force,[10] which linked a level of social aggregation to each economic sector (2-digit NACE Rev.2 classification) and integrated risks from low to high. Activities at high

[8] The 'made in Italy' manufacturing LLMs are characterized by industrial districts. Most of them are specialized in the manufacture of food products, furniture, textiles, apparel, leather and footwear.

[9] These data are publicly available here: https://www.stimecomunalicovid19.com/.

[10] In April 2020, Italy's Prime Minister Giuseppe Conte appointed Vittorio Colao, former Vodafone Group CEO, to lead a group of lawyers, economists and experts, to outline a plan on how to restart the Italian economy after the coronavirus emergency. One of the group's objectives was to reschedule the gradual reopening of economic activities based on two criteria: the risk of social aggregation and the 'integrated' risk.

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integrated risk are those associated with the risk of coming into contact with sources of contagion at work, especially those connected to work processes (e.g. human health services, sewerage, public administration and defense), while activities at high risk of social aggregation are those that involve contact with other subjects in addition to the company's workers (e.g. catering, entertainment, hospitality).

We then build the share of short-term contracts as a metric for temporary jobs' local relative importance.[11] Additionally, in March 2020, the Italian government was forced to suspend many economic activities considered 'non-essential'. The selection of these activities was carried out on the basis of the NACE Rev.2 classification. We made use of this information to generate the share of jobs in suspended economic activities.

Other economic variables included in this phase of the analysis are income per capita, unemployment rate, the share of innovative start-ups as a proxy for local innovation, and a measure of economic fragility, i.e. the share of firms having employees in *Cassa Integrazione Guadagni Straordinaria* (CIGS), namely the most utilized Italian short-time work program providing subsidies for temporary reductions in the number of hours worked.[12]

Lastly, as mobility is one of the critical aspects linked to the epidemiological spread of COVID-19, we take this into account by using three variables:

- the number of road accidents per 10,000 inhabitants;
- the share of population living in peripheral areas;
- the index of relational intensity (IIRFL) within the local labor market. The higher the IIRFL, the greater the inter-municipal turbulence in terms of flows.

In the Appendix, Table A1 includes a more detailed description of all the variables, while Table A2 provides descriptive statistics. The availability of these indicators will allow us to identify the LLM characteristics that matter the most in explaining the treatment effects' heterogeneity.

3. Methods

Our empirical exercise consists of two tasks – a counterfactual analysis and an association analysis.

[11] Even if this variable refers to 2015, we argue that this is a valid proxy for 2020, as there is evidence of a strong temporal persistence in the variation of this variable across locations (Caselli et al., 2020).

[12] CIGS targets firms experiencing economic shocks, broadly defined: it can be a demand or revenue shock, a company crisis, a need for restructuring or reorganization, a liquidity or insolvency issue, etc. CIGS is a subsidy for partial or full-time hour reductions, replacing approximately 80% of the worker's earnings due to hours not worked, up to a cap (Giupponi & Landais, 2020).

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For both steps, we harness ML's predictive power, but with a key difference. In the counterfactual analysis, the ultimate aim is causal inference; when looking at impact predictors, instead, we tackle a purely predictive problem. The choice of the algorithm employed in each phase is in line with the different goals of the two analyses: the trade-off between accuracy and interpretability (Hastie et al., 2009; Murdoch et al., 2019) is solved in favor of the former in the counterfactual analysis, and of the latter in the association analysis. Below, we discuss the two methodologies and their different purposes and empirical frameworks separately.

3.1 Counterfactual analysis: the machine learning control method

To tackle the econometric challenges related to the pandemic shock's pervasive nature, we draw on the newly developed MLCM to generate a counterfactual scenario in which the COVID-19 crisis never hit Italy. In other words, we employ the MLCM to address the fundamental problem of causal inference, i.e. the impossibility of observing the potential outcome in the no-treatment scenario, a curse that affects all LLMs.

Although ML algorithms primarily deal with out-of-sample predictions or 'prediction policy problems' (see Kleinberg et al., 2015), more recently, they have been combined with causal inference approaches (Athey & Imbens, 2016; Athey et al., 2017; Athey et al., 2019; Belloni et al., 2017; Varian, 2016; Wager & Athey, 2018). Varian (2016) was among the first to note that counterfactual building is essentially a predictive task, which is exactly the task at which ML excels. In a panel or time series setting, he noted that one could exploit pre-treatment observations to generate an artificial control group that acts as a counterfactual in the no-treatment, 'business-as-usual' scenario. This way, one could readily retrieve treatment effects as the difference between the observed outcome and the ML-generated potential outcome. Varian called this straightforward counterfactual method the 'train-test-treat-compare' process. This process is similar to the SCM developed by Abadie et al. (2010), with the key difference that it does not require the availability of untreated units, as it draws on pre-treatment information to generate a credible estimate of the 'outcome for the treated if not treated'.

Early empirical applications of this intuitive methodology for counterfactual building have recently appeared (Abrell et al., 2019; Benatia, 2020; Benatia and de Villemeur, 2020; Bijnens et al., 2019; Burlig et al., 2020; Cerqua et al., 2020; Souza, 2019). Except Burlig et al. (2020) and Souza (2019), all the other studies cannot rely on an original control group in their research design because they only observe treated units in settings with simultaneous treatment, just as in our case.

Benatia (2020) and Cerqua et al. (2020) are the most closely related to this study because they both investigate the causal effects of the COVID-19 crisis. Benatia (2020) applies a neural network model

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to study the impact of containment measures on the demand reduction in New York's electricity markets; Cerqua et al. (2020) employ three different ML routines (LASSO, random forest, and stochastic gradient boosting) to derive municipality-level excess mortality estimates during the COVID-19 pandemic in Italy.

In the spirit of this nascent evaluation approach, we apply the MLCM to pursue our causal inference analysis of COVID-19 local economic impacts in Italy. Our artificial control group comes from an ML predictive model developed to forecast a post-treatment counterfactual for each LLM. In this way, under the crucial assumption of stable trends in the absence of the shock, we can assess the LLM-specific causal impact of the exogenous shock by comparing the observed post-shock trajectory with the most credible trajectory the LLM unit would have followed in a no-shock scenario. A critical requirement for this approach's validity is that the predictive ML model must not include predictors that may be affected by the treatment (Varian, 2016). We avert this issue by employing only pre-2020 features in our counterfactual building. Finally, the use of the MLCM is made possible from the construction of a comprehensive time-series cross-sectional database on LLMs (see Section 2).

We apply a powerful and popular ML algorithm: the random forest.[13] The random forest is a fully non-linear technique based on the aggregation of many decision trees. In particular, random forest builds many trees (1000, in our case) based on bootstrapped training samples and, at each split of a tree, uses only a random subset of the predictors as split candidates, thus introducing a double layer of decorrelation of the trees from one another (Hastie et al., 2009).

Drawing from the routine already implemented by Cerqua et al. (2020), our counterfactual analysis is based, for each outcome variable, on the following 7-step methodological sequence:

1) We randomly split the pre-2019 quarterly dataset (2016 Q3 - 2018 Q4 for employment; 2015 Q1 - 2018 Q4 for firm outcomes) into a training sample, made up of 80% of the LLMs, and a test set, consisting of the remaining 20%;[14]
2) We train our random forest algorithm on the training set and perform a 10-fold cross-validation to select the best-performing tuning hyperparameter;[15]

[13] We also tested the forecasting performance of another well-known ML technique, the Least Absolute Shrinkage and Selection Operator (LASSO), but it was always inferior to that of the random forest.

[14] We apply the random splitting of the sample at the LLM level, *not* on *LLM-year* pairs so that there is no data leakage, i.e. the same LLM only appears either in the training or the testing set.

[15] We use cross-validation to solve the bias-variance trade-off and maximize the out-of-sample performance of the random forest algorithm. (Hastie et al., 2009). Specifically, we employ 10-fold cross-validation on the *training* sample to select,

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3) We test the out-of-sample predictive performance on the corresponding pre-2019 testing sample;

4) We test model accuracy on the entire 2019 sample and compare its predictive performance with that of a before-after analysis, which has become a common and intuitive metric to gauge the magnitude of the pandemic's impact;[16]

5) We repeat the same routine on the entire pre-2020 dataset (2016 Q3 - 2019 Q4 for employment; 2015 Q1 - 2019 Q4 for firm outcomes) and finally predict, for the first three quarters of the 2020 sample, employment levels, business births, and business deaths in a 'no-COVID' ('business-as-usual') scenario;

6) We derive individual treatment effects for all LLMs as the difference between the observed 2020 outcomes and the ML-generated potential outcomes;

7) We map the individual treatment effects of the LLM-level economic impacts of COVID-19.

The critical assumption behind this MLCM routine is that the difference between our observed and counterfactual economic outcomes is due to the impact of the COVID-19 crisis. While this is not a trivial assumption, we deem it plausible given the unprecedented disruption to the economy caused by the sudden arrival of the pandemic. Finally, please note that, in our definition of shock, we include lockdowns, workplace closures, all the social distancing policies adopted to contain the spread of the contagion, as well as the related supply and demand shifts in response to the crisis (that may affect labor markets heterogeneously, depending on sectoral specialization, as demonstrated by Krueger et al., (2020)), and not just the epidemiological spread of the virus *per se*, in line with our goal of capturing the *economic* developments of the pandemic.

3.2 Association analysis: the employment change regression tree

To estimate the relationship between the estimated employment outcomes and potentially relevant covariates linked to economic, mobility, and pandemic-related LLM features, we harness the efficacy and power of another well-known ML algorithm: the regression tree.

First and foremost, bear in mind that here we abandon the causal inference setting to go back to the

among different alternatives (*p/2, p/3*, and *p/6*), the optimal value of the tuning hyperparameter *m*, i.e. the number of features *p* randomly sampled as candidates at each split.

[16] In the Italian context, see, for example, Casarico and Lattanzio (2020), as well as here: https://www.lavoce.info/archives/68205/cosi-il-coronavirus-ha-contagiato-limprenditorialita/ (in Italian) and here: https://www.bancaditalia.it/media/notizie/2020/Nota-Covid-19.11.2020.pdf?language_id=1 (in Italian) for intuitive comparisons between 2020 observed data and past trends or averages in the previous year(s).

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original ML habitat, i.e. the realm of pure prediction. What we want to do in this analysis is to get an idea of the factors which matter most in predicting the heterogeneous local economic impact of the pandemic.

Regression trees are an ideal tool to fulfill this purpose for two reasons: i) differently from complex, black-box ML methods such as random forest, regression trees allow an intuitive understanding of the mechanism through which the outcome variable of interest is linked to its most relevant predictors, thus producing an easy-to-interpret output which can be particularly valuable when the model must be shared to support public decision-making (Andini et al., 2018; Lantz, 2019); ii) regression trees are extremely flexible methods that can easily capture, in the sequence of splits, the entire range of potential non-linearities and interactions between the features, without imposing any parametric functional form to the underlying data-generating process.

From a technical point of view, this ML algorithm divides the data into progressively smaller subsets to identify significant patterns that are then used to predict the continuous output. Compared to standard regression tree analyses, two necessary clarifications are in order. First, we do not divide our sample into a training and testing set. The reason is straightforward: instead of testing for the out-of-sample accuracy of our regression tree model, we want to investigate the main predictors of our outcome variable, i.e. the estimated treatment effect for employment change in 2020 Q3, on the full sample of Italy's LLMs. Second, and related, we do not apply cross-validation to select the hyperparameter of the regression tree method (named 'complexity parameter', *cp*).

