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Abstract

Social scientists often assume that complex externalities, such as pandemics, should be governed through a Pigouvian approach that deems top-down coercion and restrictions sufficient to govern externalities. Yet, the production of public health requires citizens to actively adopt precautionary and cooperative measures. Moreover, as Elinor Ostrom's work on global warming suggests, externalities can be governed through polycentric approaches that match the scale and nestedness of the externality with appropriate governance structures from the bottom-up. Drawing on Vincent and Elinor Ostrom's work, this paper explores the notions of nestedness, polycentricity and coproduction to shed light on the nature of modern public health challenges. It provides a framework for understanding global challenges by pointing out two crucial, yet neglected, features of complex externalities: first, social distancing and other public health measures are coproduction processes. Second, responding to health externalities is a problem of governing nested externalities at different scales. This provides a suitable conceptual foundation for responding to future global challenges.

Keywords: externalities; governance; public health; Elinor Ostrom; polycentricity.

JEL codes: H4; H1; I18; D7; D62.

Pablo Paniagua, University of London, King's College, United Kingdom. E-mail: pablo.paniagua_prieto@kcl.ac.uk.

Introduction: Public health and new global challenges

The recent global pandemic has brought out several unexpected challenges into the way we conceive the economy, society and their vital interactions (Langley, 2021). Undeniably, the pandemic has ‘wrought severe disruptions throughout economy and society, forcing a host of latent tendencies, tensions and divisions to the surface of public consciousness and political debate’ (Langley, 2021, p. 151). Hence, there is a growing need to encourage interdisciplinary social science research applied to public health, beyond the boundaries of economics (Paniagua, 2021; Paniagua & Rayamajhee, *forthcoming*).¹

Yet, while economists have mostly focused on optimal control approaches and the impact of lockdowns on the macroeconomy (Acemoglu *et al.*, 2020; Brodeur *et al.*, 2021), they have largely disregarded how pandemics and public policy interact with society and communities at large (Langley, 2021). Such approaches neglect key socioeconomic issues related to local governance, civil society, and informal institutions that underpin a well-functioning society able to solve public health dilemmas (Bentkowska, 2021; Paniagua, 2021; Rayamajhee & Paniagua, 2021; Rayamajhee *et al.*, 2021). Incorporating these neglected issues into a broad socioeconomic analysis of public health serves as the major task of this paper.

While social distancing can reduce the transmission rate of viral externalities such as the COVID-19 (Anderson *et al.*, 2020; Cato *et al.*, 2020; Coccia, 2021), most studies conceptualize it strictly from a top-down engineering approach as part of the solution to a social planner’s optimality problem (Alvarez *et al.*, 2020; Gersovitz & Hammer, 2004; Toxvaerd, 2020). Thus, most studies underemphasize the central role that citizens play in the production of social distancing and public health (Rayamajhee *et al.*, 2021). Because a pandemic, by nature, is a global externality problem, the conventional policy approach has sought national or global optimal-control solutions to such public health dilemmas (Acemoglu *et al.*, 2020).²

Accordingly, cross-country comparisons about the governance of viral externalities mostly focus on successes and failures of national governments and international organizations (Robinson, 2021). However, social distancing, which is key to containing the spread of communicable diseases, is a local solution adopted by users at the community level (Cato *et al.*, 2020; Cheng *et al.*, 2020). This paper argues that the dominant top-down, or centralist, conceptualization of public health³ in the presence of externalities — as a public service to be produced merely through stay-at-home orders and to be enforced through top-down surveillance, monitoring and sanctioning — is misleading and potentially pernicious.

The conventional notion of a centralist or top-down intervention to govern a pandemic or viral externalities is akin to the logic that economists invoke to use coercive and top-down intervention to manage market failures (Vormann, 2018). Economists use the concept of market failure (e.g. externalities, public goods and information asymmetries) to articulate reasons to promote a unitary state intervention into an undesirable state in society, with the intention to improve it. The underlying logic is to use the state’s coercive power to align private vices and narrow attitudes with public virtue or the common good.

As Callon (1998, pp. 245–246), in his sociological analysis of externalities states, the concept of externality ‘could be extended to include behaviour which is not exclusively economic in nature. . . . Negative externalities imply social costs that are not taken into account by private decision-makers’. This discrepancy between private actions and the common good in public health seems to be exactly the situation that societies face with infectious diseases and pandemics (Leeson & Rouanet, 2021). Alas, this framework leads social scientists to think strictly about centralist and coercive solutions to correct them (Boettke & Powell, 2021). Such logic has even led central governments to use military language, thus framing pandemics analogous to a war economy, in which governments alone can ‘contain’ and ‘defeat’ a viral enemy through ‘rolling out’ responses (Langley, 2021).

Yet, there is a largely unexplored bottom-up alternative based on cooperation and the polycentric provision of public goods. Indeed, the work of Elinor Ostrom (1990, 2012) shows that massive externalities and large-scale collective action problems are better framed as ‘nested externalities’ (Ostrom, 2012) in which polycentric institutions and small-scale local communities have a significant role in *coproducing* nested and overlapping solutions to resolve global dilemmas (Paniagua, 2020).⁴ Ultimately, the governance of large-scale social challenges is a ‘public service’ that might be better produced through a nested and overlapping manner by different nodes of authority, rather than by a central government (Ostrom, 2014; Paniagua, 2020).

To elaborate, in this paper’s conceptualization, coproducing social distancing requires inputs from citizen-clients and a government-producer (Cheng *et al.*, 2020; Parks *et al.*, 1981). Instead of the standard view, in which all relevant inputs are under the command of a single producer who decides on the combination of inputs, coproduction emphasizes a complementarity between what a government does and what citizens do to provide public goods and public services (Ostrom *et al.*, 1961; Rayamajhee & Paniagua, 2021). Such a synergy is possible when the inputs from a government and citizens are complementary and not mutually exclusive; when that is not the case, *crowding out* can occur with detrimental consequences for governance (Ostrom, 2000a).⁵

Understanding viral externalities, particularly outbreaks of communicable diseases, with this alternative framework, sheds light on a fundamental, yet neglected, issue in the production of public health services: their factual production *does not* depend only on coercion and the standard monitoring tools available for governments. This conceptualization shows that coercion might be necessary to produce social distancing and other health measures, but it is not sufficient to govern global problems posed by large health challenges. The central thesis is, first, that a government’s role in producing social distancing should be one of providing accurate information and fostering general trust and a sense of solidarity conducive to citizen participation and, second, that social-distancing policies that do not foster mutual trust may be potentially counterproductive and create public resentment.

