Experts vs. policymakers in the COVID-19 policy response*

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Abstract

We build an evolutionary game-theoretic model of the interaction between policymakers and experts in shaping the policy response to the COVID-19 pandemic. Players' decisions concern two alternative strategies of pandemic management: a "hard" approach, enforcing potentially unpopular measures such as strict confinement orders, and a "soft" approach, based upon voluntary and short-lived social distancing. Policymakers' decisions may also rely upon expert advice. Unlike experts, policymakers are sensitive to a public consensus incentive that makes lifting restrictions as soon as possible especially desirable. This incentive may conflict with the overall goal of mitigating the effects of the pandemic, leading to a typical policy dilemma. We show that the selection of strategies may be path-dependent, as their initial distribution is a crucial driver of players' choices. Contingent on cultural factors and the epidemiological conditions, steady states in which both types of players unanimously endorse the strict strategy can coexist with others where experts and policymakers agree on the soft strategy, depending on the initial conditions. The model can also lead to attractive asymmetric equilibria where experts and policymakers endorse different strategies, or to cyclical dynamics where the shares of adoption of strategies oscillate indefinitely around a mixed strategy equilibrium. This multiplicity of equilibria can explain the coexistence of contrasting pandemic countermeasures observed across countries in the first wave of the outbreak. Our results suggest that cross-country differences in the COVID-19 policy response need not be the effect of poor decision making. Instead, they can endogenously result from the interplay between policymakers and experts incentives under the local social, cultural and epidemiological conditions.

Keywords: COVID-19; coronavirus; lockdown; culture; evolutionary game theory.

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1 Introduction

The COVID-19 pandemic puts policymakers in front of a tough trade-off between two crucial priorities: saving lives through mitigation of the effects of the pandemic and preventing the collapse of the economy that may ensue from mitigation measures. Despite the ongoing vaccination campaigns and the gradual availability of better therapeutic approaches to severe cases, there is a broad consensus that a full recovery from the pandemic crisis will take time, and restrictive measures of some kind will have to be called for also in the coming future according to circumstances (Li et al., 2020; Iftekhar et al., 2021). Therefore, a key element of the policy debate is what kind of containment measures are necessary and for how long, depending on the observed dynamic of contagion and the emergence of new variants of the virus (Kaplan et al., 2020). Restrictive orders help coping with exponential growth stages of contagion (Dehning et al., 2020; Flaxman et al., 2020). However, they come at the cost of tremendous economic damage (Chetty et al., 2020; Coibion et al., 2020) and threaten incumbent governments' popularity (Aksoy et al., 2020; Pulejo and Querubín, 2021), the more so, the more prolonged the state of emergency and the related uncertainty.[1] Therefore, policy response must strike a compromise between the competing needs to flatten the contagion curve on the one side and to support the economy and manage political consensus on the other. In the UK and the US, for instance, policymakers initially adopted gradual step-by-step social distancing in the hope of flattening the curve without compromising political consensus and economic activity. But governments pragmatically replaced this light approach with strict stay-at-home orders as the outbreak went out of control (Amuedo-Dorantes et al., 2021).

In justifying their choices, policymakers often rely upon expert advice, to take advantage of competent judgment to decide in the public interest and to share responsibility on the policy's outcomes, also exploiting the expert as a possible scapegoat in case of adverse results. During the pandemic, the role of the experts (epidemiologists, virologists, public health scientists) has been prominent in the public debate about the measures to be implemented, with significant cross-country differences (Gallotti et al., 2020; Eichengreen et al., 2021). For example, in the U.S., the popularity of Anthony Fauci, the country leading expert on infectious diseases who often dismissed President Donald Trump's anti-scientific statements, remarkably rose throughout the crisis, not only among democrats but even in some of republicans' core demographics. However, the recent rise in science-related populism (Mede and Schäfer, 2020) has contributed to undermine confidence in scientists and scholarly institutions in parts of the public opinion, leading some citizens to trust experts less, often in favor of political leaders who question the role of science in public statements (Krause et al., 2019). But it may even be the case that the expert themselves endorse populist positions to gain

[1] For example, in the first months of the outbreak, proactive testing has been a controversial issue, with the World Health Organization (WHO) and many governments initially recommending testing only patients with apparent symptoms of infection. Massive testing is unpopular because it requires substantial investments to open large numbers of temporary facilities decentralized from hospitals and clinics and the massive purchase of reagents and machinery. Today, proactive testing is acknowledged as a fundamental tool to mitigate the spreading of the virus, as most infections carry no symptoms and remain undocumented, with asymptomatic patients being almost as infectious as severe ones (Li et al., 2020; Lavezzo et al., 2020). Despite that, former U.S. President Donald Trump described testing for the virus as a "double-edged sword" because it led to identifying more cases, and said he ordered "to slow the testing down" speaking at a campaign rally in Tulsa, Oklahoma. Two months later, the U.S. Center for Disease Control and Prevention abruptly changed its recommendations, establishing that people without COVID-19 symptoms should not get tested (Stolberg, 2020). As for contact tracing, alert systems through mobile apps potentially play a fundamental role in breaking contagion chains (Ferretti et al., 2020). However, despite the successful experience of East Asian countries, digital tracing has been widely criticized due to privacy issues and was never made compulsory in Western democracies (see, for example, https://www.nytimes.com/2020/03/23/world/asia/coronavirus-south-korea-flatten-curve.html).

visibility. For instance, in Italy, a few experts openly contradicted the available evidence about the danger of the SARS-Cov-2 and the measures required to contain its spread, downplaying the seriousness of the pandemic threat and criticizing the strong policy response that the government took after initial hesitation. This contrarian stance was heavily rebuked by most peers but garnered the attention of the media and the public, granting some celebrity to the skeptics.[2]

The relationship between policymakers and experts is therefore a difficult one, as they face different incentives, and the current crisis exacerbated existing disagreements (Cairney, 2021). In February 2020, early warnings from doctors and scientists about the potentially disruptive effects of a rising pandemic were largely met with skepticism by most political leaders in Europe and the US, despite the already observed impact on China. In particular, experts warned that a timely and swift response was crucial in the event of exponential growth of cases and called for precautionary limitations to mobility and social activities (Block et al., 2020). However, the prospect of taking very unpopular measures in a context where no major contagions were observed made policymakers reluctant to follow the advice. Such caution has a political rationale: if countermeasures are rapidly adopted and prevent the escalation of the outbreak, it will appear in retrospect as if the policy response was an overreaction, possibly causing a loss of consensus (Pisano et al., 2020).

Therefore, it is unsurprising that the pandemic has been tackled through different public health strategies across different countries, both in terms of deployed resources and the salience bestowed to expert advice in public decision-making. In several European countries, such as Italy and France, there was an early agreement between policymakers and experts about the necessity of a strong reaction to amend the damage of initial irresolution (Fazio et al., 2021; Salje et al., 2020). Instead, in Japan and Sweden, policymakers and experts agreed on a soft strategy based on voluntary compliance with social distancing measures (Sang-Wook, 2020; Watanabe and Tomoyoshi, 2021). Sweden, for example, responded to the outbreak with light guidelines asking citizens to social distance voluntarily. This response stands in stark contrast to the strong measures implemented in other Scandinavian countries, likely resulting from the explicit aim to pursue herd immunity (Orlowski and Goldsmith, 2020) and from the Swedish historical and constitutional background that makes it difficult to pass laws restricting individual liberties (Sheridan et al., 2020). Japan's strategy against the virus, instead, leveraged upon citizens' propensity for compliance and trust in institutions to prompt a "voluntary lockdown" and the pervasive use of protection devices (Watanabe and Tomoyoshi, 2021). In other cases, conflicts arose between scientists advocating for non-pharmaceutical interventions (NPIs) and political leaders who downplayed the gravity of the pandemic and even invited the public opinion not to heed the experts' advice, as in the U.S. (Allcott et al., 2020) and Brazil (Ajzenman et al., 2020). For example, former US President Donald Trump clashed with the scientific community from the beginning of the pandemic, openly disagreeing with his government officials over the gravity of the outbreak, the need for NPIs, the potential treatments, and testing policies (see, for example, Yamey and Gonsalves, 2020). In Brazil, president Jair Bolsonaro condemned the "hysteria" around the virus and railed against experts' recommendations and local authorities' decisions to impose stay-at-home measures to contain the outbreak (Ricard and Medeiros, 2020).[3] Given the massive societal implications of the COVID-19 policy response, the

[2]Giulio Tarro, a retired virologist, openly claimed that social distancing, masks, and even vaccines were unnecessary, as the virus was an over-hyped threat that would spontaneously disappear with the rising temperatures of the summer and the achievement of herd immunity. These claims were in stark contrast with the hard policy response prevailing in Italy in the first phase of the outbreak and were met with scorn by the scientific community. Still, Tarro benefited from massive attention by the public, making of him a most requested guest in TV shows, where he was often hyped as "the top world virologist of the year". Likewise, in the US, several physicians gained media exposure by spreading COVID-19 misinformation (see, for example, https://time.com/6099700/covid-doctors-misinformation/).