Therefore, we run a basic regression tree model of the employment effects to uncover the most relevant predictors of treatment effect unevenness at the local level. Notably, the associations emerging from the regression tree should not be interpreted in a causal sense, but rather as a way to uncover significant correlations between the most important features and the outcome variable of interest.

4. Counterfactual analysis

We begin by reporting in Table 1 the random forest technique's predictive performance compared to the intuitive before-after method often adopted to gauge the magnitude of the COVID-19 shock.

As signaled by the Mean Squared Error (MSE) and Median Squared Error (MEDSE) of the various methods, random forest predictions substantially outperform the intuitive methodology in the out-of-sample predictive test on the 2019 sample. Using MSE as the reference metric, the predictive gain of the random forest performance is of more than 26% compared to last year's figures, and of 77% compared to the three-year (2016-2018) average of the outcome variable, two of the most commonly adopted metrics to gauge the impact of the pandemic. MEDSE performances are even more dramatically unbalanced in favor of the random forest. This test demonstrates that data-driven methodologies lead to far more accurate predictions of potential outcomes in a given, 'ordinary' year.

Table 1 – Predictive performances for 2019 (log) overall employment levels

Predictive method	MSE	MEDSE
Corresponding quarter – Last year (2018)	0.0011209	0.0005058
Corresponding quarter – 3-year average (2016-2018)	0.0036044	0.0024622
Random forest	0.0008268	0.0001938

Notes: Estimates on the 2019 full LLM sample (2440 observations; 610 per quarter). MSE stands for Mean Squared Error; MEDSE for Median Squared Error.

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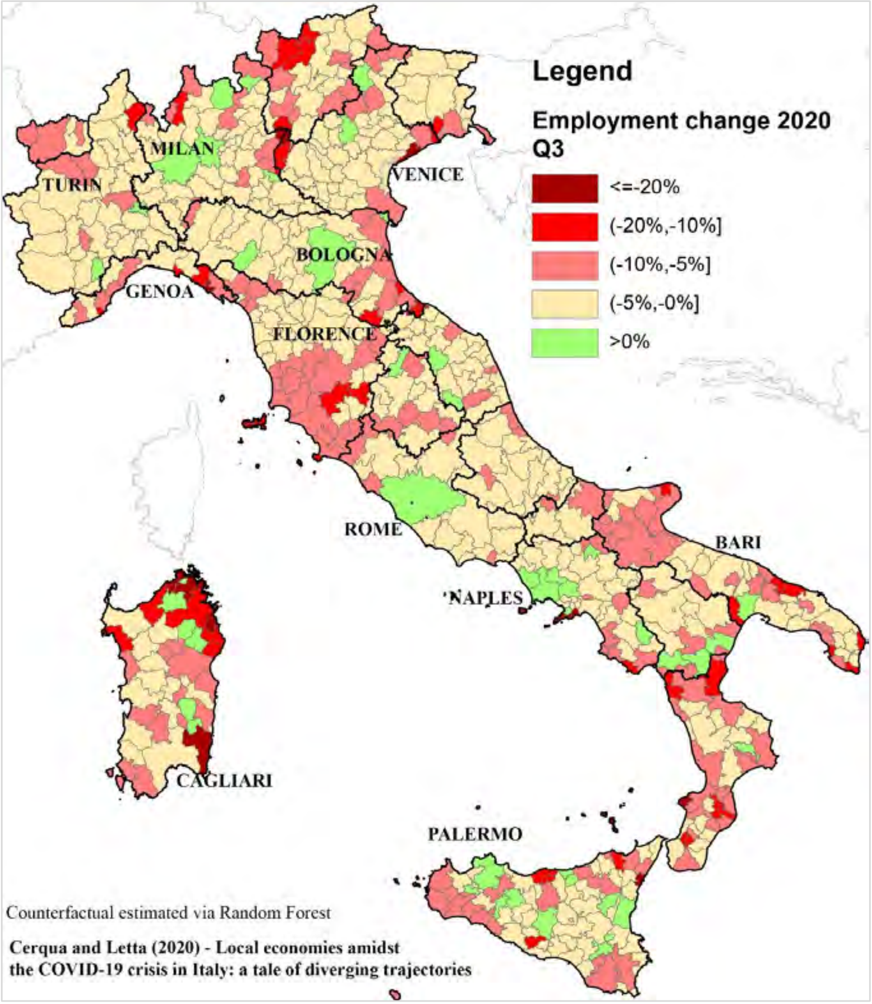
Having established that ML algorithms exploit past information to predict future outcomes much better than descriptive methods, we take a quick look at the aggregate treatment effects of the coronavirus crisis for the employment outcome. By the end of the third quarter of 2020, the pandemic has entailed a 1.86 % decrease in overall employment in Italy, compared to what employment levels would have been had the pandemic never reached the country.

As we mainly focus on the local heterogeneous impact of COVID-19, in the following sections, we first map LLM-specific treatment effects and then gauge the heterogeneity in COVID-19 impacts across local economies.

4.1 Employment

Figure 1 shows the map of the 2020 Q3 employment change at the LLM level. The degree of treatment effect heterogeneity is striking. Except for a few small clusters, the crisis does not seem to unfold along well-defined spatial dimensions or the North-South axis. Nevertheless, some local economies have been hit much harder than others, with impacts ranging from drops larger than 20% in some LLMs of Lombardy, Veneto, Liguria, Calabria, Sicily and Sardinia, to small decreases or even mildly positive effects in Piedmont, Marche, Umbria, Lazio, Abruzzo and Molise. What is even more striking is the *within-region* heterogeneity, which shows how, in all Italian regions, some LLMs fared much better than others despite being geographically close and often contiguous. From an economic geography perspective, our findings suggest that the spatial dimension played a minor role as a transmission channel of the crisis's impacts and suggests a far more prominent role of LLM-specific sectoral characteristics and labor market features. Figure A1 in the Appendix displays the temporal evolution of the employment effects over the first three quarters of 2020: only in the third quarter of 2020, do the impacts appear, and local trajectories start to diverge.

Figure 1 – Employment change 2020 Q3



We then inspect the geographic distribution of the employment and epidemiological outcomes engendered by COVID-19. Figure A4 in the Appendix presents a visual comparison between the economic vs. epidemiological effects of COVID-19 in Italy. Looking at the maps, the geographic distribution of impacts does not mirror the COVID-19 epidemiological spread during the first wave, which is proxied by excess mortality estimates from February 21, 2020, to August 31, 2020. To test the spatial correlation between these outcomes, we measure their overall spatial relationship across

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all LLMs using the bivariate Moran's I. This index ranges from -1 (perfect negative spatial correlation) to 1 (perfect positive spatial correlation), and we obtained a Moran's I coefficient close to 0 (+0.108), which suggests a lack of significant spatial correlation between employment and epidemiological outcomes.

It is worth noting that the documented employment impacts are net of the Italian government's protective measures. This means that without these protective measures (the layoff freeze and CIGS extensions in particular), local impacts would have likely been even more sizeable.[17]

4.2 Employment by sector

If LLMs' regional or spatial location is not a primary driver, where does the heterogeneous impact on overall employment originate? Sectoral specialization of LLMs is part of the answer. As shown in the maps of employment change in manufacturing and services, depicted in Figure 2 below, the tertiary sector was much more severely affected than the manufacturing one and appears to be the leading cause of the overall employment change observed in Figure 1.[18] This is not unexpected, as workplace closures primarily affected economic activities in the tertiary sector. At the same time, a large share of manufacturing firms could avert the shutdown thanks to being comprised in the list of 'essential activities' that the government decided to keep open to guarantee the basic functioning of Italy's economic system. The tertiary sector is also notably the one with the highest prevalence of temporary jobs and seasonal workers, which could only marginally benefit from the layoff freeze measure. Given these facets, it comes as no surprise that employment losses primarily affected LLMs specialized in services.

Figures A2 (for manufacturing) and A3 (for services) in the Appendix also provide the evolution of impacts by quarter: while the manufacturing sector experienced only a moderate negative trend over the year, the services sector suffered a massive blow during the third quarter, in line with the trajectory of overall employment illustrated in Figure A1.

4.3 Business demography

We then look at how COVID-19 affected business demography outcomes. At the national level, by

[17] For example, a recent study by the Bank of Italy suggests that the government's protective policies avoided at least 600,000 layoffs in 2020: https://www.bancaditalia.it/media/notizie/2020/Nota-Covid-19.11.2020.pdf?language_id=1 (source in Italian).

[18] This is confirmed by the national-level estimates, which reveal an aggregate 0.28% decrease in manufacturing compared to a 2.13% decrease in services.

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the end of the third quarter of 2020, the crisis determined a 20.99% decrease in business births and a 2.11% decrease in business deaths. Figure 3 disaggregates these country-level estimates and maps the cumulative impact of COVID-19 for business births change (i.e. firm entries) and business deaths change (firm exits) over the first three quarters of 2020.

The impact on business births is particularly acute and, with almost no exception, involves the entire national territory. This anomalous plunge happened despite the so-called *Decreto Rilancio* (May 14, 2020), which included a set of protective measures intended to support investments in start-ups (Fini & Sobrero, 2020). By contrast, the impact on firm exits is more polarized and geographically dispersed, with several regions experiencing substantial reductions in cessations of trading, e.g. Emilia-Romagna and Marche, whereas others (Lazio, Abruzzi, Basilicata and, in particular, Sardinia) saw a significant increase in firm exits. Sardinia's case is emblematic as tourism, arguably the hardest-hit sector, plays a vital role in its economy.

The generalized drop in the number of newly-born firms across the country is particularly troublesome because start-ups and young firms are usually the most innovative ones, thus pointing to dire forecasts about the potentially long-lasting effects of the fall in business births in terms of aggregate productivity growth.[19] Moreover, this lost generation of firms creates a persistent dent in overall employment as subsequent years will be characterized by a lower number of firms (Sedláček, 2020). This is all the more worrying in Italy, a country whose economic dynamism – its ability and willingness to allocate resources efficiently – has been steadily declining in the last quarter of a century (Rossi & Mingardi, 2020).

[19] On this issue, see also https://www.lavoce.info/archives/68205/cosi-il-coronavirus-ha-contagiato-limprenditorialita/ (in Italian).