Section 2 employs both E. Ostrom's (2012) notion of nested externalities and Ronald Coase's (1960) exchanged-based framework for solving externalities in order to examine the nested set of collective action problems associated with health challenges and pandemics. Section 3 presents the production of social distancing and certain aspects of public health as coproduction and cooperative problems, thus suggesting a polycentric framework. Section 3 also reflects on the potential limits and fragilities of the polycentric approach to public health, delineating the arguments' limits. Section 4 concludes by discussing key implications of viewing public health as a coproduction problem and viewing pandemics as nested externalities. The paper ends by suggesting that polycentricity could be a more consistent framework to examine policy responses to future public health crises, thus proposing a fruitful way forward for the literature on the governance of public health.

Coase and the Ostroms on global externalities

From an epidemiological perspective, the COVID-19 pandemic is a global health crisis (Acemoglu *et al.*, 2020). By the definition of a pandemic, the problem is large scale or global. From an economic perspective, it is an externality problem with large-scale characteristics (Leeson & Rouanet, 2021). This view sometimes leads economists to think strictly in Pigouvian or optimal-control terms, neglecting the institutional insights of political economists such as Coase (1960) and Ostrom (2012) who thought about global externalities in different terms. Most of the economic and health policies implemented throughout the world to address the spread of the recent pandemic have been based on strictly Pigouvian thinking (Pigou, 1920): they assume a benevolent social planner with epistemic access to a well-defined social welfare function who engages in social cost–benefit analysis to design implicit taxes, coercive measures and subsidies (Alvarez *et al.*, 2020; Boettke & Powell, 2021). In contrast, this section draws on the works of Vincent Ostrom (2008) and Elinor Ostrom (2012, 2014) to develop a political-economic framework to understand how to better govern pandemics and public health challenges, viewed as nested externalities. And it shows how a framework that combines both ‘nestedness’⁶ and exchange-based approaches might give us a better grasp on how to solve health and social-related externalities better, quicker, at lowest social cost, and without ‘crowding out citizenship’ (Ostrom 2000a, p. 3).

Standard economic models treat pandemic response as a social-planner problem (Gersovitz & Hammer, 2004; Alvarez *et al.*, 2020). They assume, for instance, that a benevolent public health planner is equipped with the knowledge and tools to act swiftly and can directly control ‘all preventative and therapeutic actions’ (Gersovitz & Hammer, 2004, p. 3). Their proponents argue that because infectious diseases, by definition, are rife with externalities that are unlikely to be fully internalized through voluntary actions, the decentralized solution does not maximize social welfare (Toxvaerd, 2020). Thus, the

planner's role is to coercively intervene to control the spread of the infectious disease so as to maximize a social-welfare function and impose optimal-control social distancing measures. Under this approach, public health is seen as produced via the exercise of top-down coercive tools such as quarantines, business closures, mandatory curfews, restrictions on mobility, etc.

In this manner, the Pigouvian response to the current pandemic has been to impose major mandatory social-distancing policies – such as lockdowns, business closures and confinements – which are equivalent to a 100 per cent tax on certain social activities (Boettke & Powell, 2021). While analytically useful as a conceptual introduction to the problem, the Pigouvian optimal-control approach suffers from too serious epistemic and public choice problems to draw any useful policy and governance conclusions from it (Coyne *et al.*, 2021; Leeson & Rouanet, 2021; Rayamajhee *et al.*, 2021).

Because risk calculus and the size and scope of large-scale externalities are constantly evolving, the planner faces epistemic challenges in gathering relevant and local information (Ostrom, 1990). Governing such externalities requires producing different bundles of services at different scales, which poses severe efficiency challenges to hierarchical forms of government and top-down coercive solutions (Ostrom, 2008). In short, the standard approach into the governance of externalities faces three severe challenges: first, knowledge problems and lack of information about the local conditions concerning the collective challenges that individuals face at a particular time and place (Ostrom, 1990, chapter 1); second, incentive problems associated with encouraging policymakers to enact the supposedly correct solution and then to effectively monitor at reasonable cost (Ostrom, 1990, chapter 1); third, problems associated with the rigidity of the scale of the Pigouvian administrative structure and the dynamic scale (heterogeneity) of the collective challenges that communities face (that is, the scale and institutional *mismatch* between the overarching central bureaucracy and the local heterogenous collective challenges) (Ostrom, 2008; Tarko, 2017).⁷

Indeed, the Bloomington-school scholarship shows that 'a consolidated, hierarchical administration would unavoidably lead to massive inefficiencies because the administrative units operate at rigid scales, while the scale of public [and health related] issues are varied and always changing ... a given administrative unit is always faced with challenges that do not properly fit its administrative scale' (Tarko, 2017, p. 40). Thus, such scholarship recognizes that global Pigouvian approaches are rampant with inefficiencies because of the heterogeneity of collective challenges, and also because large externalities are overlapping, dynamic, and varying according to the social and geographical context (Ostrom, 2008; Ostrom, 2014; Paniagua, 2020).

Moreover, a central planner, even a benevolent one, dealing with a large public health problem and with the ability to coerce at will, suffers radical ignorance and faces incentives that lead it to make choices that have malignant consequences and could even generate resentment among the population (Coyne *et al.*, 2021). This is because complex phenomena such as large externalities are complex at various levels and the direction and magnitude of the

impacts of external stimuli are difficult to determine (Ostrom, 2014). In dealing with externalities, making trade-offs requires interpreting the situation, accounting for differences in opportunity costs and discount rates, and making a wide range of assumptions about contextual factors, which makes precise predictions highly unreliable (Coase, 1960). Indeed, the work of E. Ostrom (2014) on global warming suggests that ‘single policies adopted only at a global scale are unlikely to generate sufficient trust among citizens and firms so that collective action can take place in a comprehensive and transparent manner that will effectively reduce global warming’; furthermore, ‘simply recommending a single governmental unit to solve global collective action problems is inherently weak because of free-rider problems’ (Ostrom, 2014, p. 97). Similar problems can be found in large public health challenges.