[3]In Brazil, president Bolsonaro repeatedly contrasted experts' recommendations and local governors' orders to enforce social distancing. The federal government initially restricted testing to the most severe COVID-19 cases only. In April 2020, Bolsonaro

results of the strategic interaction between scientists and policymakers deserve careful study.

In this paper, we build an evolutionary game-theoretic model to study how the interaction between policymakers and experts shapes the policy response to the pandemic. Our research question is: what explains the variation in COVID-19 policy responses across socio-economically similar countries (or regions) that were hit by the pandemic in a similar way? We model players' decisions in terms of the choice between two strategies: 1) a "hard" strategy, entailing restrictive orders and other potentially unpopular measures such as massive testing and strongly enforced quarantine for potential cases; and 2) a "soft" strategy, based on short-lasting limited-scope social distancing orders, primarily relying on citizens' voluntary compliance with precautionary measures, in the hope to flatten the curve while limiting restrictions on the economic activity. We analyze how the adoption dynamics of the two strategies depend on the rewards that experts and policymakers derive from their choices, leading to various possible dynamic regimes, whose onset also depends on the achieved level of consensus between the two parties given the epidemiological constraints.

We find that the adoption dynamics may be path-dependent, as the initial distribution of strategies within the populations of experts and policymakers is a crucial choice driver. For certain model parameters, one can observe steady states in which unanimous adoption of either the hard or the soft strategy can result, depending on initial conditions. Therefore, socio-economically and epidemiologically similar countries or regions may end up in very different policy equilibria. The potential coexistence of opposite equilibria where experts and policymakers agree on either the hard or the soft strategy according to local conditions explains the diversity of policy responses observed across countries, such as the strict lockdown implemented in Italy and France (after initial hesitation) versus the light social distancing measures implemented in Sweden and Japan. In other cases, conflicting incentives can lead players to disagree. This kind of outcome has been observed in countries with varying levels of socio-economic development, such as the US, Brazil, and India, where policymakers publicly discredited experts in front of the public opinion, and experts did the same with policymakers, albeit generally with more circumspection to avoid retaliation. However, our model also contemplates the possibility of a cyclical oscillation between different policies, as we observe in the late phase of the pandemic, where many countries tend to toggle between strict lockdown measures and lighter, voluntary restrictions, generally following the evolution of the levels of contagion with an eye to the mood of the public opinion. Therefore, also this seemingly erratic behavior may be rationalized as the outcome of the strategic interaction between the two types of players.

The kind of dynamic regime that tends to prevail in each case depends on how parameters reflect local cultural conditions such as compliance with norms, trust in science and policymakers, and sociability habits, among others (Bicchieri et al., 2021). The incentives of policymakers and experts are therefore shaped by the interplay of such factors in role-specific combinations. Past public health crises also play a fundamental role as they affect the initial distribution of strategies. For example, the effective response of South Korea took advantage of the pandemic plans prepared against the SARS and MERS outbreaks (Park and Chung, 2021) and of the heightened public awareness that ensued.

Our work relates to different strands of the growing COVID-19-focused economics literature. Many studies analyze the policy response to the outbreak. Early NPIs save lives (Fang et al., 2020; Sang-Wook, 2020; Cerqueti et al., 2021), but bring severe economic losses in the short run (Coibion et al., 2020) and a potential electoral punishment for the incumbent (Aksoy et al., 2020; Fazio et al., 2021). Weak, irresolute reactions to

fired his Minister of Health, Luiz Henrique Mandetta, after disagreeing over NPIs. His next Minister of Health, Nelson Teich, resigned from office after policy disagreements and refusing to yield to Bolsonaro's pressures on the use of hydroxychloroquine as a COVID-19 treatment. Bolsonaro then appointed Eduardo Pazuello, an Army General with no medical experience, as the interim Minister of Health, a post he has held from early June 2020 to March 2021 (Barberia and Gómez, 2020).

the pandemic, on the other hand, cost lives and bring about uncertain economic outcomes (Amuedo-Dorantes et al., 2021). Recent work shows that lockdowns are only partially accountable for the slump in economic activity, suggesting that most economic losses stem from changes in behavior caused by uncertainty and anxiety (Amuedo-Dorantes et al., 2020; Kong and Prinz, 2020; Sheridan et al., 2020). We add to this literature by focusing on the behavioral drivers, instead of the outcomes, of COVID-19 containment strategies. We specifically analyze the strategic reasons that motivate experts and policymakers' choices, given the current state of knowledge and epidemiological constraints. We argue that culture plays a fundamental role not only in determining compliance with social distancing measures - as shown by Barrios et al. (2021), Briscese et al. (2020), and Durante et al. (2021) - but also in inspiring experts and policymakers' evaluations and decisions. We also relate to the cross-disciplinary literature that studies the timing and strength of the policy response to the pandemic. In recent months, new work has shown that public health measures are tightly connected to policymakers' electoral concerns (Daniele et al., 2020; Hargreaves Heap et al., 2020). Pulejo and Querubín (2021) document that leaders who can run for re-election have implemented less stringent restrictions when the election is closer in time. Aksoy et al. (2020) consistently find that weak governments took longer to introduce a policy response to the COVID-19 outbreak. Sebhatu et al. (2020) show that strong democracies are reluctant to initiate restrictive policies and are more likely to follow the policies of nearby countries. We add to these studies by showing that policymakers' interaction with experts also plays a non-trivial role in public health choices and by providing a framework to interpret cross-country and regional differences in the management of the crisis.

The remainder of the paper is organized as follows: Section 2 presents the model. Section 3 provides the results. Section 4 contains the discussion.

2 Model

2.1 Players and strategies

Let us consider an evolutionary game with two populations, *experts* (players E) and *policymakers* (players P), with a random matching structure. In each instant of time t, several pairwise encounters between players of types E and P take place. On the occasion of each matching, players have to choose between two (pure) strategies, H and S. The H strategy represents a "hard" approach to fighting the virus, based on strong policy actions, such as pervasive and strictly enforced restrictive measures, massive testing, and aggressive contact tracing. These actions have proven effective in flattening the infection curve, but they are unpopular as they cause severe economic losses (Chetty et al., 2020; Coibion et al., 2020), threaten civil liberties (Bjørnskov and Voigt, 2021), and undermine incumbents' popularity (Aksoy et al., 2020; Fazio et al., 2021). As a result of these side effects, many policymakers in democratic countries hesitated to take strong actions against the outbreak (Pulejo and Querubín, 2021; Sebhatu et al., 2020). Instead, the S strategy represents a "soft" approach to the outbreak, entailing limited and short-lived social distancing orders.

The H (respectively, S) strategy ex-post turns out to be the best strategy with exogenous probability $p \in (0, 1)$ (respectively, $1-p$). This probability basically depends on the country's (or region's) position on the pandemic curve and other variables exogenous to policymakers, such as the extent of nursing home connections via shared staff (Amuedo-Dorantes et al., 2021; Chen et al., 2021).

We assume that if both types of players choose the same strategy (either H or S), such a strategy will be adopted. However, if they choose different strategies, then player P's choice prevails, as the final decision is up to the policymaker.