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Figure 2 – Employment change 2020 Q3 by sector

Manufacturing | Services

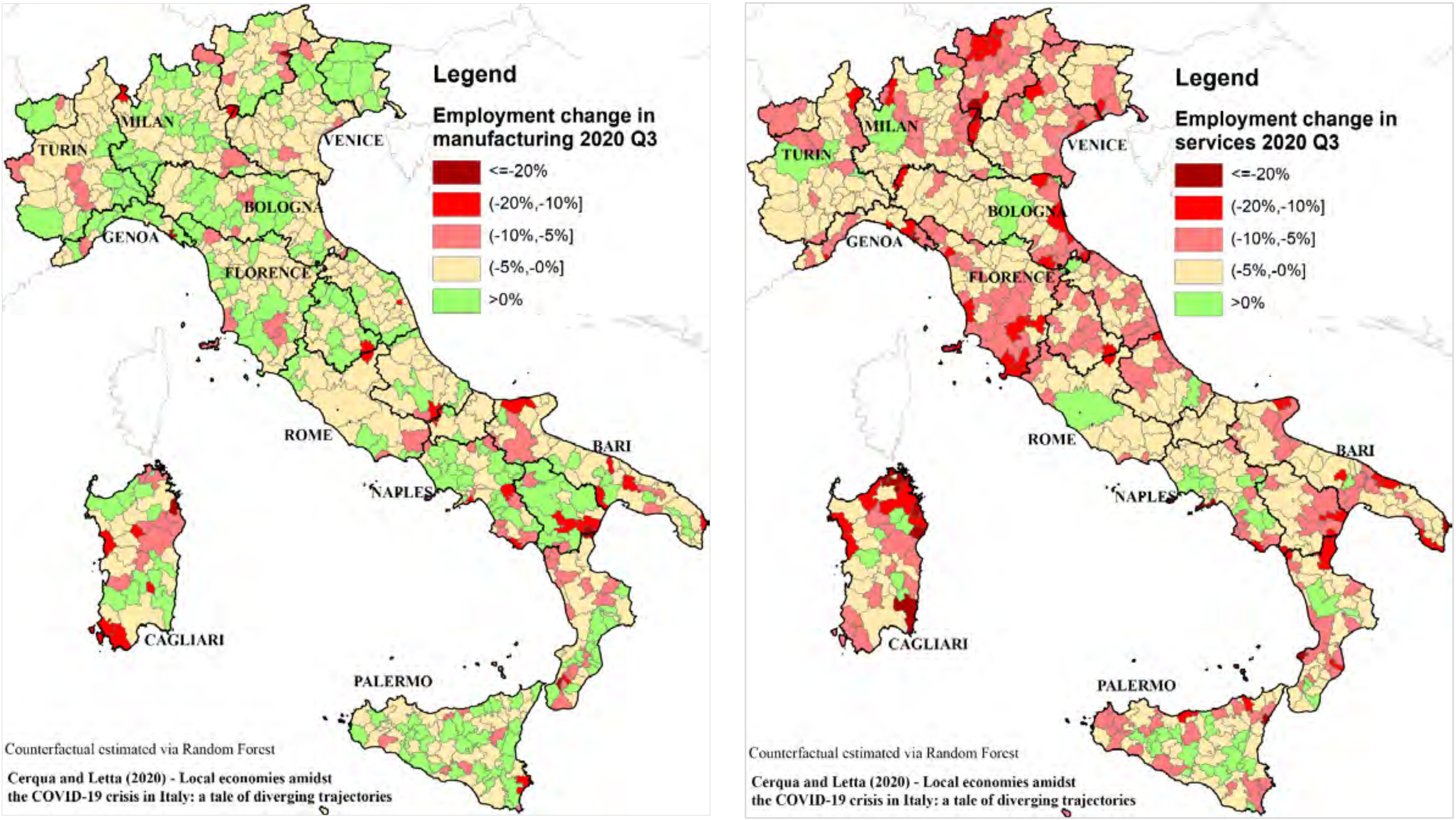
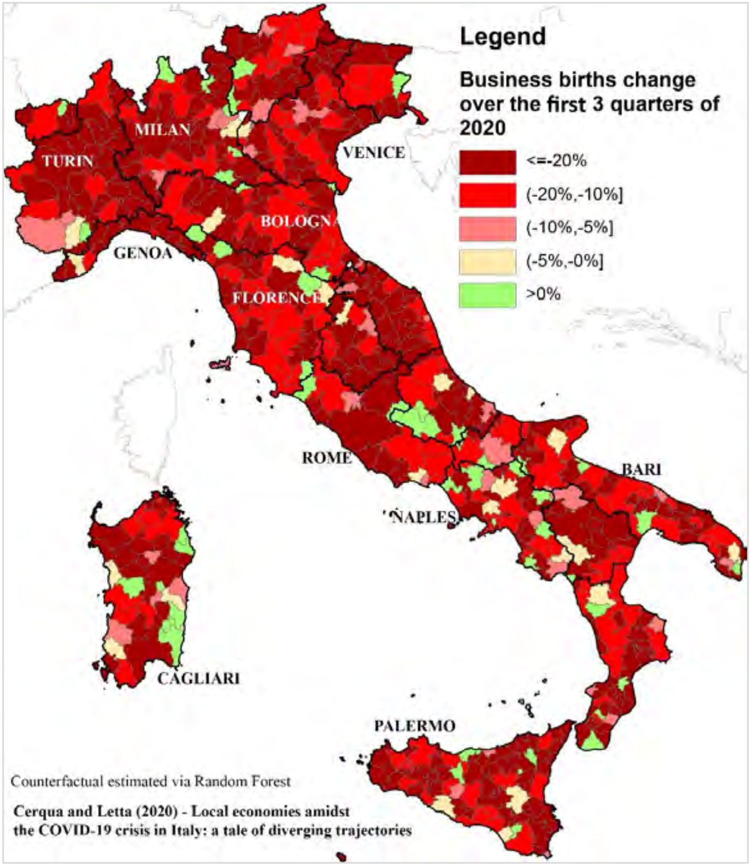
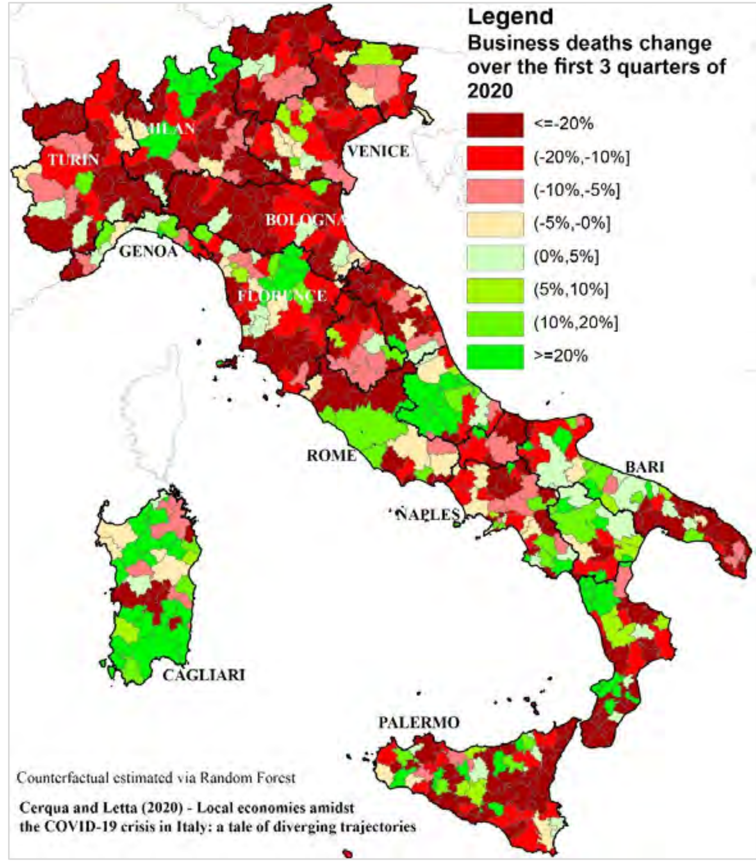


Figure 3 – Business births and deaths change 2020 Q1-Q3

Business births



Business deaths



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5. Association analysis

The counterfactual analysis revealed a substantial heterogeneity of the pandemic economic effects. Such heterogeneity does not stem from regional or intra-regional clusters but is partly driven by the LLMs sectoral specialization. Nevertheless, we want to go further than this and understand the factors that matter the most in generating such a fragmented landscape. Therefore, in this section, we use a regression tree to examine the main predictors of our primary variable of interest, employment.

Figure 4 illustrates the regression tree of the LLM-specific overall employment treatment effects. The tree reveals interesting patterns. First, the few variables that generate the tree belong exclusively to two variable groups: aggregation and mobility features and labor market characteristics. Second, the most severely affected LLMs are those in which there is a high share of jobs at a high risk of social aggregation and a high share of jobs suspended in March 2020, and, even more importantly, a high share of temporary contracts. For instance, the tree predicts that LLMs with a share of jobs having a risk of aggregation equal to or higher than 43% and a share of temporary contracts equal to or higher than 29%, will experience a 33% drop in employment.

Exposure to high aggregation and proximity risk seems to be a primary discriminant of impacts across LLMs with different shares or 'workers at risk' (Barbieri et al., 2020). The relevance of these labor market attributes in generating the regression tree provides empirical support for the above discussion on the unequal exposure of different workers' categories and types of contracts in the face of the crisis, in line with the heterogeneous findings of Casarico and Lattanzio (2020) for Italy and Blundell et al. (2020) for the UK. This analysis also suggests that emergency measures and fiscal packages were by design effective only for specific categories of workers and types of contracts. By contrast, more fragile categories (think of seasonal workers and occasional jobs) proved to be more vulnerable to the crisis's labor market consequences.

In sum, the interactions between economic sectors having high social aggregation risks and fragile labor markets are associated with sharp drops in overall employment at the local level.

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Figure 4 – Regression tree on employment change 2020 Q3

6. Conclusions

We have documented the striking level of inequality of the economic impacts of the coronavirus crisis across the Italian territory. This heterogeneity is associated with LLM-specific features such as sectoral specialization, exposure of economic activities to high social aggregation risks, and pre-existing labor market vulnerabilities. By contrast, there is no discernible spatial correlation between the economic and epidemiological geographical patterns of the pandemic.

We deem the local and sectoral dimensions of the crisis to be policy-relevant, especially in light of the current political debate on the allocation of the forthcoming resources from the aid mechanisms developed by the European Union, namely the *Recovery Plan* and the *NextGenerationEU* initiative. A broad glance at the national level can capture the generalized sharp drop in firm entries, but overlooks the high degree of unevenness in the effects on employment levels and business deaths across the Italian territory.

Coupled with the relevant role played by labor markets' insecurity emerging from the association analysis, these findings call for more research to untangle the local economic impacts of the pandemic, and for a place- and sector-based approach in the policy response to the crisis. National policies and top-down plans will be insufficient to lead the recovery (Bailey et al., 2020). Therefore, to inequality and heterogeneity must correspond *ad hoc*, well-targeted policy interventions based on a local and place-based perspective that considers the territorial profile and sectoral specialization of local economic systems (Ascani et al., 2020). Only in this way will it be possible to attenuate the disruptive consequences of the COVID-19 upheavals and prevent the unfolding crisis from further exacerbating pre-existing inequalities among Italian local economies.