In her work on global warming, Ostrom (2014) also hints at a crucial feature of global externalities: global efforts to govern dilemmas ‘are a classic collective action problem that is best addressed at multiple scales and levels’ (Ostrom, 2014, p. 97). Thus, political economists need to seriously question the presumption that global challenges *must have* a single global solution provided by a central planner. In other words, we need to seriously consider the following question: ‘Are large-scale governments usually better equipped to cope with collective-action problems that have outcomes that are large scale themselves? ... There is no reason to presume that a monopoly government is more efficient than a system of governmental units at multiple scales. Economic theory teaches us about the dangers of allocating all capabilities to a single unit’ (Ostrom, 2012, p. 355). Answering this question is crucial for arriving at a more clearheaded public health and governance analysis.

Thus, a public response motivated by the theoretical predictions of the Pigouvian optimal-control framework, in which the benevolent planner designs and implements policies at zero transaction cost, is likely to overestimate the ability of central governments and underestimate the possibility of policy blunders, making it unable to minimize social cost (Coase, 1960; Leeson & Rouanet, 2021). The optimal solution might be unavailable in practice for governments that employ a hierarchical approach to deal with externalities, even if they can exercise a high degree of coercion and internalize the long-run effects on economic growth (Ostrom, 2014). Hence, the Ostromian framework applied to public health issues strongly suggests that effective and efficient central-government solutions to massive externalities, such as pandemics, may lie outside the range of institutional possibilities. In contrast to the standard approach to dealing with externalities, the approach suggested here builds upon Coase’s (1960) exchange-based paradigm and Elinor Ostrom’s (2012) nested-externality analysis, to suggest a more suitable way to deal with global externalities and complex governance dilemmas. I focus on how economic theory in general, and institutional economics in particular, can help us understand the fundamental nature of a modern pandemic, shedding light on the most suitable institutional structures for governing them, and ultimately mitigate effectively their social and economic costs.

Nested externalities and actions at different levels

The framework that sees externalities as nested and occurring at multiple scales provides a more suitable foundation to analyse global contemporary challenges, including pandemics and global warming (Ostrom, 2012). Concerning large-scale externalities, a global or top-down policy response is frequently seen as the only strategy required. Yet, we need to recognize that valuable – and perhaps even irreplaceable – actions can be taken at multiple, smaller scales to start the process of mitigating and governing externalities. As E. Ostrom (2012) reminds us, ‘We need to make a scholarly investment in a more appropriate theory of global change that offers a better explanation of micro-level incentives and outcomes as well as being a foundation for more effective public policies’ (2012, p. 353). A suitable step in this direction could be framing global challenges as nested dilemmas. Trying to end or mitigate pandemics through providing public goods is deemed a classic collective action problem, yet assuming that any collective action problem with large effects must be solved entirely at the global or state level is wrongheaded (Ostrom, 2010; Paniagua, 2020, 2021). To deal effectively with modern pandemics, we should interpret them as collective health problems composed of multiple and nested externalities occurring at different levels (Paniagua & Rayamajhee, forthcoming).

As we know from the biological and viral events of the last few years (Robinson, 2021; Coccia, 2021), pandemics and the spread of communicable diseases more generally are the result of many actions taken at multiple scales: at the individual, family, club, firm and other levels (Anderson *et al.*, 2020; Cheng *et al.*, 2020). Thus, nested externalities ‘occur when actions taken within one decision-making unit simultaneously generate costs or benefits for other units organized at different scales’ (Ostrom, 2012, p. 356). This is exactly the case with pandemics, which are the result of many actions taken at multiple and nested scales. For example, decisions at the individual level, within a household, within a school, or in the private sector all have small but relevant effects on the spread of the virus across the globe. Hence, actions taken at smaller levels have potential costs and ripple effects at other larger scales, determining the spread of a pandemic (Cato *et al.*, 2020; Steen & Brandsen, 2020).

Given that many of the actions that facilitate the spread of the virus are taken at multiple scales (and in public and private spaces), the public health activities required to contain the spread of contagious diseases must also be organized at multiple, overlapping scales ranging from households to local communities to the global level. In fact, the existence of multiple and overlapping jurisdictions, on the one hand, and multiple health and social-distancing challenges that are heterogenous and interconnected across localities, on the other, suggests that no single centre of authority, by itself, can govern the collective health challenges and mitigate the global externality by commanding compliance. This is a strong *prima facie* argument suggesting that public health and the

governance of large externalities cannot be effectively provided by central governments alone.⁸

The implication of interpreting pandemics as nested health externalities is non-trivial since it suggests that ‘researchers need to understand the strength of polycentric systems where enterprises at multiple levels may complement each other’ (Ostrom, 2012, p. 353). Alas, the literature has not yet conceived of public health challenges as nested externalities that require polycentric solutions (Rayamajhee *et al.*, 2021); this is probably the reason why economists are still trapped in the Hobbesian paradigm of standard public economics, thus promoting top-down solutions that cannot minimize social cost and might even generate resentment and protest among citizens, as seen in certain parts of the world during the pandemic.

Indeed, Pigouvian and centralist solutions could potentially exclude local efforts to deal with externalities, which could exacerbate the problem of crowding out citizens’ active involvement in solving nested collective action problems, undermining the governance of externalities (Ostrom, 2000a). This is challenging because ‘contemporary assignments of regional, national, or international governments with the exclusive responsibility for providing local public goods and common-pool resources (CPRs) *remove authority* from local officials and citizens to solve local problems that differ from one location to the next’ (Ostrom, 2012, p. 361). Removing authority from local officials and communities is problematic, as we will see in section 3, since it can crowd out citizens’ coproduction efforts, which are crucial to deal with the externality at the local level.⁹

Another benefit of analysing the governance of public health in this alternative Ostromian manner is that it allows us ‘to balance the arguments made in the policy literature that a global solution is the *only* way to cope with’ global challenges. Top-down “‘global solution” negotiated at a global level—if not backed up by a variety of efforts at national, regional, and local levels—are not guaranteed to work effectively’ (Ostrom, 2012, p. 354). In other words, understanding the nested nature of the problem allows us to question the widespread presumption in political economy that any collective action problem that has global effects must be solved entirely at the global or national level (Ostrom, 2010). Hence, it challenges both the efficiency claims and scale claims of top-down Pigouvian approaches, by suggesting not only that those solutions might be unable to minimize social cost, but also that they are insufficient to govern public health dilemmas (Geloso & Murtazashvili, 2021).