2.2 Payoffs

The dynamics of adoption of the two strategies depend on the reward that players get from their choices. In this section, we describe experts' and policymakers' payoffs in the two scenarios where the hard or the soft strategy respectively turns out to be the most effective ex post. We then illustrate the expected payoffs matrices.

2.2.1 Experts' payoffs

When the H strategy turns out to be the most effective (which happens with probability p), we assume that the payoffs of player E are given by the following payoff matrix:

$$\begin{array}{ccc} & H_P & S_P \\ H_E & 1 & -1+\beta \\ S_E & 1-\alpha & -1 \end{array} \tag{1}$$

Where α and β are positive parameters. By H_i and S_i we indicate the H and the S strategy, respectively, chosen by player $i = E, P$. We normalize to 1 the payoff that players obtain when they both choose the best strategy, H. When both players choose the worst strategy, S, their payoff is assumed to be equal to -1. When the expert chooses the most effective approach, H, but the policymaker decides for the soft strategy, S, the expert gets -1 plus a reward β. This reward captures the reputation gain from the public's and peer experts' recognition of the correctness of the expert's evaluation. Likewise, α captures the reputation damage resulting from the adoption of the wrong strategy when the policymaker chooses the right one.
From an evolutionary perspective, our framework models the interaction between two populations of experts and policymakers randomly matched in pairs. In this context, payoff matrices are the same for each type of player and the selection of Nash equilibria depends on the initial distribution of strategies, as we will explain in detail below.
Symmetrically, if S proves to be the best strategy (which happens with probability $1-p$), player E's payoffs are assumed to be:

$$\begin{array}{ccc} & H_P & S_P \\ H_E & -1 & 1-\alpha \\ S_E & -1+\beta & 1 \end{array} \tag{2}$$

If experts choose the wrong strategy, H, dissenting from the policymaker, their payoff is diminished by the reputation penalty α. If experts choose the best strategy, S, while the policymaker stands for H, their payoff is increased by the reputation reward β.

2.2.2 Policymakers' payoffs

Similarly, we assume that, if the H strategy turns out to be the most effective, the payoffs of policymakers are given by the following matrix:

$$\begin{array}{ccc} & H_E & S_E \\ H_P & 1 & 1+a \\ S_P & -1-b & -1 \end{array}$$

Symmetrically, if S proves to be the best strategy, the payoffs of the policymaker are given by the following matrix:

$$\begin{array}{ccc} & H_E & S_E \\ H_P & -1 & -1-b \\ S_P & 1+a & 1 \end{array}$$

The meaning of parameters α, β, a, and b is summarized in Table 1.

Table 1: Interpretation of parameters α, β, a, and b

Agent	Par.	Interpretation	May increase with:
Expert	α	Measures the expert's reputation damage for praising the wrong strategy when the policymaker chooses the right approach.	Academic freedom Scientific literacy Trust in science
	β	Measures the expert's reward for praising the most effective strategy when the policymaker chooses a wrong approach.	
Policymaker	a	Measures the policymaker's reputation reward for choosing the most effective strategy when the expert praises a wrong approach.	Scientific literacy Trust in science
	b	Measures the policymaker's reputation damage for choosing the wrong strategy when the expert praises the right approach.	

2.2.3 Expected payoff matrices

Taking into account that the H (respectively, S) strategy ex-post turns out to be the best strategy with probability p (respectively, $1-p$), the expected payoffs for players E and P are respectively given by the following matrices:

$$\begin{array}{ccc} & H_P & S_P \\ H_E & p-(1-p) & (-1+\beta)\,p+(1-\alpha)\,(1-p) \\ S_E & (1-\alpha)\,p+(-1+\beta)\,(1-p) & -p+(1-p) \end{array} \tag{3}$$

$$\begin{array}{ccc} & H_E & S_E \\ H_P & p-(1-p) & (1+a)\,p-(1+b)\,(1-p) \\ S_P & -(1+b)\,p+(1+a)\,(1-p) & -p+(1-p) \end{array} \tag{4}$$

Without loss of generality (see, e.g., Weibull, 1997; Hofbauer and Sigmund, 1998), we can write matrices (3) and (4) in the following normalized forms:

$$\begin{array}{ccc} & H_P & S_P \\ H_E & p\,(\alpha+\beta)-\beta & 0 \\ S_E & 0 & \alpha-p\,(\alpha+\beta) \end{array} \tag{5}$$

$$\begin{array}{ccc} & H_E & S_E \\ H_P & p\,(4+a+b)-2-a & 0 \\ L_P & 0 & -p\,(4+a+b)+2+b \end{array} \tag{6}$$

Matrix (5) is obtained by adding the constants:

$$-\left[(1-\alpha)\,p+(-1+\beta)\,(1-p)\right] \qquad \text{and} \qquad -\left[(-1+\beta)\,p+(1-\alpha)\,(1-p)\right]$$

to each entry of the first and second columns of matrix (3), respectively. Similarly, matrix (6) is obtained by adding the constants:

$$-\left[-(1+b)\,p+(1+a)\,(1-p)\right] \qquad \text{and} \qquad -\left[(1+a)\,p-(1+b)\,(1-p)\right]$$

to each entry of the first and second columns of matrix (4), respectively.

2.3 Evolutionary dynamics

Let us denote by $x(t)$ and $y(t)$ the shares of players E and P respectively adopting the H strategy at time t, with $1 \geq x(t), y(t) \geq 0$. Thus, $1-x(t)$ and $1-y(t)$ represent the shares of players adopting the S strategy.

The shares x and y also measure the probabilities to be matched with a player E or with a player P adopting the H strategy, respectively, in the occasion of random pairwise encounters. As a result, the expected payoffs of the strategies H_E, S_E, H_P, and S_P are respectively:

$$\Pi_H^E(y) = [p\,(\alpha + \beta) - \beta] \cdot y$$

$$\Pi_S^E(y) = [\alpha - p\,(\alpha + \beta)] \cdot (1 - y)$$

$$\Pi_H^P(x) = [p\,(4 + a + b) - 2 - a] \cdot x$$

$$\Pi_S^P(x) = [2 + b - p\,(4 + a + b)] \cdot (1 - x)$$

We assume that the adoption dynamic of strategies is described by the replicator equations (Taylor, 1979):

$$\begin{aligned} \dot{x} &= x(1-x)\left[\Pi_H^E(y) - \Pi_S^E(y)\right] \\ \dot{y} &= y(1-y)\left[\Pi_H^P(x) - \Pi_S^P(x)\right] \end{aligned} \tag{7}$$

where the symbols $\dot{x}$ and $\dot{y}$ represent the time derivatives of $x(t)$ and $y(t)$, respectively.
The dynamic system (7) describes an imitation-based learning process (Björnerstedt and Weibull, 1994). According to it, the more rewarding strategies spread in the two populations of players at the expenses of the less rewarding ones.
Notice that:

$$\Pi_H^E(y) - \Pi_S^E(y) = (\alpha - \beta)\,y + p\,(\alpha + \beta) - \alpha \tag{8}$$

$$\Pi_H^P(x) - \Pi_S^P(x) = (b - a)\,x + p\,(a + b + 4) - b - 2 \tag{9}$$

So, if $\alpha - \beta > 0$ (i.e. $\alpha > \beta$), then the payoff difference (8) increases if y increases. This implies that, for *Experts*, the relative performance of the H strategy increases when the share of *Policymakers* adopting H increases.
These dynamics allow us to interpret the relationship between experts and policymakers from an evolutionary

perspective based on the sign of the two expressions $\alpha - \beta$ and $b - a$.