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Appendix

Table A1 – Definition of the variables included in the analysis

Variable name	Definition	Time period	Source
	Counterfactual analysis		
Employment	Overall employment of private non-financial sector firms	2014 Q3 – 2020 Q3	Business Register
Employment in manufacturing	Overall manufacturing employment	2014 Q3 – 2020 Q3	Business Register
Employment in services	Overall services employment	2014 Q3 – 2020 Q3	Business Register
Business births	Companies that have registered in the period under review	2014 Q1 – 2020 Q3	Business Register
Business deaths	Companies that went out of business in the period under review	2014 Q1 – 2020 Q3	Business Register
Economic classification dummies	Without specialization, non-manufacturing (touristic), non-manufacturing (non-touristic), made in Italy, other manufacturing	2011	Istat
Geographical dummies	North-East, North-West, Centre, South		Istat
Population density	Resident population per unit area	2014-2019	Istat
Unemployment rate	Resident population aged 15+ not in employment but currently available for work	2014-2019	Istat
Activity rate	The number of people employed and those unemployed as a % of the total population	2014-2019	Istat
	Association analysis		
Employment change Q3 2020	Treatment effect of the COVID-19 crisis on overall employment levels	2020 Q3	Estimated via the MLCM
Unemployment rate	Resident population aged 15+ not in employment but currently available for work	2019	Istat
Excess mortality estimates	Local excess mortality estimated via applying ML techniques to all-cause deaths data	From Feb 21, 2020 to Aug 31, 2020	Cerqua et al. (2020)
Share of jobs having a high risk of social aggregation	Number of employees exposed to a medium-high or high risk of social aggregation divided by the number of employees	2019	Own calculations using Business Register data

Table A1 – Continued

Share of jobs having a high integrated risk	Number of employees exposed to a medium-high or high integrated risk divided by the number of employees	2019	Own calculations using Business Register data
Share of short-term contracts	Number of employees with short-term contracts in October divided by the number of employees in October	2015	Istat
Share of jobs in suspended economic activities	Share of jobs in activities suspended in March 2020 by the Italian Government due to the spread of the pandemic	2017	Istat
Income per capita	The amount of money earned per person	2018	Ministry of Economy and Finance
Share of innovative start-ups	The ratio between innovative start-ups and the universe of firms registered in the Business Register	Average (2016-2019)	Business Register
Share of firms having employees in CIGS	The number of firms with employees in CIGS divided by the universe of firms registered in the Business Register	Average (2015-2018)	Ministry of Labor and Social Policies
Number of road accidents per 10,000 inhabitants	The number of road accidents with injuries to persons divided by resident population * 10,000.	2019	Istat
Dependency ratio	The ratio of those typically not in the labor force (the dependent part, ages 0 to 14 and 65+) and those typically in the labor force (the productive part, ages 15 to 64)	Jan 1, 2020	Istat
Share of population living in peripheral areas	Share of population living in areas defined by Istat as peripheral or ultra-peripheral	Jan 1, 2020	Istat
Index of relational intensity (IIRFL)	The percentage of flows within an LLM that connect different municipalities on the total of flows within the LLM. This indicator ranges from values close to 0 to 100 (case in which all the workers of the municipalities of the LLM go to work in another municipality). The higher the indicator, the greater the inter-municipal turbulence in terms of flows.	2011	Istat

Notes: To determine the flow of registrations in a given period – e.g. 2nd trimester 2019 - the firms' universe extracted from the archive on June 30 is compared with that extracted in the previous quarter (March 31). Firms that are present in the 2nd (1st) quarter but not in the 1st (2nd) are classified as new registrations (companies that went out of business). Outcome variables in bold.

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Table A2 – Descriptive statistics

Variable name	Mean	SD	Min	Max
Counterfactual analysis				
Employment (log)	9.31	1.25	5.95	14.41
Employment in manufacturing (log)	7.53	1.61	3.37	12.65
Employment in services (log)	8.89	1.29	5.51	14.22
Business births	55.97	236.18	0	5173
Business deaths	44.63	202.79	0	9685
Share of LLMs without specialization	0.19	0.39	0	1
Share of touristic LLMs	0.14	0.34	0	1
Share of non-manufacturing (non-touristic) LLMs	0.23	0.42	0	1
Share of *made in Italy* LLMs	0.31	0.46	0	1
Share of manufacturing LLMs	0.14	0.35	0	1
<=10,000 inhabitants	0.08	0.28	0	1
(10,000; 50,000]	0.46	0.50	0	1
(50,000; 100,000]	0.25	0.43	0	1
(100,000; 500,000]	0.18	0.39	0	1
> 500,000 inhabitants	0.03	0.16	0	1
Activity rate	48.26	6.66	30.15	63.91
Unemployment rate	11.85	6.17	1.19	39.08
Population density	0.21	0.30	0.01	3.17
Association analysis				
Employment change Q3 2020 (%)	-5.17	5.50	-44.73	6.78
Unemployment rate (%)	10.99	5.91	1.19	36.19
Excess mortality estimates (%)	7.98	22.38	-32.28	173.01
Share of jobs in suspended economic activities	0.47	0.08	0.25	0.79
Income per capita (€)	12705	3588	5882	22118
Share of firms having employees in CIGS	0.0008	0.0007	0	0.0046
Share of population living in peripheral areas	0.29	0.40	0	1
Share of short-term contracts	0.19	0.08	0.10	0.56
Number of road accidents per 10,000 inhabitants	2.18	1.20	0	6.94
Index of relational intensity (IIRFL)	25.70	14.48	0.2	66.1
Dependency ratio	0.58	0.05	0.43	0.78
Share of innovative start-ups	0.003	0.003	0	0.017
Share of jobs having a high risk of social aggregation	0.23	0.11	0.06	0.76
Share of jobs having a high integrated risk	0.06	0.03	0.01	0.37
Number of LLM-quarters (whole sample)	10,370			
Number of LLMs	610			

Figure A1 – 2020 Employment change by quarter

Quarter 1 | Quarter 2 | Quarter 3

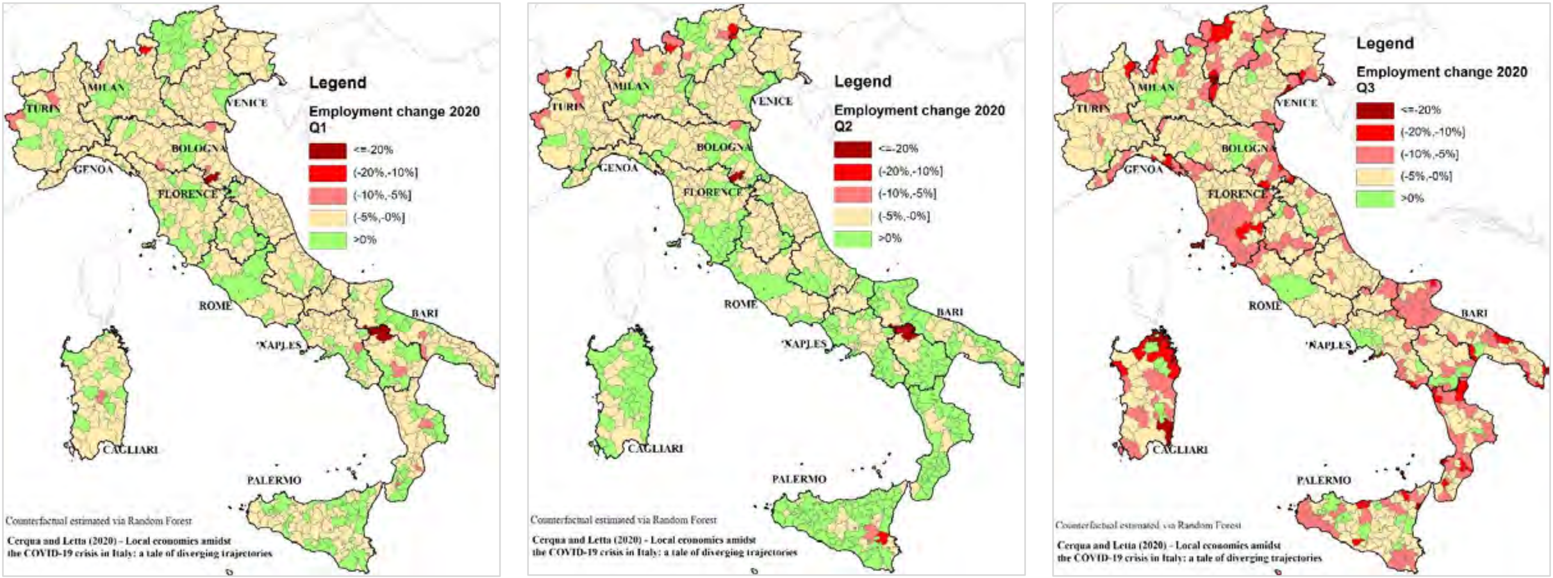

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Figure A2 – 2020 Employment change in manufacturing by quarter

Quarter 1 Quarter 2 Quarter 3

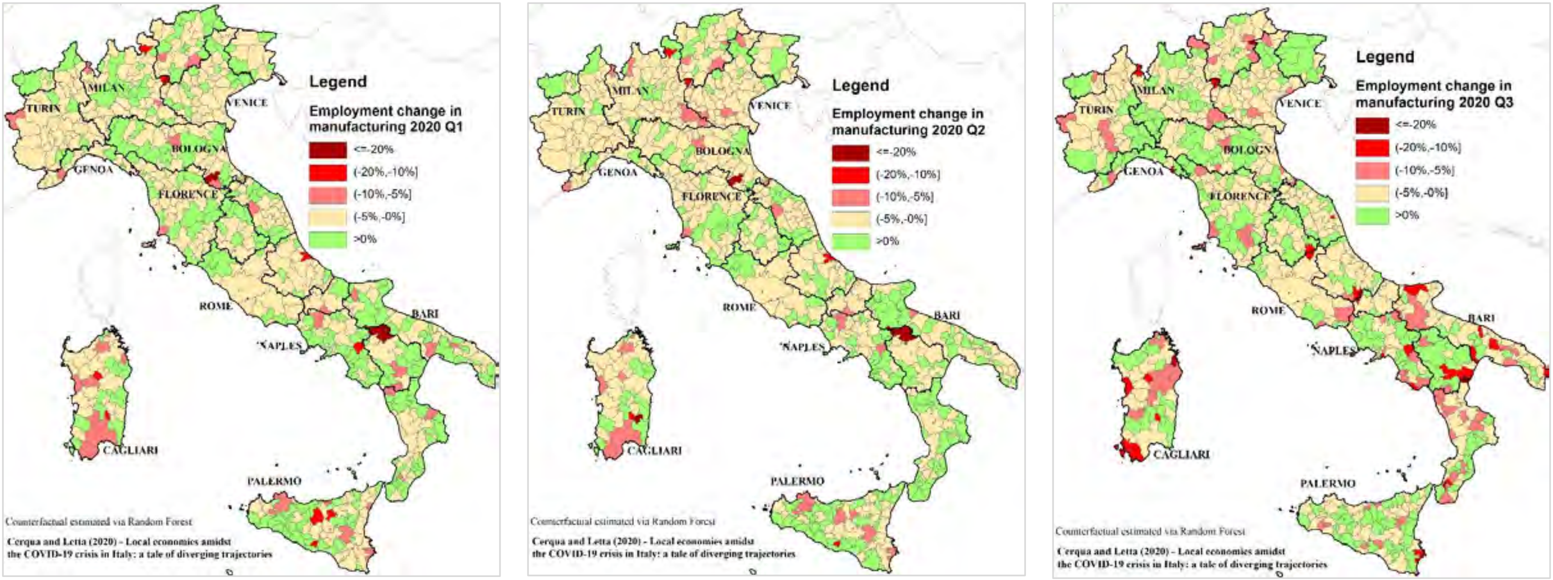

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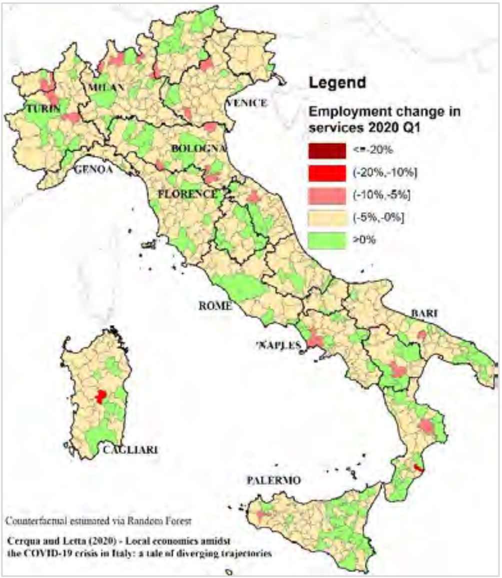
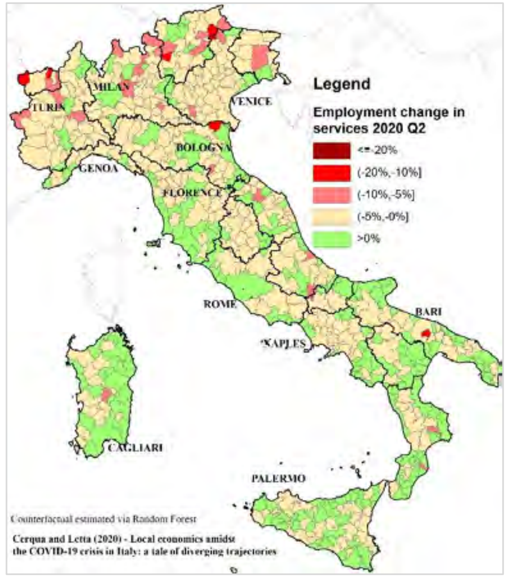
Figure A3 – 2020 Employment change in services by quarter