As hinted, whether social distancing yields the intended results depends on the actions taken at various levels – neighbourhoods, schools, counties, cities, states, regions and countries (Steen & Brandsen, 2020). The positive and negative externalities of decisions at each level, including those taken individually and within families, have spillover effects that permeate across all levels (Paniagua, 2020; Paniagua & Rayamajhee, *forthcoming*). In other words, the nodes of authority exist at all levels and thus governance and monitoring efforts for compliance are nested. Strategies and policies adopted by a city’s mayor generate

costs and benefits for other cities, states, regions, countries and the world. At an even more local level, decisions taken within and between families and businesses generate externalities within and across communities, regardless of macro-level or global decisions (Rayamajhee *et al.*, 2021).

Consequently, the high degree of dispersal of nodes of authority over social distancing and mask-wearing, for example, implies that the problem is better viewed as one of achieving multilevel and overlapping collective action than one of providing a national or global 'public good' through implementing an optimal-control policy. Thus, the production of social distancing and other public health measures should emerge via bottom-up processes from different levels of authority.

Polycentricity and the governance of health challenges

Unlike the Pigouvian hierarchical approach (Pigou, 1920), a decentralized, polycentric approach can better address the nested nature of the health problem since multiple governance units can 'take each other into account' (Ostrom *et al.*, 1961). A polycentric system thus involves different amounts and types of action (and collaboration) throughout the social sphere, helping to avoid scale mismatch between the decision centres and the externality problem to be solved. Vincent Ostrom (2008) describes the potential for scale mismatch in dealing with large externalities from one overarching decision centre as the rationale for having multiple centres of authority that can interact and collaborate with each other (see also Ostrom, 2010). A foundational premise of cooperation in a system that disperses authority among overlapping centres is that the centres, working together, can scale up, bargain, and achieve results that extend beyond the boundaries of any single centre. This dynamic logic (scaling up or scaling down collaborative efforts) for dealing with externalities and ecological commons has been described by Elinor Ostrom (1990) as 'nestedness'.

Nestedness is an institutional advantage of polycentricity compared with the rigid structure of a top-down global or national solution to an externality problem since localities and local groups can tailor actions to the local and cultural circumstances and scale up collective efforts if they deem it necessary (Aligica, 2014). With nestedness, the centres at the lower (local) levels can come together to undertake concerted actions at higher levels, either by coordinating their work and bargain, or by designing new arrangements to deal with problems that arise at higher levels and require more coordination among the centres (Ostrom, 2005).

Cooperation and information sharing among the different local and nested levels are crucial to deal with nested externalities since cooperation in a decentralized and polycentric setting makes both bottom-up coordination across space and institutional diversity possible, which help address problems that are spatially or geographically interconnected and overlapping. Thus, unlike

a monocentric approach, ‘a polycentric approach has the main advantage of encouraging experimental efforts at multiple levels, leading to the development of methods for assessing the benefits and costs of particular strategies adopted in one type of ecosystem and compared to results obtained in other ecosystems’ (Ostrom, 2014, p. 97). This strengthens the learning and imitation process of the entire system, which can produce valuable health services and knowledge at the different scales, whilst facilitating the dissemination of valuable information about the underlying nature of the problem. In this manner, different measures and solutions can be developed at multiple scales so that relevant decision-making units can discover which health policies can be adopted that fit the ecology, properties and culture at that particular scale.

As hinted earlier, this nestedness can be interpreted as an extension of the Coase (1960) theorem in that it helps to extend the Coasean *exchange-based* logic toward non-market decision-making structures based on collaboration and bargaining among different governance structures and on institutional diversity. Indeed, Vincent Ostrom’s (2008) take on externalities and Elinor Ostrom’s (1990) take on the governance of ecological commons or CPRs suggest that to accurately internalize the costs and benefits of CPRs, the levels of financing, provisioning and monitoring *should match* the levels at which a resource or an externality affects users (Ostrom & Ostrom, 1977; Rayamajhee & Paniagua, 2021). According to V. Ostrom, Tiebout and Warren (1961), when the level of exclusion and the levels of financing, provisioning and evaluative performance concerning a collective dilemma (or externality) *coincide*, then the governance system efficiently allocates resources and properly structures political representation and control, thus minimizing social cost and internalizing all the relevant external effects. This institutional and scale matching or convergence is crucial in the correct governance of collective dilemmas; albeit this insight is rarely emphasized in the literature on governance, externalities, and in the efficiency of the public sector.

Consequently, this Ostromian extension of Coase’s (1960) exchanged-based paradigm shows that in order to overcome problems of institutional mismatch and minimize the social cost of externalities, the governance of public health needs to be an emergent discovery process among units organized in different forms and at diverse scales. In this way, their collaborations and bargains could coincide with the levels at which exclusion and monitoring are feasible, which may themselves vary over time and across places (Ostrom, 2008). Thus, we should expect an ever-changing scalar configuration of the governance of public health, which helps to minimize social cost over time. This approach to externalities challenges the optimal-control attitude and suggests that ‘reliance on a single ‘solution’ may be more of a problem than a solution. It is important that we recognize that devising policies related to complex ... processes are a grand challenge and reliance on one scale and one model alone to solve these problems is naive’ (Ostrom, 2012, p. 363).

Finally, the work of E. Ostrom on global warming (2012, 2014) also suggests that global externalities could be more effectively governed through bottom-up

approaches that better match the local culture and the specificity and complexity of the problem at different levels and scales. This not only promotes solutions that are respectful of local economies and local cultures, but also allows the scaling up or scaling down of joint efforts across different centres of authority, thus promoting institutional diversity and compliance (Ostrom, 1990, 2005). This in turn allows solutions to extend *beyond* the boundaries of an individual centre and help to tackle the heterogeneity of the problems that form a global (nested) externality. In her words, ‘Rather than only a global effort, it would be better to self-consciously adopt a polycentric approach to the problem ... in order to gain the benefits at multiple scales as well as to encourage experimentation and learning from diverse policies adopted by multiple scales’ (Ostrom, 2012, p. 365). Irreplaceable and necessary actions can be taken at multiple, smaller centres to start scaling up the process of mitigating externalities and thus to match collective action units with health and geographical features of pandemics and minimize social cost while maximizing compliance and trust.

Public health as a large coproduction effort

The concept of coproduction of public services has captured some attention in economics as a mechanism to potentially improve the effectiveness and efficiency of local governments and the local production of public goods (Alford, 2014; Bovaird, 2007; Parks *et al.*, 1981).¹⁰ This paper has hinted at two major insights in the governance of public health: First, there are plausible reasons to conceptualize pandemics as nested health externalities, similarly to the case of global warming (Ostrom, 2012). Second, there are several public-economics and scale arguments that show that even if governments *should* deal with pandemics, they might fall short at effectively governing nested public health challenges; thus, as noted above, effective central-government solutions to pandemics ‘may be outside the range of institutional possibilities’ (Geloso & Murtazashvili, 2021).