3 Results

3.1 Classification of dynamic regimes

According to the payoff matrix (5), one of the two strategies H or S dominates the other in the population of *Experts* if the following condition holds:

$$[p(\alpha + \beta) - \beta] \cdot [\alpha - p(\alpha + \beta)] \leq 0 \tag{10}$$

Similarly, according to the payoff matrix (6), one of the two strategies H or S dominates the other in the population of *Policymakers* if the following condition holds:

$$[p(4 + a + b) - 2 - a] \cdot [-p(4 + a + b) + 2 + b] \leq 0 \tag{11}$$

If both types of agents have no dominant strategies (that is, if neither condition (10) nor condition (11) hold), then there exists an internal steady state of the dynamic system (7), whose coordinates are:

$$\widetilde{x} = \frac{p(a + b + 4) - b - 2}{a - b} \tag{12}$$

$$\widetilde{y} = \frac{p(\alpha + \beta) - \alpha}{\beta - \alpha} \tag{13}$$

where $1 > \widetilde{x}, \widetilde{y} > 0$; therefore, both strategies coexist in both populations at the steady state $(\widetilde{x}, \widetilde{y})$.[4] In addition to $(\widetilde{x}, \widetilde{y})$, there exist the pure population steady states $(x, y) = (1, 1)$, $(1, 0)$, $(0, 1)$, and $(0, 0)$.
In $(1, 1)$ (respectively, in $(0, 0)$), the H (respectively, S) strategy is the unique strategy played in both populations. In $(1, 0)$, all *Experts* play H while all *Policymakers* play S; vice-versa in $(0, 1)$.[5]
We illustrate the taxonomy of the dynamic regimes that can be observed under the dynamic system (7) below. The conditions on parameter values leading to each dynamic regime in the taxonomy are obtained by applying well-known classification results in evolutionary game theory (see, e.g., Hofbauer and Sigmund, 1998, p.119). The interpretation of parameters α, β, a, and b is summarized in Table 1.

3.1.1 *Bi-stable concurrent dynamic regime*

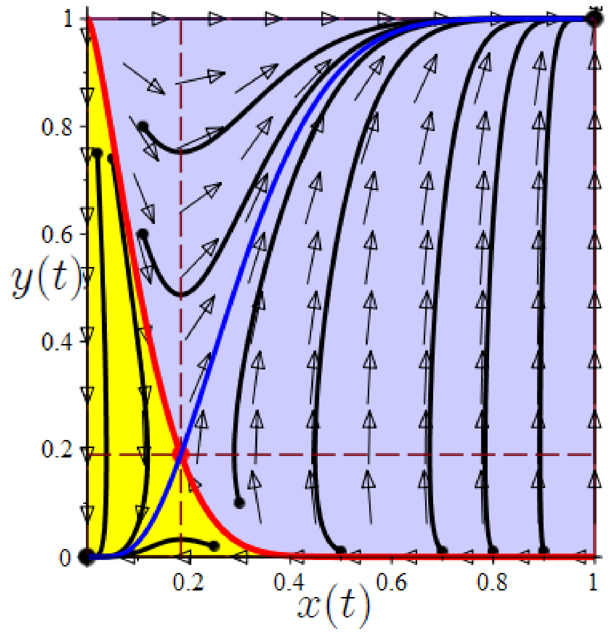
If conditions:

$$\alpha > p(\alpha + \beta) > \beta \;\text{ and }\; 2 + b > p(4 + a + b) > 2 + a \tag{14}$$

[4] Such a steady state corresponds to the mixed strategy Nash equilibrium of the static 2×2 game with payoff matrices (5) and (6), in which player E (respectively, player P) chooses H with probability $\widetilde{x}$ $(\widetilde{y})$ and S with probability $1 - \widetilde{x}$ $(1 - \widetilde{y})$.

[5] When the steady states $(x, y) = (1, 1)$, $(1, 0)$, $(0, 1)$, $(0, 0)$ are locally attractive, they respectively correspond to the pure strategy Nash equilibria (H_E, H_P), (H_E, S_P), (S_E, H_P), (S_E, S_P) of the static 2×2 game with payoff matrices (5) and (6).

Figure 1: Steady states $(1, 1)$ and $(0, 0)$ are locally attractive



hold (notice that conditions (14) can be satisfied only if $\alpha > \beta$ and $a < b$), the strategy profiles (H_E, H_P) and (S_E, S_P) are pure strategy strict Nash equilibria of the 2×2 one-shot game represented by the payoff matrices (5) and (6). Thus, the resulting strategic context is that of the standard *coordination game*. In such a case, the steady states $(x, y) = (1, 1)$ and $(x, y) = (0, 0)$ –where all players adopt, respectively, the H strategy and the S strategy– are locally attractive under the dynamic system (7) (see Figure 1). Their basins of attraction are separated by the stable arm of the internal steady state $(\widetilde{x}, \widetilde{y})$, which is a saddle point (i.e., an unstable steady state). If the starting point $(x(0), y(0))$ lies above the stable arm of $(\widetilde{x}, \widetilde{y})$ (that is, if the initial shares $x(0)$ and $y(0)$ of players adopting the H strategy are high enough), then the trajectory that starts in $(x(0), y(0))$ converges to $(1, 1)$. If the starting point $(x(0), y(0))$ lies below the stable arm of $(\widetilde{x}, \widetilde{y})$, then the trajectory that starts in $(x(0), y(0))$ converges to $(0, 0)$.
In the *bi-stable concurrent dynamic regime*, both the hard and the soft strategy may emerge at equilibrium depending on the initial conditions, and in either case experts and policymakers will always concur in their judgment. As shown by the parameter inequalities that are necessary conditions for this regime, the incentive structure of every player is such that agreeing with the judgment of the other player always is the best reply.

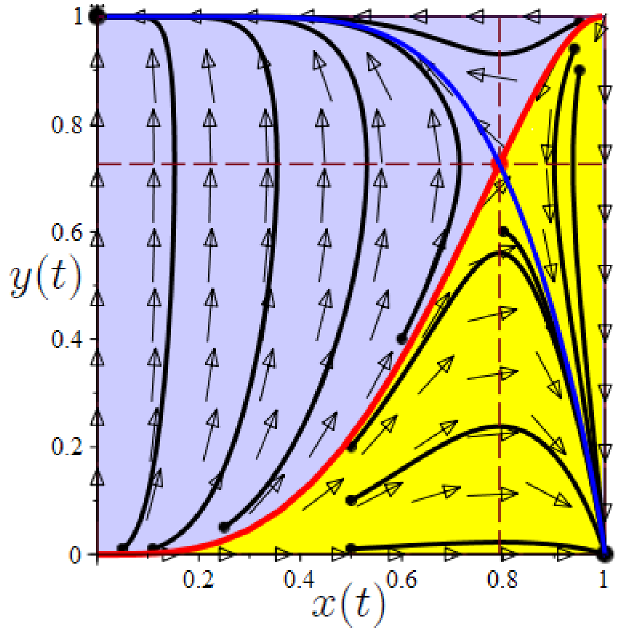
3.1.2 *Bi-stable dissenting dynamic regime*

If conditions:

$$\beta > p\,(\alpha + \beta) > \alpha \quad \text{and} \quad 2 + a > p\,(4 + a + b) > 2 + b \tag{15}$$

hold (notice that conditions (15) can be satisfied only if $\alpha < \beta$ and $a > b$), the asymmetric strategy profiles (H_E, S_P) and (S_E, H_P) are pure strategy strict Nash equilibria of the 2×2 one-shot game represented by the payoff matrices (5) and (6). Therefore, the resulting strategic context is that of an asymmetric *hawk–dove game*, where experts and policymakers may find it convenient to play either the role of the *hawk* or that of

Figure 2: Steady states $(1,0)$ and $(0,1)$ are locally attractive



the *dove*, according to the "social environment" described by the distributions of strategies x and y. In such a case, the steady states $(x,y)=(1,0)$ and $(x,y)=(0,1)$ are locally attractive under the dynamic system (7) (see Figure 2). In $(1,0)$, all experts play H_E whereas all policymakers play S_P, and vice-versa in $(0,1)$. The basins of attraction of $(1,0)$ and $(0,1)$ are separated by the stable arm of the internal steady state $(\widetilde{x},\widetilde{y})$, which is a saddle point. If the initial shares $x(0)$ and $y(0)$ are, respectively, low and high enough (that is, if the starting point $(x(0),y(0))$ lies above the stable arm of $(\widetilde{x},\widetilde{y})$), then the trajectory starting from $(x(0),y(0))$ approaches the steady state $(1,0)$, where all experts play H_E whereas all policymakers play S_P. Vice-versa, if the initial shares $x(0)$ and $y(0)$ are, respectively, high and low enough, then the trajectory starting from $(x(0),y(0))$ approaches the steady state $(0,1)$, where all experts play S_E whereas all policymakers play H_P. In the *bi-stable dissenting dynamic regime*, experts and policymakers always dissent at equilibrium, and the strategy they endorse depends on the initial conditions, i.e. on past history and prevailing socio-cultural attitudes. Notice that there can also be an equilibrium where policymakers choose the hard strategy despite that experts advise the soft one. This may depend on the fact that, given the local socio-cultural conditions, the reputation cost for politicians from choosing the soft strategy is particularly high in case of failure. In this case, the incentive structure always entails disagreement with the other player as the best possible reply.