Quarter 1



Quarter 2



Quarter 3

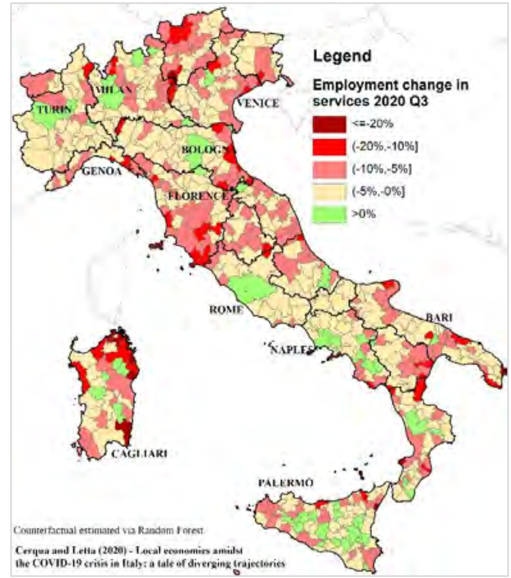


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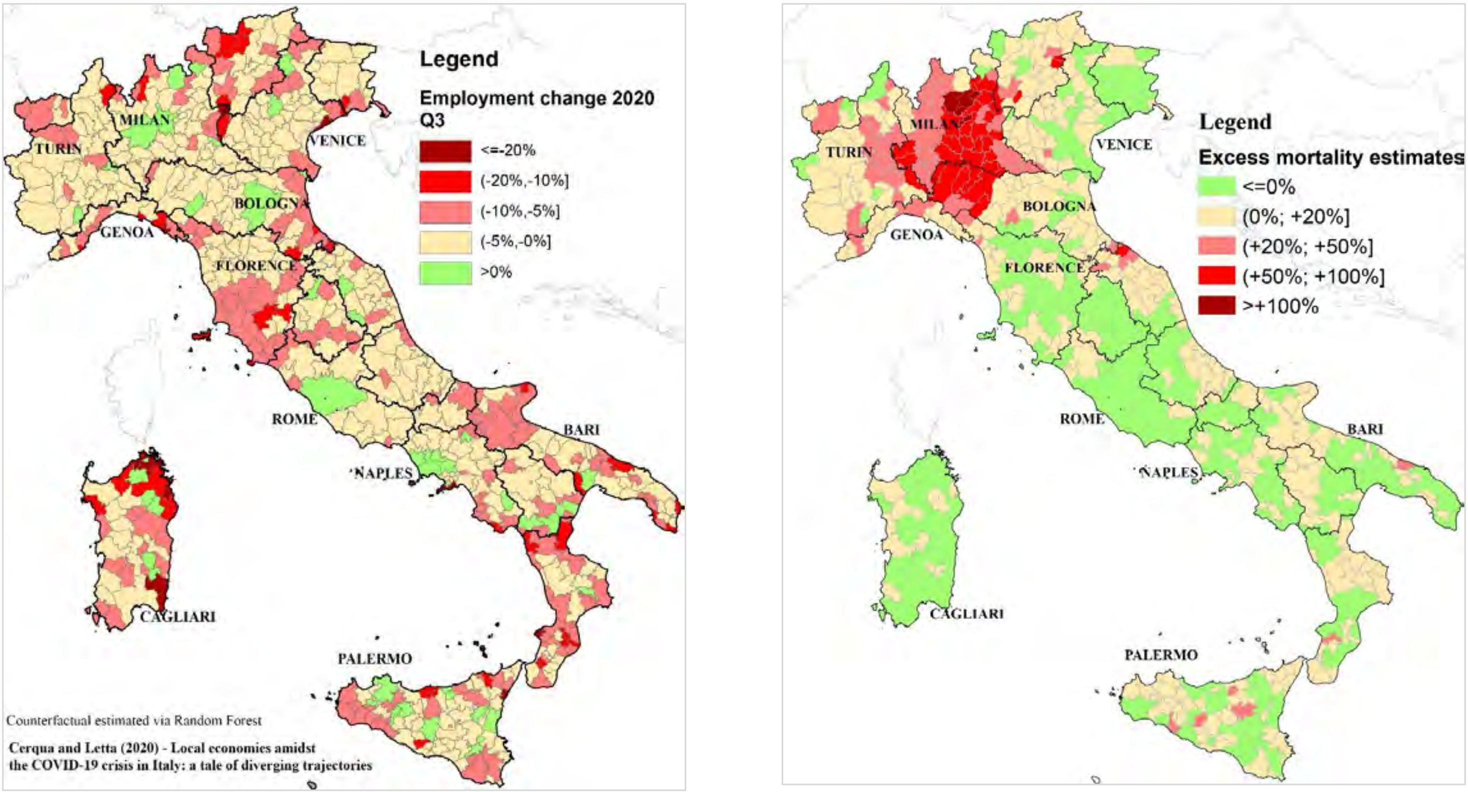
Figure A4 – Economic versus epidemiological impacts of the COVID-19 pandemic across Italy

Employment change 2020 Q3 | Excess mortality (21 Feb 2020 – 31 Aug 2020)



Notes: Excess mortality estimates are from Cerqua et al. (2020).

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Short-term trade-off between stringency and economic growth[1]

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The coronavirus disease (COVID-19) represents a simultaneous health and economic shock for the vast majority of countries around the world and a wide range of Non-Pharmaceutical Interventions (NPIs) have been used by policymakers to mitigate its spread. It is recognised that this entails an implicit trade-off between health and economic outcomes. This paper investigates this trade-off for 106 developed and developing countries by linking NPIs with quarterly economic growth outcomes. The results indicate that the NPIs that negatively affect growth differ between Advanced Economies (AEs) and Emerging Market and Developing Economies (EMDEs). Testing policy was found to have helped in mitigating the negative economic impact in EMDEs. COVID-19 mortality had a larger impact in EMDEs compared to AEs. Overall, the results might suggest a more favourable short-term trade-off between stringency and economic growth for policymakers in EMDEs. However, this does not account for longer-term economic outcomes.

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Introduction

The coronavirus disease (COVID-19) represents a simultaneous health and economic shock for the vast majority of countries around the world. The use of non-pharmaceutical interventions (NPIs) such as school closures and work from home arrangements have been commonly used by governments to tackle the spread of COVID-19. It has been widely agreed that NPIs impose an economic cost, resulting in a trade-off between health and economic outcomes that policymakers must consider when setting which NPIs to impose and the severity of NPIs.

The improvement in health outcomes from NPIs can be assessed through the effect on COVID-19 case incidence, severity, deaths and/or any other health metrics. However, the economic costs of NPIs are still being investigated with the applicability of research from past pandemics or disasters to COVID-19 being unclear, and the lack of very high frequency economic data to reliably monitor current economic conditions in countries across the world. Currently, economists' single best indicator to assess economic health and progress is real Gross Domestic Product (GDP) growth, despite the inherent limitations in the compilation of this statistic and in data timeliness for useful policymaking.

It is not yet clear whether the introduction and relaxation of NPIs within countries will be a smooth process. It may be the case that the introduction of NPIs could occur suddenly in a scenario where a large COVID-19 outbreak is detected. The development of an effective vaccine or treatment for COVID-19 is not likely to be an instantaneous resolution of the COVID-19 pandemic given potential manufacturing and global distribution challenges. Instead it seems likely that countries will have to regularly adjust NPIs based on the COVID-19 situation within their own country and globally for quite some time, which may be in the order of years.

This paper aims to contribute to the developing literature on the economic impact of COVID-19 by studying the short-term trade-off between the stringency of NPIs and economic growth. It is not the intention of this paper to suggest that economic growth should be prioritised over the health of the public. It is hoped that the paper can provide more information on the economic costs of NPI introduction and/or calibration that can help policymakers to make evidence-based decisions. This paper contributes to the literature in a number of areas; a wider sample of countries particularly developing economies are examined, the effects of NPIs on economic growth are directly assessed rather than relying on a proxy of economic activity; differentiated effects between advanced and developing economies are assessed; and the effects of a wider range of economic and health system policies are evaluated.

Literature Review

This section describes the relevant literature in the area of economic growth and NPIs. Hale et al. (2020) developed the Oxford Covid-19 Government Response Tracker (OxCGRT), which provided a standardised methodology to assess the various government policies on COVID-19. The tracker contains 17 indicators covering containment and closure policies, economic policies and health system policies. A number of indices were also developed by Hale et al. (2020) to assess certain aspects of government policy on COVID-19 such as the Government Response Index, Containment and Health Index, Economic Support Index and Stringency Index. More detailed information on OxCGRT has been made available online by the Blavatnik School of Government, University of Oxford.

Literature has tried to draw lessons from history on the potential impact of COVID-19. Jordà et al (2020) looked at the long run impact of major pandemics since the 14th century on real rates of return. They found that real rates of return are depressed for decades after a pandemic which might be due to labour scarcity. A pandemic with high mortality causes capital per unit of surviving labour to increase which may result in lower real rates of return. Beach et al (2020) undertook an extensive review of the literature on the 1918 influenza pandemic to determine the effects on mortality, fertility and the economy. There was mixed evidence on the medium-term effects of the pandemic and NPIs on economic activity. In the short-term while the pandemic was ongoing, countries experiencing higher pandemic mortality appeared to experience lower economic activity due to inadequate labour supply. Based on the estimates of Barro et al (2020), the 1918 influenza pandemic that killed on average 2% of the population of the sample countries resulted in decrease of real GDP per capita by 6% and real consumption per capita by 8%. Arthi and Parman (2020) looked at the potential long-run impact of COVID-19 on health, labour and human capital by comparing it to past pandemics and recessions. Pandemics tend to have long-term negative health outcomes for affected individuals. Recessions tend to cause long-term economic penalties (i.e. long-term scarring effect) for individuals experiencing the recession who would tend to have lower lifetime earnings.