Given these challenges, perhaps focusing on the coproduction of social distancing and other health measures (such as wearing a mask in public, following health protocols in private spaces, isolating oneself, etc.) would provide a feasible alternative to coercion while increasing the efficiency of local governments and nested governance arrangements in the production of those crucial services. Indeed, some public administration scholars have already recognized that the production of public health, social distancing, and other health measures should be considered as a ‘gigantic coproduction project’ (Steen & Brandsen, 2020, p. 852).

A relevant insight in Vincent and Elinor Ostroms’ work on public goods and externalities is that public goods are produced at different scales, diverse degrees of complexity, and different levels, implying that their production functions differ (Ostrom, 2008). This heterogeneity suggests that local public

goods and externalities could be tackled more successfully by different institutional configurations, such as private clubs, community organizations, non-profit organizations, local governments, or combinations thereof (Ostrom & Ostrom, 1977). Thus, the heterogeneity of public goods suggests the need for pluralism, organizational partnerships, and coproduction in order to arrive at plausible solutions to collective action problems (Ostrom, 2005). A crucial method for sustainably producing heterogeneous collective goods and health services is therefore coproduction and community involvement (Bovaird, 2007; Ostrom, 2000a).

Voluntary organizations and the governance of externalities

Rayamajhee *et al.* (2021) suggest that no amount of social distancing can be provided by the government alone if inputs from citizens (the beneficiaries) are missing. Without citizen inputs, governments face insurmountable epistemic challenges in gathering relevant and local information, and they face prohibitive monitoring and sanctioning costs in implementing any social-distancing policies. Once we recognize the crucial role of civil society and coproduction in the efficient supply of social distancing and other health measures, then the case for liberal democracy and the decentralization of power – rather than dictatorship – for dealing with health problems becomes much stronger than the standard approach to public health suggests. Yet, despite the relevance that social distancing, mask-wearing and self-confinement measures play in mitigating the damage of pandemics, the role of local communities and citizens in producing health measures and governance has received minimal attention (Cato *et al.*, 2020; Cheng *et al.*, 2020; Steen & Brandsen, 2020). This indicates that, in the face of complex externalities, governance failures can be at least partially attributed to: (a) the lack of complementarity between government policies and citizens' efforts and, (b) the disregard for civil society and informal institutions (Bentkowska, 2021; Cai *et al.*, 2021; Cato *et al.*, 2020).

Incipient literature points to the crucial role of civil society and voluntary organizations in helping to govern nested externalities associated with pandemics (Rayamajhee *et al.*, 2021). Both Rayamajhee *et al.* (2021) and Steen and Brandsen (2020) analyse empirical findings on the coproduction of social distancing during the COVID-19 pandemic. In parallel, Storr *et al.* (2021) survey the creation of socially isolated learning 'pods' in Seattle that provide children with in-person instruction and socialization opportunities, whilst providing a form of local governance. Shi *et al.* (2020) analyse the crucial role of non-profit organizations serving the homeless population in Dallas, Texas, during the pandemic. The authors find that non-profit organizations adopted innovative and creative methods to ensure continuity in service delivery, despite facing severe disruptions and ambiguity caused by the virus.

Moreover, Cai *et al.* (2021) survey the role of civil society in the governance of the pandemic in China, Japan and South Korea; they find that civil society

actors, ‘played essential roles in combating the pandemic, either by reinforcing government-led efforts or by filling the institutional voids left by the government’ (Cai *et al.*, 2021, p. 107). For Japan, Watanabe and Yabu (2020) find that the government’s coercive measures are only responsible for about a quarter of the decreases in people leaving their homes (i.e. mobility) in Tokyo, while three quarters were spurred by citizens obtaining new information about COVID-19 (Watanabe & Yabu, 2020, p. 1). Similar outcomes appeared in areas with ‘lockdowns’ across the United States (Goolsbee & Syverson, 2020). This underlines the crucial role of informal institutions and culture in underpinning the actual governance of viral externalities (Bentkowska, 2021).

Alas, given the standard optimal-control view that permeates public health economics and externality analysis, it is often assumed that the states that are better able to deal with pandemics – or large externalities in general – are those that possess a greater capacity to implement coercive measures such as economic lockdowns and mandatory quarantines (Geloso & Murtazashvili, 2021). Thus, ‘most analysts of public service delivery ... have focused on the efforts of organized bureaus and firms, ignoring consumer inputs or assigning them only an insignificant, supplementary role’ (Parks *et al.*, 1981, p. 1002). However, that assumption becomes questionable once we recognize, first, the nested and complex nature of global externalities (see section 2) and, second, the fact that *coproduction* from the bottom up is required in order to produce social distancing at diverse scales (Steen & Brandsen, 2020).

Nevertheless, individual consumers and families ‘may contribute to the production of some of the goods and services they consume. In such cases they act as *consumer producers*’; when that occurs, ‘consumer production is an essential complement to the efforts of regular producers; without the productive activities of consumers nothing of value will result. This appears to be characteristic of much public service production’ (Parks *et al.*, 1981, p. 1002). A paradigmatic example of this is public education, in which it does not matter how much local governments spend on better teachers and better schools, because if students ultimately do not desire to learn or be actively involved in class, then education will never be produced.

There are two ideal-types of relationships in which coproduction is feasible. First, regular producers’ and consumer producers’ inputs might be *substitutes*, which means that the two types of inputs can be substituted for one another. For instance, municipal trash collectors and local citizens can be substituted for each other in transporting refuse to collection locations (Parks *et al.*, 1981, p. 1003). In that kind of production relationship, a one-unit reduction in regular-producer inputs can be easily replaced by a one-unit increase in consumer-producer inputs, and vice versa. The second type of relationship is one of *interdependence*; once we have complete interdependence, ‘no output can be obtained without inputs from both regular and consumer producers’ (Parks *et al.*, 1981, p. 1003). As hinted, a clear example is education, in which the active involvement of both teacher and student is vital.