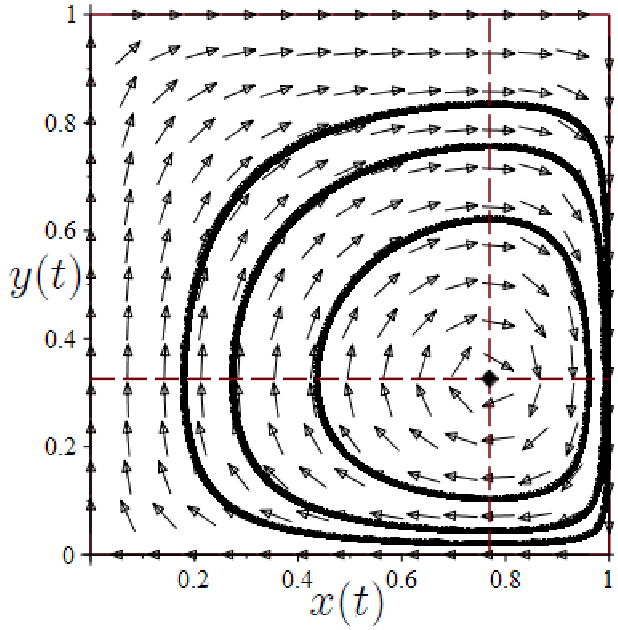
3.1.3 *Cyclic homeostatic policymaker dynamic regime*

If conditions:

$$\alpha > p\,(\alpha+\beta) > \beta \quad \text{and} \quad 2+a > p\,(4+a+b) > 2+b \tag{16}$$

hold (notice that conditions (16) can be satisfied only if $\alpha > \beta$ and $a > b$), then there exists a unique

Figure 3: The values of x and y oscillate clockwise around $(\widetilde{x}, \widetilde{y})$ for any initial distribution of strategies



Nash equilibrium of the 2×2 one-shot game represented by the payoff matrices (5) and (6): the mixed strategy equilibrium $(\widetilde{x}, \widetilde{y})$, where the expert (respectively, the policymaker) plays the H_E (H_P) strategy with probability $\widetilde{x}$ ($\widetilde{y}$) and the S_E (S_P) strategy with probability $1 - \widetilde{x}$ ($1 - \widetilde{y}$). The resulting strategic context is that of a *matching pennies game*. Expert's H_E strategy (respectively, S_E) is the best reply to policymaker's H_P (S_P) strategy. However, for policymakers, the H_P strategy (respectively, S_P) is the best reply when experts play S_E (H_E). According to the dynamic system (7), the internal steady state $(\widetilde{x}, \widetilde{y})$ is (Lyapunov) stable and all the trajectories are closed curves surrounding $(\widetilde{x}, \widetilde{y})$ (see Figure 3). In such a case, the dynamic is characterized by cyclic behavior, with values of x and y oscillating clockwise around $(\widetilde{x}, \widetilde{y})$ for any initial distribution of strategies $(x(0), y(0))$, with $1 > x(0), y(0) > 0$. Every initial distribution $(x(0), y(0))$ will be reached again at the end of the cycle.

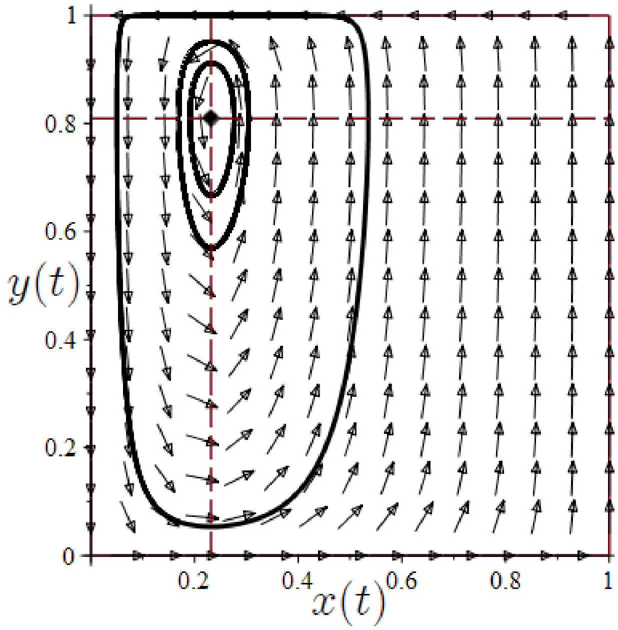
In the *cyclic homeostatic policymaker dynamic regime*, we notice that when the shares of policymakers and experts agreeing on the hard strategy are relatively high, policymakers tend to increasingly opt for the soft strategy whereas experts push for tougher measures. By contrast, when the endorsement of the hard strategy is relatively infrequent, policymakers push for stronger measures. In other words, in this regime it is the policymakers who have the incentive to push towards a balanced mix of hard and soft strategies responses, whereas experts tend to go for extreme positions (advocate for the strategy that is currently more widely adopted). These cyclic phases of dissent alternate with cyclic phases of consensus where both experts and policymakers tend to jointly advocate for harder/softer strategies according to cases. These cyclical trajectories can be interpreted as a predator-prey dynamic.

3.1.4 *Cyclic homeostatic expert dynamic regime*

If conditions:

$$\beta > p(\alpha + \beta) > \alpha \quad \text{and} \quad 2 + b > p(4 + a + b) > 2 + a \tag{17}$$

Figure 4: The values of x and y oscillate counterclockwise around $(\widetilde{x}, \widetilde{y})$, for any initial distribution of strategies



hold (notice that conditions (17) can be satisfied only if $\alpha < \beta$ and $a < b$), then there exists a unique Nash equilibrium of the 2×2 one-shot game represented by the payoff matrices (5) and (6): the mixed strategy equilibrium $(\widetilde{x}, \widetilde{y})$. The resulting strategic context is that of a *matching pennies game*. Differently from the previous regime, in this case the expert's H_E strategy (respectively, S_E) is the best reply to the policymaker's S_P (H_P) strategy. However, the policymaker's strategy H_P (respectively, S_P) is the best reply to expert's strategy H_E (S_E). According to the dynamic system (7), the internal steady state $(\widetilde{x}, \widetilde{y})$ is (Lyapunov) stable and all the trajectories are closed curves surrounding $(\widetilde{x}, \widetilde{y})$ (see Figure 4). In this case, the values of x and y oscillate counterclockwise around $(\widetilde{x}, \widetilde{y})$, for any initial distribution of strategies $(x(0), y(0))$, with $1 > x(0), y(0) > 0$.

In the *cyclic homeostatic expert regime*, it is the experts who tend to go against the current by calling for less restrictive measures when policymakers adopt the hard strategy. Instead, when the soft strategy prevails, experts tend to call for more restrictive measures. Here, the leadership style of policymaking is more conformist whereas experts compete for visibility and could find it rewarding to distinguish themselves by taking a minority position.