Some authors have developed real-time indicators of economic activity to provide up-to-date monitoring of economic conditions during the recession caused by COVID-19. Chetty et al (2020) utilised anonymised data from private companies to provide a real time county-level view of the US economy in terms of consumer spending, small business revenue, small business openings, job postings and online math participation. Lewis et al (2020) developed a Weekly Economic Index (WEI) of the US based on 10 indicators of real economic activity. Luohan Academy (2020) developed a Global Pandemic Economy Tracker based on the relationship between mobility and economic growth. Given COVID-19 impact is still on-going, readers may obtain up-to-date estimates of economic activity for the papers mentioned in this paragraph online.

Literature has explored the potential differing impacts of COVID-19 in developed and developing countries. Dingel and Nieman (2020) undertook an exercise to classify the feasibility of working from home on an occupation level basis for 86 countries. They found that around 5% to 60% of jobs can be carried out from home, and this percentage has a positive correlation with GDP per capita, i.e. higher income countries have a higher proportion of jobs that can be carried out from home. This suggests that developing economies face more challenges in work from home arrangements. Saltiel (2020) used the Skills Towards Employability and Productivity (STEP) survey of ten low and middle income economies to estimate that only between 6% to23% of the workers in the sample countries can work from home. Gottlieb et al (2020) found that in poor countries only about 20% of workers can work from home compared to around 40% in rich countries. This is driven by a larger share of agricultural and self-employed work in poor countries. Alfaro et al. (2020) investigated how the economic structure in developing economies, particularly relating to microenterprises and informal work, might cause differing economic outcomes compared to developed economies. They explored the structures of the United States and Colombia to identify the differing impact that COVID-19 might have on employment and aggregate value added.

Voluntary reductions in mobility and economic activity has come up as a key driver for reductions in economic activity. Goolsbee and Syverson (2020) used mobile data to determine the extent to which declines in US consumer activity were driven by state shutdown orders and voluntarily staying at home. They found that consumer activity mainly declined due to voluntary curtailment of activities due to fears

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of infection that appeared to be linked to the number of COVID-19 deaths in the county. Maloney and Taskin (2020) used Google mobility data to identify that voluntary reductions in mobility were the major contributor for the decrease in mobility across country income groups, except for low income countries. NPIs also reduced mobility but much less than voluntary reductions. Voluntary reductions in mobility appeared to be driven by the number of COVID-19 cases. Chen et al. (2020) used high frequency indicators on electricity usage and unemployment in Europe and the US to assess the economic impact of COVID-19. They found that the main economic impact was due to reduced mobility, with voluntary social distancing playing a key role and there was no evidence that NPIs had any additional impact.

This paper most closely follows upon the work by Deb et al. (2020) and König and Winkler (2020). Deb et al. (2020) assessed the economic impact of the OxCGRT Containment and Closure Policies on real-time indicators of economic activity in 57 countries. Economic activity was represented by mainly Nitrogen Dioxide emissions with some assessment using alternative indicators such as international and domestic flights, energy consumption, maritime trade, as well as retail and transit-station mobility indices. They explored the impact up to 30 days after the introduction of measures. High levels of fiscal or monetary stimulus helped to alleviate the decline in economic activity relative to low levels of fiscal or monetary stimulus. Further, they assessed the effectiveness of individual components of Containment and Closure Policies in reducing COVID-19 cases and deaths, along with their economic costs proxied by Nitrogen Dioxide emissions. Only workplace closures, stay-at-home requirements, restrictions on gathering size, closures of public transport and restrictions on internal movement were found to have statistically significant negative economic effect after 30 days. König and Winkler (2020) looked at the impact of the OxCGRT Stringency Index on year-on-year quarterly GDP growth for 46 countries. They accounted for fatality rate, average GDP growth between 2014-2019, GDP per capita, trade openness, and tourism receipts as a percent of exports. Subsequently, instrumental variable regressions were run with speed of governments enacting stringency measures, life expectancy, and population size acting as instruments for COVID-19 variables (Stringency Index and fatality rate). They found that stringency measures and fatality rate negatively impacted growth, with tourism and trade openness significantly accounting for cross-country differences in growth.

Methodology and Data

This section describes the methodology and data used to assess the relationship between the stringency of NPIs and economic growth. A cross-sectional regression using Ordinary Least Squares (OLS) is utilised with data for the first and second quarters of 2020 being pooled together and treated as the same time period in order to provide sufficient variation in the independent variables. Separate regressions are estimated for AEs and EMDEs. This allows for COVID-19 to have differing impacts on developed compared to developing countries. The relatively simple methodology allows the inclusion of a larger number of countries, particularly EMDEs that may not have the same detailed statistics as AEs. The OLS regression examined is of the form:

$$Y = Z + X + \varepsilon$$

where Y is real GDP growth, and X is a matrix of indicators from OxCGRT and Z is a matrix of control variables.

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Real GDP growth in 2019 is used as a control variable in order to represent the approximate growth trajectory of each economy prior to COVID-19. This can be thought of as substituting for an autoregressive process with growth depending on its observation in the previous period. Alternatively, it can also be thought of as providing the baseline level of economic activity prior to COVID-19. A single year (2019) was chosen rather than a range of years (e.g. past 3 or 5 years) in order to better capture the short-term growth trajectory relevant for quarterly growth values. This differs from the approach of König and Winkler (2020) that looked at a 5-year growth trajectory prior to COVID-19. Adopting an output gap approach was not considered due to the uncertainty regarding output gap estimates for all countries in the sample as well as the difficulties determining the short term impact of COVID-19 on potential growth. This variable is expected to have a positive relationship with real GDP growth reflecting persistent growth trends.

The severity of the COVID-19 outbreak in each country serves as additional control variables to account for the differing impact that the pandemic has had in each country. This is expressed in terms of COVID-19 Cases per Million and COVID-19 Deaths per Million, which scales the magnitude of the impact to the population size of each economy. Deb et al. (2020) utilised cases and deaths in absolute terms which may not fully account for the difference between 100 cases or deaths in a country with a population of 1 million compared to a country with a population of 100 million. König and Winkler (2020) only assessed the fatality rate which was expressed as deaths per 100,000. The inclusion of these severity variables would likely account for voluntary reductions in economic activity as found by Goolsbee and Syverson (2020), Maloney and Taskin (2020) and Chen et al. (2020). These variables are expected to have a negative relationship with real GDP growth as a more severe outbreak is likely to depress economic activity.

The final control variables are to account for the fiscal and international aid support provided to countries that may counteract the negative economic impacts of COVID-19. These variables are represented as a percent of nominal GDP in order to scale the magnitude of fiscal and international aid support to the size of the economy. Deb et al. (2020) instead used a smooth transition model to differentiate between low and high fiscal stimulus. This paper considers the direct impact of fiscal support as well as international aid support and unlike Deb et al. (2020) the monetary policy response is not included. These variables are expected to have a positive relationship with real GDP growth as increased stimulus would likely boost economic growth.

The indicators from OxCGRT are the main independent variables examined for their effects on short-term economic growth. Rather than utilising the indices from OxCGRT, this paper examines the indicators to identify NPIs that may have statistically significant impact on growth. Indicators under Containment and Closure Policies are expected to have a negative relationship with real GDP growth as economic activities will be curtailed. Indicators under Economic Policies are expected to have a positive relationship with real GDP growth as they alleviate negative economic outcomes (e.g. default, unemployment). Indicators under Health System Policies are expected to have a positive relationship with real GDP growth as good health systems are likely to benefit consumer and business confidence. Deb et al. (2020) only considered Containment and Closure Policies. Unlike Deb et al. (2020), this paper does not attempt to assess the effectiveness of individual Containment and Closure Policies at reducing COVID-19 cases and deaths as this ventures into epidemiological forecasting and introduces additional complexity into the factors that need to be considered. König and Winkler (2020) looked at the overall Stringency Index rather than individual components of measures and their impact on short-term growth.

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A total of 106 countries were selected as the sample for this cross-sectional analysis, which is almost double the number of countries examined in Deb et al. (2020) and König and Winkler (2020). The countries were chosen based on their membership in the Group of 20 (G20) membership in Organization for Economic Cooperation and Development (OECD), as well as EMDEs as defined by the International Monetary Fund (IMF). The selection of EMDEs was based on countries for which quarterly real GDP growth statistics were available for at least the first quarter of 2020. Taiwan and Singapore were also considered in the sample as these countries have been highlighted as success stories of COVID-19 containment. Table 1 below summarises the countries selected.

Table 1: Matrix of Countries

Country	G20	OECD	EMDE	Country	G20	OECD	EMDE
Albania			X	**Lithuania**		X	
Algeria			X	**Luxembourg**		X	
Angola			X	**Malaysia**			X
Argentina	X		X	**Mali**			X
Australia	X	X		**Mauritius**			X
Austria		X		**Mexico**	X	X	X
Bahrain			X	**Mongolia**			X
Belarus			X	**Morocco**			X
Belgium		X		**Mozambique**			X
Bolivia			X	**Namibia**			X
Bosnia and Herzegovina			X	**Netherlands**		X	
Botswana			X	**New Zealand**		X	
Brazil	X		X	**Nicaragua**			X
Brunei Darussalam			X	**Niger**			X
Bulgaria			X	**Nigeria**			X
Burkina Faso			X	**Norway**		X	
Canada	X	X		**Panama**			X
Chile			X	**Paraguay**			X
China	X		X	**Peru**			X
Colombia		X	X	**Philippines**			X
Costa Rica			X	**Poland**		X	X
Cote d'Ivoire			X	**Portugal**		X	
Croatia			X	**Qatar**			X
Czech Republic		X		**Romania**			X
Denmark		X		**Russia**	X		X
Dominican Republic			X	**Rwanda**			X
Ecuador			X	**Saudi Arabia**	X		X
Egypt			X	**Senegal**			X

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Country	G20	OECD	EMDE	Country	G20	OECD	EMDE
El Salvador			X	Serbia			X
Estonia		X		Seychelles			X
Finland		X		Singapore			
France	X	X		Slovak Republic		X	
Georgia			X	Slovenia		X	
Germany	X	X		South Africa	X		X
Ghana			X	South Korea	X	X	
Greece		X		Spain		X	
Guatemala			X	Sri Lanka			X
Honduras			X	Sweden		X	
Hungary		X	X	Switzerland		X	
Iceland		X		Taiwan			
India	X		X	Tanzania			X
Indonesia	X		X	Thailand			X
Ireland		X		Togo			X
Israel		X		Trinidad and Tobago			X
Italy	X	X		Tunisia			X
Jamaica			X	Turkey	X	X	X
Japan	X	X		Uganda			X
Jordan			X	Ukraine			X
Kazakhstan			X	United Kingdom	X	X	
Kenya			X	United States	X	X	
Kosovo			X	Uruguay			X
Latvia		X		Vietnam			X
Lesotho			X	Zambia			X

Real GDP growth data was obtained from Trading Economics[3] on 30 September 2020 and is expressed as a whole number with no percent symbol (i.e. 3% is 3). All 106 countries had GDP growth data for the first quarter of 2020, at the same time a number of countries had not yet published GDP growth data for the second quarter of 2020 at the time of data compilation, namely Algeria, Angola, Burkina Faso, Bolivia, Bosnia and Herzegovina, Côte d'Ivoire, Dominican Republic, Ecuador, El Salvador, Egypt, Guatemala, Jamaica, Jordan, Kenya, Lesotho, Mali, Nicaragua, Niger, Panama, Qatar, Sri Lanka, Tanzania, Togo, Trinidad and Tobago, and Uganda.