The relevant point is that real-world public services most likely combine segments of both ideal types: some inputs are substitutes, while others are interdependent (Aligica & Tarko, 2013). Obviously, the sort of coproduction hinted at in this section is one in which there is a high degree of interdependence between governments and citizens in the production of social distancing, mask-wearing, and self-isolation to control communicable diseases (Rayamajhee *et al.*, 2021).¹¹ Moreover, E. Ostrom's (1990, 2010) work shifted the emphasis from a naïve faith in bureaucracies and central governments to solve massive externality problems and collective action problems, since she redirected attention to the capacity of individuals and communities to trust each other, take the right course of action, and thus not wait for governments to make the first move to solve collective dilemmas. This cooperative vision also applies to the governance of large externalities and public health once we recognize the coproduction of public health services during the COVID-19 pandemic.

The degree of co-productiveness and the complementary role of civil society

Moreover, the conceptualization of the *degree of co-productiveness* that public and health services possess is pivotal in understanding the vital role of civil society and citizens in the production and maintenance of public health. It challenges the prevailing conception that central governments should be the first movers in solving social challenges over time. This shift in emphasis is clearly stated in Ostrom's and her collaborators' conceptualization of interdependent coproduction: 'Most of present authors would relax strict interdependence in service production, agreeing that some levels of output *can* be obtained via consumer production alone, though few of us would entertain the possibility of much service production using *only* regular producer inputs Indeed, by the nature of interdependency, some minimum quantity of input from each is required before any output can be obtained' (Parks *et al.*, 1981, pp. 1003–1006).

The above analysis encapsulates neatly the challenge and the idea behind viewing the production of social distancing and other preventative measures as a massive coproduction problem (Steen & Brandsen, 2020). The proper production of social distancing can, in theory, be obtained via citizens' production alone, but social distancing *cannot* be produced using only coercion and central governments' traditional coercive inputs (that is, policing, military interventions, public surveillance, repression, etc.). Hence, this alternative framework for understanding how social distancing is ultimately produced challenges the standard paradigm for thinking about the appropriate solution to modern public health challenges. And thus, the notion that authoritarian regimes are better able to cope with pandemics should be severely questioned (Cheng *et al.*, 2020); since it is ultimately inconsistent with the political economy of coproducing complex public goods as discussed here. Furthermore, even if we leave epistemological problems aside in considering how to attain the

appropriate production of social distancing and other key health measures (Coyné *et al.*, 2021), the above analysis also suggests that coercive lockdowns and imposed social distancing might not be the only, and perhaps not the most efficient, way of producing public health during a pandemic (Goolsbee & Syverson, 2020; Watanabe & Yabu, 2020).

In fact, a recent meta-study assessed COVID-19 responses around the world and found that mandatory lockdown orders early in the pandemic did not significantly lower the disease from spreading, relative to optional and bottom-up responses, such as local (endogenously produced) social distancing or voluntary travel reduction (Bendavid *et al.*, 2021).¹² Moreover, Kepp and Bjørnskov (2021) also find that, while infection levels decreased in lockdown areas, ‘they did so before lockdown was effective, and infection numbers also decreased in neighbour municipalities without mandates. ... The data suggest that efficient infection surveillance and voluntary compliance make full lockdowns unnecessary at least in some circumstances’ (Kepp & Bjørnskov, 2021, p. 1). Similarly, Berry *et al.* (2021) find that ‘shelter-in-place orders had no detectable health benefits, only modest effects on behavior, and small but adverse effects on the economy’. Thus, the evidence seems to suggest that most people voluntarily change their behaviour before the introduction of coercive shelter-in-place orders, thus coproducing public health measures without needing central government enforcement (Rayamajhee *et al.*, 2021).

Bendavid *et al.* (2021) analyse COVID-19 case growth in 10 countries by contrasting such countries as England, France, Germany, Iran, Italy, the Netherlands, Spain and the United States – all countries that implemented mandatory lockdown orders and business closures —with South Korea and Sweden, which instituted less coercive, more voluntary responses (both countries did not implement mandatory lockdowns and business closure). The meta-study analysed the effect that less restrictive (voluntary and bottom-up responses) or more coercive (imposed) measures had on individual behaviour and curbing the transmission and spread of the virus. It found ‘no clear, significant beneficial effect of mrNPIs [more restrictive nonpharmaceutical interventions] on case growth in any country’ (Bendavid *et al.*, 2021, p. 2). The results led the authors to conclude that ‘while small benefits cannot be excluded, we do not find significant benefits on case growth of more restrictive NPIs [nonpharmaceutical interventions]. Similar reductions in case growth may be achievable with less restrictive interventions’ (Bendavid *et al.*, 2021, p. 2). In essence, the study,

fail[s] to find strong evidence supporting a role for more restrictive NPIs in the control of COVID We do not question the role of all public health interventions, or of coordinated communications about the epidemic, but we fail to find an additional benefit of stay-at-home orders and business closures. The data cannot fully exclude the possibility of some benefits. However, even if they exist, these benefits may not match the numerous harms of these aggressive measures. More targeted public health interventions that more effectively

reduce transmissions may be important for future epidemic control. (Bendavid *et al.*, 2021, p. 11)

Even though more research is certainly required to make definitive claims about the comparative efficiency of voluntarily produced, bottom-up public health measures versus more coercive, imposed lockdown measures, the work of the Bloomington scholars suggests that, given the *interdependence* between citizens and governments in the production of services, the appropriate and efficient production of social distancing can be achieved only when citizens are voluntarily involved in the production of those services and when local governments serve as catalysts in monitoring, coordinating, enhancing trust and protocols, and spreading accurate scientific information (Steen & Brandsen, 2020). In such a collaborative manner, social distancing can be effectively coproduced without excessive input from coercive and centralized governments, thus avoiding the negative and damaging counter effects of crowding out citizens' active engagement and input in the crucial production of health services (Ostrom, 2000a, 2000b). For instance, Goolsbee and Syverson (2020) notice that private initiatives accounted for *most* of the reduction in US social and commercial interactions during the pandemic. In other words, it was an endogenous and voluntary reduction that largely anticipated coercive measures for the purpose of governing the externality (see also Leeson & Rouanet, 2021). Watanabe and Yabu (2020) also find that three quarters of decreased Japanese social activity during the pandemic were driven by *uncoercive* measures.