3.2 Ranking and selection of equilibria

In this section, we compare experts and policymakers' payoffs evaluated at the locally attractive steady states, i.e., in the *bi-stable concurrent dynamic regime* (where the attractive steady states are $(x, y) = (1, 1)$ and $(x, y) = (0, 0)$) and in the *bi-stable dissenting dynamic regime* (where the attractive steady states are $(x, y) = (1, 0)$ and $(x, y) = (0, 1)$). Moreover, following Bergstrom and Lachmann (2003), we consider the problem of equilibrium selection in a context in which experts and policymakers revise their strategy choices

at different speeds.
Remember that the *bi-stable concurrent dynamic regime* occurs if the following conditions hold:

$$\alpha > p\,(\alpha + \beta) > \beta \ \text{ and } \ 2 + b > p\,(4 + a + b) > 2 + a$$

whereas the *bi-stable dissenting dynamic regime* takes place if:

$$\beta > p\,(\alpha + \beta) > \alpha \ \text{ and } \ 2 + a > p\,(4 + a + b) > 2 + b$$

In both dynamic regimes, the basins of attraction of the attractive steady states are separated by the stable arm of the internal steady state $(\widetilde{x}, \widetilde{y})$, which is a saddle point (see Figures 1 and 2).
Let us start by analyzing the former regime. According to the payoff matrices (3) and (4), experts and policymakers' payoffs in $(x, y) = (1, 1)$ and $(x, y) = (0, 0)$ are respectively:

$$\Pi_H^E(1,1) = \Pi_H^P(1,1) = p - (1 - p)$$

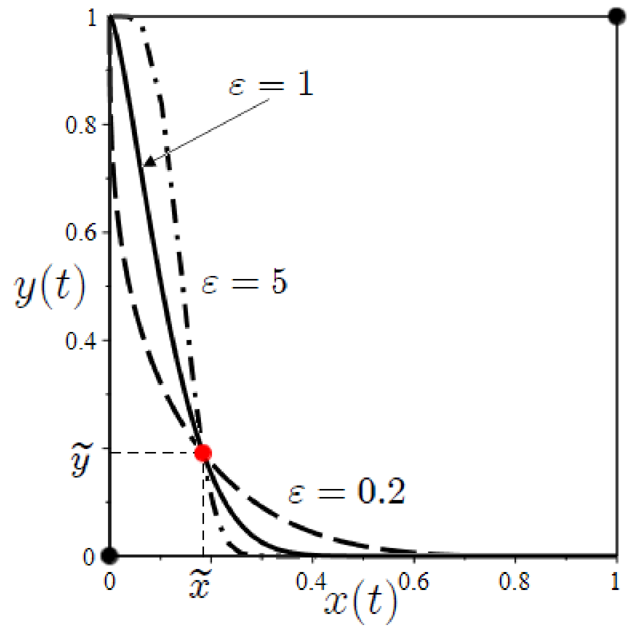
$$\Pi_S^E(0,0) = \Pi_S^P(0,0) = -p + (1 - p)$$

Notice that $\Pi_H^E = \Pi_H^P > \Pi_S^E = \Pi_S^P$ if $p > 1/2$. Since $p > 1/2$ by assumption, we have that experts and policymakers always prefer the steady state $(x, y) = (1, 1)$. However, if the initial distribution of strategies $(x(0), y(0))$ lies below the stable arm of the internal steady state $(\widetilde{x}, \widetilde{y})$ - that is, if high enough shares of experts and policymakers initially choose to adopt the S strategy (see Figure 1) - the trajectory starting from $(x(0), y(0))$ will approach the steady state $(x, y) = (0, 0)$.
In the context described above, the sizes of the basins of attraction of the two steady states play a key role, in that they determine the probabilities of convergence to each steady state, when the starting point $(x(0), y(0))$ is determined "at random". Following Bergstrom and Lachmann (2003), we show how the morphology of the basins is affected by changes in the relative speed at which experts and policymakers revise their strategy choices. More specifically, we consider the following modified replicator dynamics:

$$\begin{aligned} \dot{x} &= x(1-x)\left[\Pi_H^E(y) - \Pi_S^E(y)\right] \\ \dot{y} &= \varepsilon \cdot y(1-y)\left[\Pi_H^P(x) - \Pi_S^P(x)\right] \end{aligned} \tag{18}$$

where the parameter $\varepsilon > 0$ measures the relative speed at which policymakers revise their strategy choices. According to the dynamic system (18), policymakers revise their choices faster (slower) than experts if $\varepsilon > 1$ ($\varepsilon < 1$). As in Bergstrom and Lachmann (2003), variations in ε do not modify the steady states of the dynamic system (18) and their local stability properties, but they affect their basins of attraction.
The numerical exercise illustrated in Figure 5 shows the effects of a variation in ε. The continuous curve

Figure 5: The effect of a variation in ε in the *bi-stable concurrent dynamic regime*



represents the stable arm of $(\widetilde{x}, \widetilde{y})$ for $\varepsilon = 1$ (that is, experts and policymakers revise their strategy choices at the same speed). The dashed and the dotted–dashed curves represent the stable arm of $(\widetilde{x}, \widetilde{y})$ for $\varepsilon = 0.2$ and $\varepsilon = 5$, respectively. All these curves meet at the internal steady state $(\widetilde{x}, \widetilde{y})$. Notice that the dashed curve $(\varepsilon = 0.2)$ lies above the continuous one $(\varepsilon = 1)$ in correspondence of x–values greater than the threshold value $\widetilde{x}$ (that is, for $x > \widetilde{x}$) and below it in correspondence of x–values lower than $\widetilde{x}$ (that is, for $x < \widetilde{x}$). Vice versa, the dotted–dashed curve $(\varepsilon = 5)$ lies below the continuous curve for $x > \widetilde{x}$, and above it for $x < \widetilde{x}$.

These results imply that, if the initial share $x(0)$ of experts adopting the H_E strategy is high enough (that is, it is such that $x(0) > \widetilde{x}$), then a higher speed of reaction by policymakers increases the size of the basin of attraction of the virtuous steady state $(x, y) = (1, 1)$. That is, fixed $x(0) > \widetilde{x}$, an increase in ε leads to an expansion of the interval of initial values $y(0)$ from which the dynamic system (18) converges to $(x, y) = (1, 1)$. The opposite holds if the initial share $x(0)$ of experts adopting the H_E strategy is low enough (that is, $x(0) < \widetilde{x}$). In such a case, a lower reaction speed of policymakers favors the convergence to the virtuous steady state $(x, y) = (1, 1)$.

Let us now consider the *bi-stable dissenting dynamic regime*, where the steady states $(x, y) = (1, 0)$ and $(x, y) = (0, 1)$ are attractive. According to the payoff matrices (3) and (4), experts and policymakers' payoffs in $(x, y) = (1, 0)$ and $(x, y) = (0, 1)$ are:

$$\Pi_H^E(1, 0) = (-1 + \beta)\, p + (1 - \alpha)\, (1 - p)$$

$$\Pi_S^E(0, 1) = (1 - \alpha)\, p + (-1 + \beta)\, (1 - p)$$

$$\Pi_H^P(0,1) = (1+a)\,p - (1+b)\,(1-p)$$

$$\Pi_S^P(1,0) = -\,(1+b)\,p + (1+a)\,(1-p)$$

Notice that $\Pi_H^E(1,0) > \Pi_S^E(0,1)$ if:

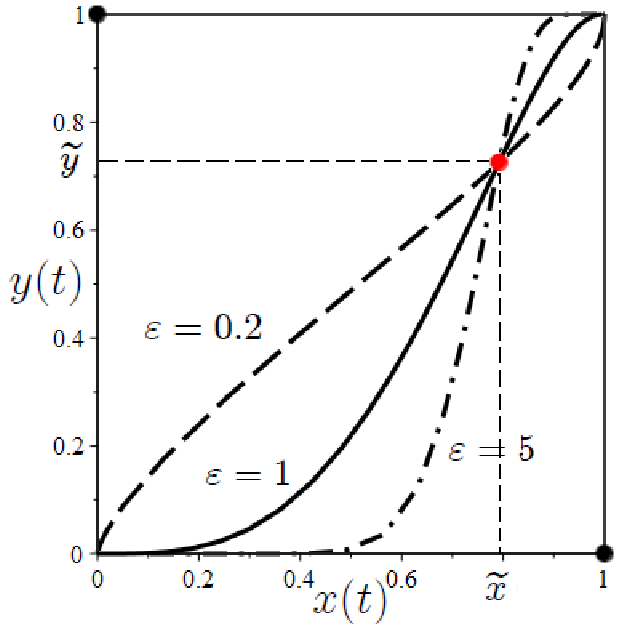
$$(2p-1)\,(\alpha+\beta-2) > 0$$

that is, if $\alpha+\beta-2>0$ (being $p>1/2$ by assumption). Therefore, if reputational payoffs are high enough (that is, $\alpha+\beta>2$), experts prefer the steady state $(x,y)=(1,0)$ –where they play H_E while policymakers play S_P– to the steady state $(x,y)=(0,1)$, where the opposite holds.
Analogously, $\Pi_H^P(1,0) < \Pi_S^P(0,1)$ if:

$$-\,(2p-1)\,(a+b+2) < 0 \tag{19}$$

Condition (19) is always satisfied since, by assumption, $p>1/2$, $a>0$, and $b>0$. This implies that policymakers always prefer the steady state $(x,y)=(0,1)$ –where they play H_P while experts play S_E.
The numerical exercise illustrated in Figure 6 shows the effects of a variation in ε. Observe that the dashed curve ($\varepsilon=0.2$) lies below the continuous one ($\varepsilon=1$) for $x>\widetilde{x}$ and above it for $x<\widetilde{x}$. Vice versa, the dotted–dashed curve ($\varepsilon=5$) lies above the continuous curve for $x>\widetilde{x}$, and below it for $x>\widetilde{x}$. These results imply that, if the initial share $x(0)$ of experts adopting the H_E strategy is high enough (that is, $x(0)>\widetilde{x}$), then a lower speed of reaction by policymakers increases the size of the basin of attraction of the steady state they prefer, $(x,y)=(0,1)$. The opposite holds if the initial share $x(0)$ of experts adopting the H_E strategy is low enough (that is, $x(0)<\widetilde{x}$). This result coincides with the one obtained by Bergstrom and Lachmann (2003) in a game with the same payoff structure that gives rise to the *bi-stable dissenting dynamic regime* in our analysis.
In general population biology terms, these results imply that the effect of changes in the evolutionary rate on the dynamics depends on the position of the starting point, i.e., the initial distribution of strategies. Slow changes may give a species a higher chance to reach more favorable equilibrium. In our framework, this result may imply that by limiting available options, a greater inertia in the choice of the strategy strengthens the bargaining power of a player. For example, a payoff structure that rewards experts' rigor and consistency of judgment as informed by the slow evolution of scientific consensus makes them less susceptible to the temptation of tactically praising scientifically ill-founded policy responses to reap short-term benefits in terms of increased popular consensus or political rewards. This constraint makes experts less susceptible to political pressures, and enhances their credibility in the policy debate about the most appropriate mitigation measures, giving them a strategic advantage in the interaction with policymakers. An institutional and socio-cultural context that safeguards academic freedom and rewards scientific reputation may make experts' incentives consistent with this scenario, creating the conditions for what Bergstrom and Lachmann (2003) call the Red King effect.

Figure 6: The effect of a variation in ε in the *bi-stable dissenting dynamic regime*



4 Discussion

4.1 Interpretation of the parameters

What explains the variation in the policy responses of similar countries and regions hit by the COVID-19 pandemic with similar timing and intensity? In this paper, we argue that the interaction between experts and policymakers plays a crucial role, with culture affecting players' behavior through its impact on the consequences of their choices in terms of reputation.

To model such phenomena, we have adopted an evolutionary game-theoretic approach based upon a simple random matching structure. The rationale behind random matching is that there is a multiplicity of experts that are potentially available to advise policymakers at various administrative levels (e.g., national, regional, urban), and in fact in different countries the response to the pandemic shock has been defined at various territorial scales depending on the specific institutional framework. The resulting social dynamics have a replicator structure, reflecting the fact that in conditions of high uncertainty following a major structural shock as in the case of the current pandemic crisis, players cannot adopt already well-tested rules of decision and conduct but tend to learn from the social imitation of relatively more rewarding behaviors. Imitation is far from a passive, unsophisticated social learning strategy and is increasingly understood as an important cognitive gadget for the rapid and effective acquisition of sophisticated knowledge and skills (Heyes, 2018), which is shaped and fine-tuned by cultural evolution (Heyes, 2020). Therefore, modeling social dynamics in a context where players face complex reputational trade-offs in an uncertain and unfamiliar environment by means of a simple imitation-driven process seems an appropriate and parsimonious choice.

To understand the implications of our results, it is useful to reflect in some detail on the meaning of the parameters. For experts, the size of α and β mainly depends on cultural factors that affect experts' reputation as a consequence of their choices. If the public tends to trust scientists, then the expert will gain prestige and popularity for having stood against the wrong choice, resulting in a higher value of β. The expert's reputation also benefits from increased respect from the scientific community to the extent to which the academia appreciates transparency, independence, and scientific rigor. The reputation effects captured by α and β also crucially depend on the public's understanding of the effectiveness of alternative strategies. If the hard approach to the outbreak turns out to be effective, low scientific literacy can paradoxically lead the public to believe, in retrospect, that strong NPIs and other unpopular measures were an overreaction. This misinterpretation could cause a reduction of the reputational reward when the expert stands for the right strategy against the policymakerâs decision - thus decreasing the level of β - or a reduction of the reputational damage when the expert chooses the wrong strategy while disagreeing with the policymaker - thus decreasing the level of α.

The experts' reward for praising a correct policy approach, or standing against a wrong one, also depends on the degree of academic freedom. In contexts where political power can affect freedom of speech in the scientific debate, experts may find it convenient to praise a wrong policy approach in support of policymakers' choices (Berggren and Bjørnskov, 2021). Overall, the value of α is likely to increase with academic freedom and colleagues' peer pressure.

If we interpret the model as a one-shot static game, the payoff matrices may vary across experts depending on individual preferences. Each expert may place a different weight on the reputation losses related to the adoption of the wrong strategy and the gains possibly stemming from support to the most effective policy response. The size of α and β may also vary based on the weight that each expert attributes to the sources of reputation effects. Experts who have less interest in academic reputation and prioritize the appreciation of the public may have the incentive to adopt the more popular strategy independently of its effectiveness. In other cases, strongly loss averse experts may consider the possible reputation losses from retrospectively wrong indications, α, much more than the reputation gains β potentially accruing from support to the best strategy in contrast to policymakers' choices. In this case, the expert may prefer to support any choice of the policymaker to minimize expected losses.[6]

Likewise for policymakers, the values of a and b basically depend on cultural factors. Behaviors that are consistent with a low value of b and a high value of a, for instance imply that, *ceteris paribus*, policymakers may find it convenient to contradict experts independently of their beliefs about the effectiveness of the policy response. This way of weighting parameters is likely encouraged by the rise of scientific populism (Mede and Schäfer, 2020), which nurtures mistrust in scientists and scholarly institutions, making anti-scientific narratives seductive exactly because they contradict the recommendations of experts.

Choosing the hard approach against the experts' advice will cause a loss of public reputation for policymakers, captured by the parameter b. Deciding for a soft action against the experts' recommendation for the hard strategy, on the other hand, will bring a gain of popularity, captured by the parameter a. Once again, the entity of these gains and losses depends on the public's ability to properly understand and assess the implications of each strategy, which in turn depends on cultural factors.

To sum up, when the reputation damage α resulting from the adoption of the wrong strategy is higher than the reputation reward β resulting from the adoption of the right strategy, experts get higher rewards from following the approach that prevails among policymakers to minimize the risk of reputation losses. In such a context, the payoff difference (8) increases if y increases. This implies that, for Experts, the relative performance of the H strategy increases when the share of Policymakers adopting H increases. The opposite holds if $\alpha - \beta < 0$. If the premium for choosing the right strategy, β, is higher than the reputation damage

[6] If α is disproportionately high and β is disproportionately low, contradicting the policymaker's choices may lead to systematically lower payoffs independently of which strategy turns out to be the most effective. For example, if the policymaker sticks to a soft policy response, "super-loss averse experts" may find it convenient to support the S strategy independently of their belief about which countermeasures may work best.

brought by a wrong choice, α, then experts get a lower reward from following the strategy preferred by policymakers.