Real GDP growth data for 2019 was obtained from IMF's World Economic Outlook Database April 2020. The countries in this sample accounted for roughly 96% of global nominal GDP in US Dollars in 2019. The OxCGRT dataset was used as the source for confirmed COVID-19 cases and deaths. The exception is for

[3] https://tradingeconomics.com/

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Taiwan where confirmed COVID-19 cases and deaths was sourced from Our World in Data[4]. Quarterly estimates of confirmed COVID-19 cases and deaths were derived by taking the average of daily cases and deaths in a particular quarter. These were then divided by the population size in 2019 with data from IMF World Economic Outlook Database October 2019.

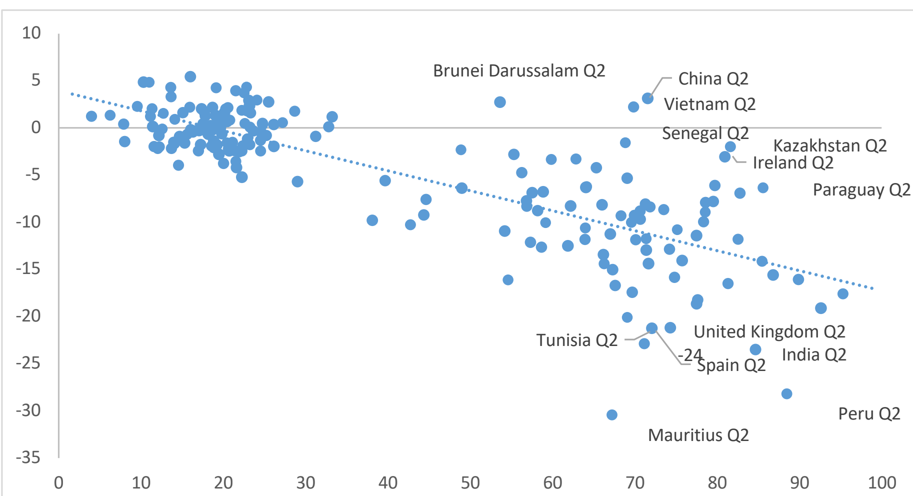
Fiscal and international aid support was taken to be the sum of daily announcements of US Dollar packages as reported in the OxCGRT dataset (E3, E4) for the relevant quarters. These were then divided by the nominal GDP in US Dollars for 2019 from IMF World Economic Outlook Database October 2019.

Data from OxCGRT was used to assess the NPIs, with daily data converted into quarterly data by taking the average of the respective indicators under Containment and Closure Policies (C1, C2, C3, C4, C5, C6, C7, C8), Economic Policies (E1, E2), and Health System Policies (H1, H2, H3) across the relevant dates in a quarter. The indicators mentioned above are measured in an ordinal scale with 0 being no relevant policies in place, to the maximum value (2, 3 or 4) representing differing magnitudes of stringency based on each indicator. The full definition for each of the indicators are available at the OxCGRT website.

Analysis

This section will analyse the relationship between short-term economic growth and the stringency of NPIs. Firstly, Graph 1 shows a simple graph of the Stringency Index (comprised of C1, C2, C3, C4, C5, C6, C7, C8, H1) against real GDP growth YoY. Visually, there appears to be a strong negative relationship between the Stringency Index and economic growth. There are a number of outliers that performed better or worse than the simple relationship, which have been labelled accordingly. However, this simple analysis cannot provide concrete results on the underlying relationship between stringency of NPIs and economic growth. To present concisely in the charts, Q1 2020 and Q2 2020 have been shortened to Q1 and Q2 respectively.

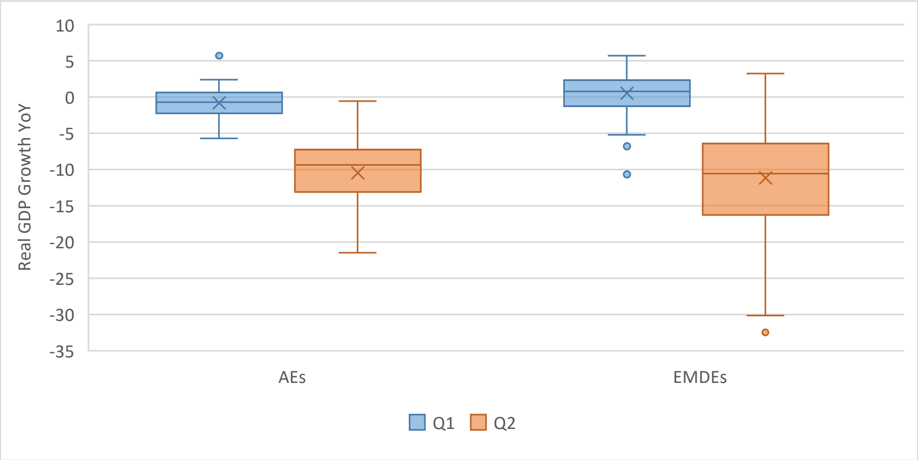
Graph 1: Scatterplot of Stringency Index and Real GDP Growth YoY



[4] https://ourworldindata.org/coronavirus

Graph 2 shows the GDP growth outcomes for AEs and EMDEs. It can be observed that AEs tend to have less variable growth outcomes. However by the second quarter of 2020, AEs were more unlikely to maintain positive growth rates.

Graph 2: Box and Whisker Plot of GDP Growth in AEs and EMDEs



Tables 2 and 3 below highlight that AEs tended to experience a more widespread COVID-19 outbreak with higher number of cases and deaths. However, in the second quarter of 2020 there were signs of significant COVID-19 outbreaks in EMDEs as seen by the higher maximum cases per million in Table 2. The averages in Tables 2 and 3 below were calculated by taking the average of the quarterly number of confirmed COVID-19 Cases per million across the countries in the relevant time period and country group.

Table 2: Confirmed COVID-19 Cases per Million

	AEs		EMDEs	
	Q1	**Q2**	**Q1**	**Q2**
Minimum	1.98	18.05	0.00	2.38
Average	76.29	2,086.73	12.90	770.22
Maximum	314.56	6,118.28	167.04	13,811.17

Table 3: Confirmed COVID-19 Deaths per Million

	AEs		EMDEs	
	Q1	**Q2**	**Q1**	**Q2**
Minimum	0.00	0.27	0.00	0.00
Average	1.74	140.35	0.16	15.14
Maximum	18.98	678.66	1.38	129.81

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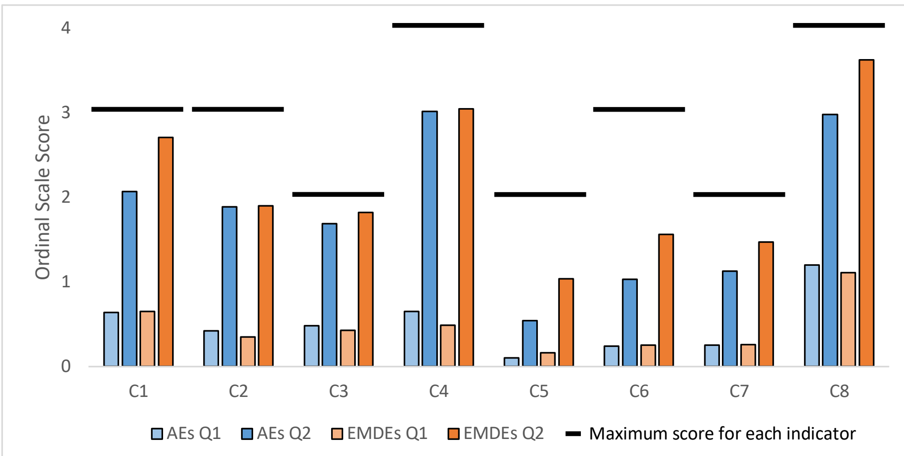
Graph 3 below compares the Containment and Closure Policies used in AEs (blue) and EMDEs (orange). In the first quarter of 2020, there was no substantial difference in policies chosen by AEs and EMDEs. However, by the second quarter of 2020 there was clearer differentiation with EMDEs utilising "School closing", "Close public transport", "Stay at home requirements", "Restrictions on internal movement" and "International travel controls" more than AEs.

Graph 3: Evolution of Containment and Closure Policies usage in AEs and EMDEs
(C1= School closing; C2= Workplace closing; C3= Cancel public events; C4= Restrictions on gatherings; C5= Close public transport; C6= Stay at home requirements; C7= Restrictions on internal movement; C8= International travel controls)



Tables 5 and 6 in the Appendix show the correlations between different components of Containment and Closure Policies differentiated between AEs and EMDEs. In general, the components are all strongly positively correlated for EMDEs which suggests the policymakers are implementing most of the measures concurrently as a policy mix. On the other hand, AEs use of "Close public transport" and "International travel controls" were less correlated with other Containment and Closure Policies, albeit still positively correlated. This is a relationship that was not obvious from Graph 3.

Graph 4 below compares the Economic Policies and Health System Policies used in AEs (blue) and EMDEs (orange). AEs in general were more likely to use all the policies compared to EMDEs. This tendency was maintained in the first and second quarters of 2020. Taken together with Graph 3, AEs have tended to use more Economic Policies and Health System Policies, and less of Containment and Closure Policies compared to EMDEs.

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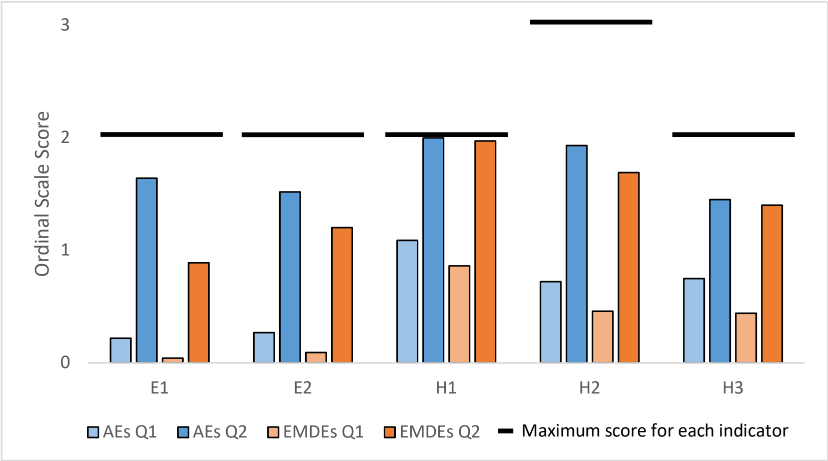
Graph 4: Evolution of Economic Policies and Health System Policies usage in AEs and EMDEs
(E1= Income support; E2= Debt/contract relief; H1= Public information campaigns; H2= Testing policy; H3= Contact tracing)



Next, we will examine the regression results of a number of model specifications examined as shown in Table 4 below. Specification (1) looked at a full specification including all control variables and relevant indicators from OxCGRT. Quite a number of the variables were not statistically significant.