In sum, the recent studies by Bendavid *et al.* (2021), Boesch (2021), Kepp and Bjørnskov (2021) and Coccia (2021) seem to validate these Ostromian conjectures about the coproduction of public health. For example, E. Ostrom (2012b, p. 128), in her work on public policy and institutional diversity, explicitly alerted policymakers to the dangers of imposing policy 'monocropping' detached from the local context and citizens' input. Nevertheless, more research in the political economy of pandemics and public health should be definitely encouraged in this novel Ostromian framework before making more definitive claims. When conceptualizing pandemics as externalities, the presence of nestedness in large social challenges (Ostrom, 2012, 2014) – alongside institutional diversity and heterogeneity in the production functions of diverse public (health) goods (Ostrom & Ostrom, 1977) – suggests that policy and institutional 'monocropping' from the top down is a highly dangerous and narrow-minded approach. As E. Ostrom (2012b) warned us:

When a single governing authority makes decisions about rules for an entire region, policymakers have to make plans for all of the territory within a jurisdiction, with each policy change. And, once an initial policy has been made and implemented, further changes will not be made rapidly. The process of experimentation will usually be slow, and information about results may be contradictory and difficult to interpret. Thus, a policy that is based on erroneous data

about one key structural variable, or one false assumption about how actors will react, can lead to a very large disaster. ... We cause harm, however, by recommending one-size-fits-all institutional prescriptions based on overly simplified models. (pp. 129, 139)

Hence, in regard to complex and nested social challenges, public administration scholars and economists must embrace an intellectual transition away from the narrow Pigouvian approach to externalities and the chimerical quest to design optimal solutions to be imposed from above. Instead, they should adopt a polycentric approach that fosters 'adaptive multilevel governance' (Ostrom, 2012b, p. 139). The most relevant institutional features for governing complex externalities become: bottom-up experimentation, coproduction, learning and information-dissemination mechanisms, and adaptation at multiple scales.

Taking these concerns seriously, the Bloomington scholarship suggests that polycentric systems with multiple and decentralized overlapping centres for decision-making are the ones better able to promote such features and hence better able to govern complex social phenomena (Aligica, 2014; Tarko, 2017). Indeed, 'if experimentalism is a central issue ... then one can hardly think of a better arena of experimentation than polycentricity. It is a system of reciprocal monitoring and assessment in dynamic interdependence. ... They must stay informed about (and be prepared to adjust to) the evolutions of other units' (Aligica, 2014, p. 66).

Now that governments across the world are facing deep budget constraints and backlash against the severe and repeated coercive public measures – in large part due to the economic recession inflicted by governing the pandemic in a top-down fashion without citizens' input (Coccia, 2021) – and now that citizens are becoming increasingly aware of the importance of their own efforts in governing communicable diseases and global externalities, an intellectual shift concerning how to best govern public health challenges is deeply warranted.

Potential limits in the polycentric governance of public health

While the notion of coproduction and the role of civil society have been highlighted as crucial in the provision of public health, it is relevant to also acknowledge the shortcomings and limits of such a polycentric approach. Potential fragilities may arise when there is a lack of a central authority, for instance in weak or non-transparent states (Lieberman, 2011). Lieberman notes that such a scenario can pose severe coordination challenges and management difficulties that could hamper the provision of public health and the coproduction of health measures. This seems to be particularly acute in weak states with low state capacity, governance fragmentation, and low political accountability (Lieberman, 2011, p. 684).

Moreover, ambiguously defined jurisdictions and opacity in allocating different political tasks and duties (attributed to different authorities) can

incentivize local government actors to free ride on the efforts of others, or blame other jurisdictions, for inefficiencies and failures (Lieberman, 2011, p. 680). These fragilities are exacerbated in young democracies and in developing countries with less accountable political systems, non-transparent or opaque bureaucracies, and ill-defined political roles and jurisdictions (Lieberman, 2011).

In addition, Bentkowska (2021) highlights that informal institutions play a crucial role in the success or failure of coproducing public health and in the governance of infectious diseases. Informal institutions ‘embody societies’ mentality and perceptions of the world’ and they can be reflected through, ‘culture or level of trust in the society’ (Bentkowska, 2021, p. 730). Countries with better informal institutions (e.g. a culture of cooperation, a strong civil society, high social capital, and higher levels of trust) can ‘expect their formal rules to be followed’; furthermore, ‘there is a need for less formal rules as informal institutions may complement them’ (Bentkowska, 2021, p. 742). Such cultural settings could decrease the cost of creating and enforcing formal rules, in turn enabling the propitious milieu for policy coordination and polycentric governance to function (Ostrom, 2000b; Storr *et al.*, 2021). Inversely, countries with weak informal institutions might encounter difficulties in promoting successful polycentric governance, thus they might require more coercive and top-down measures and a focus on better enforcement mechanisms via centralized means (Cheng *et al.*, 2020).

These findings and qualms remain preliminary; much more research is needed to make a definitive claim on the effectiveness of polycentric governance and its proper limits. However, these studies do suggest, *prima facie*, that an adaptive and polycentric approach to public health seems to be more feasible in well-established democracies with higher levels of social capital and trust, and a liberally-oriented political realm, in which local-level incentives are important for policy uptake and some forms of local resistance and accountability are possible. Contrarily, a polycentric approach to public health might be unfitting in weak states and young democracies with ill-defined political jurisdictions and lower levels of social capital and trust. It is warranted additional, ‘empirical scrutiny of polycentric governance as a normative model for infectious disease control’ (Lieberman, 2011, p. 676). This paper’s analysis concerning the nested nature of public health and local coproduction challenges nonetheless provides intellectual support for Leeson and Rouanet’s (2021, p. 1108) conjecture that, ‘negative infectious disease externalities are less prevalent in the absence of government intervention and less costly to society than is often supposed’ by standard economic analysis.

Conclusions

The goal of this paper has been to point to an alternative way forward to intellectually grapple with public health challenges and pandemics as nested

externalities. To summarize, the approach put forth here recognizes that ‘instead of presuming that one can design an optimal system in advance and then make it work, we must think about ways to analyse the structure’ and nature of collective challenges – in this case a negative and nested externality —and consequently think about ‘how these [challenges] change over time, and adopt a multilevel, experimental approach rather than a top-down approach to the design of effective institutions’ (Ostrom, 2012b, p. 141). Once we adopt a nested and complex view of the nature of health externalities, we can recognize that whenever Pigouvian public policy is enacted by a single governing authority for an entire nation, this imposes a fixed and large-scale institutional structure to tackle different problems that require diverse production functions and different degrees of coproduction in order to be governed successfully. In other words, the standard approach to nested externalities has the tendency to generate institutional mismatch, crowding out, and inefficiencies because of the rigidities imposed from the top down (Ostrom, 2014).

This paper has argued that one plausible way forward is to move away from developing Pigouvian models of optimal taxation and coercion to attain optimal outcomes – based on false assumptions about how actors will react – and focus instead on promoting self-governing and polycentric systems that foster coproduction, citizenship engagement, and bottom-up collaborative processes so that institutional adaptability can scale up (or scale down) to match the different production functions required to govern the different parts of a nested externality.