Table 4: Regression results

	All countries		AEs	EMDEs
	(1)	(2)	(3)	(4)
Real GDP Growth in 2019	0.73*** (0.14)	0.74*** (0.12)	1.23*** (0.23)	0.56*** (0.15)
COVID-19 Cases per Million	0.000 (0.000)		0.001** (0.000)	
COVID-19 Deaths per Million	-0.01** (0.005)		-0.01*** (0.003)	-0.06* (0.03)
Fiscal Support as % of GDP	-0.02*** (0.01)	-0.02*** (0.01)		-0.02** (0.01)
International Support as % of GDP	0.10 (0.24)			
Containment and Closure Policies				
School closing (C1)	-1.58* (0.88)	-1.95*** (0.58)		-1.40* (0.82)
Workplace closing (C2)	-2.33** (0.93)	-2.87*** (0.68)		-3.23*** (0.91)
Cancel public events (C3)	-1.14 (1.51)		-3.71*** (0.89)	

	(1)	(2)	(3)	(4)
Restrictions on gatherings (C4)	0.40 (0.51)			
Close public transport (C5)	-1.08 (0.95)			
Stay at home requirements (C6)	-0.11 (0.86)		-2.26** (0.99)	
Restrictions on internal movement (C7)	0.15 (1.11)			
International travel controls (C8)	-0.45 (0.48)			
Economic Policies				
Income support (E1)	0.37 (0.78)			
Debt/contract relief (E2)	-3.17*** (0.69)	-3.09*** (0.60)	-2.78*** (0.67)	-3.49*** (0.87)
Health System Policies				
Public information campaigns (H1)	0.82 (0.79)			
Testing policy (H2)	0.86 (0.66)	1.09** (0.50)		1.58** (0.72)
Contact tracing (H3)	-0.05 (0.68)			
Observations	187	187	66	121
Adjusted R-squared	0.69	0.70	0.81	0.70
Standard error	4.09	4.04	2.70	4.34

Note: Significance levels at 10%(*), 5%(**) and 1%(***). Standard errors for coefficients are presented between parentheses.

Variables were then progressively removed in order of least statistically significant, resulting in specification (2) that shows only statistically significant variables for the sample of all countries. The control variables representing severity of the COVID-19 outbreak represented by COVID-19 Cases per Million and COVID-19 Deaths per Million were not significant. The coefficient for fiscal support and "Debt/contract relief" are of the opposite sign to that expected. This may reflect endogeneity of the fiscal support and debt relief measures, where a deeper than expected economic downturn due to COVID-19 may cause policymakers to undertake more aggressive fiscal stimulus and debt relief.

Subsequently, it was explored in specifications (3) and (4) whether the relationship between NPIs and economic growth differs in AEs compared to EMDEs. Serial correlation was present in specifications (1) and (2), while there was no evidence for serial correlation in specifications (3) and (4). Heteroscedasticity is present for all four specifications which is not surprising given the dispersion of experiences seen in Graph 1, particularly at high levels of stringency.

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For specification (3), the coefficient for COVID-19 cases in AEs is of the opposite sign than expected in the literature (Goolsbee and Syverson, 2020; Maloney and Taskin, 2020; Chen et al., 2020). This may be due to the lack of AEs with high numbers of cases in the first two quarters of 2020, hence the inability to capture the voluntary reduction in activity undertaken by consumers. Alternatively, across AEs there may be divergences in consumer perceptions with some countries placing more emphasis on deaths rather than cases. Converting this control variable to change in COVID-19 Cases per Million from the previous quarter did not resolve this unexpected result. The coefficient for “Debt/contract relief” remains of the opposite sign compared to initial expectations.

Comparing between (3) and (4), there are a number of interesting observations highlighting the differences between AEs and EMDEs. AEs appear to have a stronger persistence of growth trends from 2019, which may reflect the less volatile growth among AEs shown in Graph 2. The positive coefficient for COVID-19 Cases per Million for AEs remains unexpected. This control variable was not significant for EMDEs which may reflect overall lower number of cases on average in the time period of study or increased emphasis in EMDEs on the number of deaths rather than cases due to lack of reliable testing.

Despite the lower number of COVID-19 Deaths per Million in EMDEs (Table 3), the coefficient for EMDEs is six times larger than that for AEs. The coefficient estimates would be much higher than the estimates by Barro et al (2020) of the economic impact of mortality from the 1918 influenza pandemic. This is likely due to the lower mortality of COVID-19 in the time period of study compared to the 1918 influenza. To achieve the 2% average mortality rate for a country observed by Barro et al (2020), the number of deaths in the worst affected country in the sample would need to grow by a factor of 30. This could suggest that the negative economic impact from additional deaths faces declining marginal effectiveness at higher mortality rates. The coefficient found by König and Winkler (2020) for a fatality rate scaled to a population of 1 million was -0.01, which is identical to the coefficient found for AEs. This may reflect the large number of OECD countries in the sample used by König and Winkler (2020). The larger coefficients found in this paper for EMDEs suggests there may be avenue to consider differential COVID-19 fatality impacts in developing countries.

“Testing policy” was only significant for EMDEs. This could be reflective of EMDEs being more likely to suffer from inadequate healthcare services in testing, diagnosing and treating COVID-19 cases which causes a larger economic impact than in AEs. Both AEs and EMDEs had unexpected negative coefficients on “Debt/contract relief”, albeit EMDEs’ coefficient is slightly higher in magnitude.

Fiscal support was only significant for EMDEs and of the opposite sign. This greatly differs from the findings of Deb et al. (2020) which may be due to the longer time horizon (3 months versus 1 month) examined. This could suggest short-lived effects of fiscal support. An alternative explanation may be there was some unobserved country characteristic which induced higher Nitrogen Dioxide emissions for the group of countries with high fiscal stimulus in Deb et al. (2020).

The differences in significant Containment and Closure Policies are also informative. AEs have negative economic growth impacts from requirements to “Cancel public events” and “Stay at home requirements”, which may reflect a larger services sector in AEs. Whereas for EMDEs, “School closing” and “Workplace closing” were significant policies which sequentially reduced the ability of workers to work from home as the lack of childcare services burdened households, particularly women, to take on more informal childcare at home, thereby bringing about negative economic consequences. The significant economic impact from workplace closures aligns with the concerns raised by Dingel and Nieman (2020), Saltiel

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(2020) and Gottlieb et al. (2020) on the difficulties faced by developing economies due to lower share of jobs that can be done at home compared to developed countries. Relative to the findings of this paper, Deb et al. (2020) found that “Cancel public events” and “School closing” were insignificant, while finding “Restrictions on gatherings”, “Close public transport” and “Restrictions on internal movement” rules as significant. This could be due to the differing time horizon of study in this paper (3 months versus 1 month). Additionally, Deb et al. (2020) explored the impacts of Containment and Closure Policies for their entire sample of 57 countries. Meanwhile this paper identified differing experiences in AEs compared to EMDEs.

The correlation analysis between NPIs (Table 5 and 5 in Appendix) suggests caution in interpreting the regression results as NPIs enactment and relaxation tend to move together. It is likely that the estimated coefficients are overstated, capturing some effects from other correlated NPIs. A factor analysis of the NPIs (C1-C8, E1-E2, H1-H3) indicate two derived factors. All the NPIs load for the first factor for both AEs and EMDEs. However, there is a difference in loading for the second factor for AEs (C3, C8, E1-E2, H1-H3) and EMDEs (C2, C4-C7, E2). Additional data with countries implementing varying different NPIs would help to reduce correlation between NPIs and can give greater certainty to coefficient estimates. This issue may not be resolvable in a cross-country analysis of the form explored in this paper. Disentangling the effects of specific NPIs may require a county/district level analysis within a country utilising higher frequency economic activity indicators such as the work by Goolsbee and Syverson (2020), Maloney and Taskin (2020), and Chen et al. (2020).

Discussion

This paper has investigated the short-term trade-off between the stringency of NPIs and economic growth. It was found that the NPIs that affect short-term growth differed between AEs and EMDEs. Further, EMDEs’ economic growth appeared to benefit more from mortality reductions and improved testing policies.

Based on the estimated coefficients and the average stringency of measures in the second quarter of 2020, Containment and Closure Policies deducted approximately 8.6 percentage points of growth for AEs, whereas the corresponding impact for EMDEs was a loss of 5.1 percentage points of growth. If we use the coefficients on COVID-18 Deaths per Million to estimate the required mortality benefit of NPIs required to offset the growth loss, then this would be 860 deaths per million for AEs and 85 deaths per million for EMDEs. Furthermore, EMDEs appear to have a positive growth impact from improved “Testing policy”. This result might suggest that EMDEs face a more favourable short-term trade-off between stringency and economic growth. Given the more modest improvement in mortality outcome relative to AEs, policymakers in EMDEs who focused on short-term growth could potentially undertake more stringent NPIs.

However, it is important to qualify that this analysis does not consider longer-term growth outcomes. For example, if we consider the data for the United States in the second quarter of 2020, then the Containment and Closure Policies undertaken would deduct 11.9 percentage points of growth (compared to actual real GDP growth of -9.0%) which if annualised based on 2019 GDP would equate to USD2.6 trillion. Using an estimated USD10 million value for the statistical value of a life in the US (Bosworth et al, 2017) and the estimated coefficient for COVID-19 Deaths per Million, the required reduction in mortality to negate the growth impact of the NPIs would be roughly 400,000 fewer deaths. A backwards looking epidemiological analysis would be required to assess the number of deaths averted in the US to assess the trade-off in economic growth terms.

Further research in this area would be useful to better understand the interaction of NPIs and the economy across different time periods, as for example the introduction of NPIs could have heterogeneous impact on growth compared to the relaxation of NPIs. A subsequent investigation with additional quarters of data would be beneficial to verify the findings. Exploration of the inclusion of monetary policy responses as control variable may warrant further investigation.

The lack of statistical significance for “International travel controls” is also an area that could be explored further by examining the relationship for countries with a high tourism sector share in their economy. König and Winkler (2020) had found tourism receipts and trade openness were significant at explaining cross-country differences which can be examined further by subsequently considering if there are differences between high tourism and trade dependent AEs and EMDEs.

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Appendix

Table 5: Correlation matrix for components of Containment and Closure Policies (AEs)

	C1	C2	C3	C4	C5	C6	C7	C8
C1	1.00	0.88	0.86	0.81	0.62	0.84	0.81	0.55
C2	0.88	1.00	0.91	0.90	0.59	0.84	0.79	0.56
C3	0.86	0.91	1.00	0.88	0.55	0.79	0.77	0.63
C4	0.81	0.90	0.88	1.00	0.66	0.78	0.79	0.55
C5	0.62	0.59	0.55	0.66	1.00	0.71	0.61	0.29
C6	0.84	0.84	0.79	0.78	0.71	1.00	0.81	0.44
C7	0.81	0.79	0.77	0.79	0.61	0.81	1.00	0.48
C8	0.55	0.56	0.63	0.55	0.29	0.44	0.48	1.00

Table 6: Correlation matrix for components of Containment and Closure Policies (EMDEs)

	C1	C2	C3	C4	C5	C6	C7	C8
C1	1.00	0.86	0.96	0.88	0.72	0.81	0.86	0.90
C2	0.86	1.00	0.88	0.86	0.82	0.83	0.90	0.79
C3	0.96	0.88	1.00	0.88	0.76	0.83	0.88	0.89
C4	0.88	0.86	0.88	1.00	0.75	0.80	0.82	0.81
C5	0.72	0.82	0.76	0.75	1.00	0.77	0.79	0.67
C6	0.81	0.83	0.83	0.80	0.77	1.00	0.85	0.74
C7	0.86	0.90	0.88	0.82	0.79	0.85	1.00	0.82
C8	0.90	0.79	0.89	0.81	0.67	0.74	0.82	1.00

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