In this respect, framing pandemics as nested externalities brings us to a crucial conclusion about the governance of modern global dilemmas going forward – what Elinor Ostrom (2011) calls the ‘decentralization theorem’, which maintains that decentralization and bottom-up scaling up in providing governance could be more just, better, and perhaps even more effective, than the top-down provision of governance by a single global provider. Thus, a ‘fundamental lesson that we all learned from Buchanan and Tullock’ – Ostrom (2011) recognizes – is that ‘both decentralization and size factors suggest that, when possible, collective action should be organized in small rather than large political units. Organizations in large units may be justified *only* by the overwhelming importance of the externalities that *remain after* localized and decentralized collectivization’ (Ostrom, 2011, p. 370, emphasis added; see also Buchanan & Tullock, 1962).

To conclude, once we acknowledge the nested and layered nature of global externalities, such as pandemics and climate change, we can fathom the full relevance of the decentralization theorem. This also helps us to understand the pressing relevance of polycentric systems in the contemporary analysis of complex governance structures and externalities: ‘The initial relevance of the polycentric approach is the parallel between the earlier theoretical presumption that *only* the largest scale was relevant for the provision and production of public goods for metropolitan areas, and the contemporary presumption that

only the global scale is relevant for policies' (Ostrom, 2012, p. 356). Ultimately, the proposed conceptual framework could generate a novel research agenda bridging political economy, public and health economics, and public administration in order to shed light on how societies can better deal with complex governance challenges (Paniagua, 2021; Paniagua & Rayamajhee, forthcoming). The time is ripe for taking stock of institutional and polycentric-relevant scholarship that addresses contemporary issues in global governance challenges and health externalities.

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Notes

1 The journal *Economy and Society* has been a key intellectual venue for promoting multidisciplinary research in the social sciences related to pressing public health challenges; see the recent collection of papers put forth by the Editorial Board of *Economy and Society* (Langley, 2021).

2 Externalities are 'net costs (negative externalities) or benefits (positive externalities) that a person's behavior imposes on other people for which he does not account when deciding how to behave. In the context of infectious disease, behaviors that may create externalities are those that affect other people's risk of infection' (Leeson & Rouanet, 2021, p. 1108). For an in-depth sociological analysis of externalities and market failures see Callon (1998).

3 Public health is 'the health of the population as a whole, esp. as monitored, regulated, and promoted by the state' (Oxford English Dictionary, 2020).

4 A polycentric system is one that is comprised by many heterogeneous—both collaborative and competitive—decision centres, in which: 'citizens are able to organize not just one but multiple governing authorities at different scales. ... Each unit exercises considerable independence to make and enforce rules within a circumscribed domain of authority ... In a polycentric system, some units are general-purpose governments while others may be highly specialized. ... In a polycentric system the users of each common-pool resource would have some authority to make at least some of the rules related to how that particular resource will be utilized' (Ostrom, 2005, p. 283).

5 Governance is conceived as, 'the practice of exercising authority over a particular domain, including making and enforcing rules, and directing efforts to manage the

behavior and welfare of a set of constituents. This consists of the development of budgets, the written and verbal articulation of policies and practices, and the exchange of information between authority and constituents' (Lieberman, 2011, p. 677).

6 To clarify, 'nested structures' could be interpreted as Russian dolls: there are small social orders within other larger social orders, that are governing a particular challenge in such a manner that each local set of rules and incentives align with the rules and objectives of other larger scales. Marshall (2008, p. 77) for example, conceptualizes 'nested arrangements' as cooperative systems that encourage the autonomous functioning of smaller, more exclusive units, operating within broadly agreed principles. 'Nestedness' is therefore an institutional property in which key governance functions—like monitoring and the enforcement of rules – are organized into multiple and overlapping layers of governance (Ostrom, 1990).

7 This institutionalist critique of the standard way of understanding how to govern externalities (Pigou, 1920) is complementary to the Coasean transaction-costs approach. The latter approach criticizes the Pigouvian solution to externalities as either redundant – if we consider transaction costs to be zero – or certainly not a panacea, once we consider that the institutional transaction costs and operational costs inherent in either solution are non-trivial (Coase, 1960). In this (Coasean) manner, Pigouvian solutions are either trivial or require a careful comparative institutional analysis to compare their costs and benefits with alternative, exchange-based solutions.

8 There is also evidence pointing toward viral externalities and public health more broadly. For example, there is ample evidence of government failure in public health (see Leeson & Thompson, 2021). In their literature review, they highlight three major conclusions about central governments' provision of public health: '(1) Public health regulations often are driven by private interests, not public ones. (2) The allocation of public health resources often reflects private interests, not public ones. (3) Public health policies may have perverse effects, undermining instead of promoting health-consumer welfare' (Leeson & Thompson, 2021, p. 1). See also Geloso and Mur-tazashvili (2021).

9 For evidence of the crowding-out effect in which governments could displace local communities in the production of public services, see Ostrom (2000a, 2012b), Shi *et al.* (2020) and Steen and Brandsen (2020).

10 Readers interested in detailed explorations of the concept of coproduction and its relationship with polycentricity should consult Aligica and Tarko (2013) and Alford (2014).

11 For documented cases of coproduction during the pandemic, see Rayamajhee *et al.* (2021). For US-based cases, see Steen and Brandsen (2020), Storr *et al.* (2021), and Shi *et al.* (2020). For China, see Cheng *et al.* (2020), who examine how public sector leaders coordinated with community-based organizations in Zhejiang, China, which helped to contain the COVID-19 pandemic.

12 Similar findings appear in Boesch (2021), Robinson (2021) and Coccia (2021). Coccia (2021, p. 1) even finds that, 'a longer period of lockdown has a negative impact on economic growth' and 'a longer period of lockdown does *not* reduce significantly [the] fatality rate'. For an in-depth analysis of these issues, consult Berry *et al.* (2021) and Kepp and Bjørnskov (2021).

ORCID

Pablo Paniagua  <http://orcid.org/0000-0002-1579-6203>

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Pablo Paniagua is a Research Fellow at the Centre for the Study of Governance and Society in the Department of Political Economy at King's College London and a Senior Researcher at Fundación Para el Progreso, Chile. He holds a PhD in Political Economy at the University of London, King's College. He has published widely on institutional economics, governance and political economy.