Similarly, if $b - a > 0$ (i.e. $b > a$), the payoff difference (9) increases if x increases. This implies that, from the point of view of *policymakers*, the relative performance of the H strategy increases when the share of *experts* adopting H increases. The opposite holds if $b - a < 0$.

Matching the two perspectives, we have the following. If the reputation cost that players bear for adopting the "wrong" strategy against the "right" choice of their opponent is higher than the reward gained from supporting the most effective response ($\alpha > \beta$ for experts and $a < b$ for policymakers), then the steady states in which both populations of players adopt the same strategy $(1, 1)$ and $(0, 0)$ are locally attractive. This scenario helps make sense of the variability of policy approaches observed during the first phase of the outbreak when strong restrictive measures, such as those taken in Italy and France, coexisted with light approaches based on voluntary social distancing as in Japan and Sweden.[7] Which equilibrium prevails depends on the initial distribution of strategies, which may, in turn, be shaped by exogenous factors, also depending on the social and epidemiological context.

In terms of our model's parameters, a different scenario is that in which conditions $\alpha > \beta$ and $a > b$ hold. In this case, the reward for policymakers from choosing the "right" strategy is higher than the reputation cost of opting for the "wrong" strategy against the experts' advice. In contrast, the opposite holds for experts, as the reputation cost of adopting the less effective strategy exceeds the reward of standing for the best strategy against policymakers' decisions. The resulting dynamic is characterized by a cyclical behavior for both experts and policymakers. Consequently, there will be a recurrent return to the initial distribution of strategies at the end of each cycle. A similar cyclical dynamic may also stem from the symmetric scenario in which the experts' reward from standing for the best strategy against policymakers' decisions is higher than the reputation cost of choosing the "wrong" approach, whereas, for policymakers, the reputation cost of choosing the "wrong" strategy exceeds the gain achieved by choosing the right strategy against experts' advice ($\alpha < \beta$ and $a < b$). In this case, policymakers find it convenient to follow the experts, but the experts have an incentive to contradict policymakers systematically.

The cyclical dynamics outlined above never lead to an "agreement" between the two types of players, resulting in the perpetual oscillation of policymakers and experts' choices around non-attractive steady states. This indeterminacy reminds the seemingly erratic choice patterns observed in the current phase of the pandemic, with policymakers and experts continuously adjusting their approach to changing local conditions.

A systematic clash between experts and policymakers can also occur if, for both players, the reputation reward from standing for the right strategy is higher than the potential cost of defending the wrong strategy against their opponent's choice ($\alpha < \beta$ and $a > b$). In this case, the steady states in which the experts and policymaker dissent, $(1, 0)$ and $(0, 1)$, are locally attractive.

4.2 Interpretation of the dynamic regimes

The model dynamics allow for the selection of different Nash equilibria depending on the initial distribution of strategies (cases 1 and 2). However, they might fail to lead to a stable equilibrium, resulting in the periodic oscillation between the two policy options (cases 3 and 4). This classification of the regimes of the replicator dynamics is well known (e.g. Weibull, 1997; Hofbauer and Sigmund, 1998). However, this paper

[7]Mixed approaches entailing targeted lockdowns and aggressive contact tracing through digital technologies - such as those implemented in South Korea and Taiwan - may be classified as a "hard" strategy, given their extreme unpopularity in many countries.

adds to the literature by proposing a simple application of this framework to a timely research question, i.e., what explains the heterogeneity in the policy responses of similar countries hit by the COVID-19 pandemic with similar timing and intensity. Our analysis shows that even a very simplified model can generate a remarkable diversity in policy outcomes and that local cultural conditions play a crucial role in determining such heterogeneity. Therefore, it is important to understand, with increasing depth and precision, the role that cultural factors play in shaping policy responses to major shocks with complex social and economic implications.

Let us now consider in turn the interpretation of the model's dynamic regimes with reference to real cases.

4.2.1 Bi-stable concurrent dynamic regime

This regime is more likely to occur in countries where policymakers customarily rely on the experts' advice to decide in the public interest, while experts tend to avoid conflicts with public officials for a sense of duty and responsibility. The incentives to cooperate can lead the two types of agents to agree either on the soft strategy, such as in Sweden, or the hard strategy, as observed, for example, in Denmark and Norway (Juranek and Zoutman, 2021). These neighboring countries opted for very different pandemic countermeasures despite their virtually identical systems of government and very similar cultures (Askim and Bergström, 2021). Scandinavian societies are historically characterized by exceptional levels of social cohesion (Algan and Cahuc, 2010), trust in institutions (Kumlin and Rothstein, 2005), concern for the common good (Knack and Keefer, 1997), political accountability (Svaleryd and Vlachos, 2009), and work ethics (Hofstede, 1984) that may facilitate agreement and cooperation between experts and public officials in times of crisis.

Baekkeskov et al. (2021) provide evidence that in these countries the COVID policy response was shaped by authoritative voices that offered credible reasons for one policy option only. In Denmark, experts aligned to the view of elected leaders who pursued a hard lockdown. Instead, in Sweden, health scientists played a leading role in persuading policymakers to engage in a soft policy response based on voluntary compliance with precautionary measures (Baekkeskov et al., 2021; Bylund and Packard, 2021).

However, any juxtaposition between the dynamic regimes and the anecdotal evidence regarding pandemic policy responses across countries must be taken with caution, and claiming systematic links between the incentive configurations described in our work and specific socio-cultural contexts would be far-fetched. Incentives reflect many cultural, economic, societal, and political factors, and may vary considerably throughout the various stages of the outbreak. For example, experts have a clear incentive to align their policy recommendations to the wants of public officials in authoritarian regimes (Berggren and Bjørnskov, 2021). In addition, the legacy of past public health crises may also contribute to direct the institutional and public opinion focus toward certain strategies. For example, South Korea's policy response primarily relied on the pandemic plans prepared to respond to the SARS and MERS outbreaks, which shaped scientists and political leaders' views on the most appropriate mitigation measures to undertake to prevent the exponential growth of contagion (Park and Chung, 2021).

4.2.2 Bi-stable dissenting dynamic regime

The first two years of the pandemic have provided various anecdotal evidence of dissenting dynamics, especially regarding policymakers systematically downplaying experts' advice. Several political leaders may have found it convenient to contradict experts to gain consensus. A typical example is the propensity of former US President Donald Trump to openly dissent from scientists regarding key features of the pandemic policy response (Baccini et al., 2021; Cherry et al., 2021; Rafkin et al., 2021). This adversarial behavior may be rational in socio-cultural contexts that reward personalization politics and anti-intellectualism (Antoci et al., 2020), where unscientific narratives could sound seductive exactly because they contradict the recommendations of experts (e.g., Mede and Schäfer, 2020; Merkley and Loewen, 2021). Here, political leaders may try to boost their consensus by denying evidence and showing contempt for factual accountability, portraying themselves as the voice of the common people against scientific "elites" (McKee et al., 2021). The endorsement of scientifically controversial but over-hyped therapies seems a typical manifestation of this phenomenon. For example, political leaders repeatedly praised the use of hydroxychloroquine to mitigate COVID symptoms in Brazil and the US (Lasco, 2020; Blevins et al., 2021). In India, several exponents of the Indian People's Party demanded that preparations from cow urine and dung would be used to prevent and cure the infection (Daria and Islam, 2021).

On the other hand, experts have an incentive to stand against unscientific policy stances in countries where academic careers are indissolubly tied to scientific reputation, such as the US (Petersen et al., 2014). However, the dissenting equilibrium can also stem from a situation in which political leaders prefer a tough policy response and experts can gain popularity by standing against unpopular restrictive measures. This case is seemingly less plausible, given the high level of internationalization of the scientific community. Even in countries where a few experts gained popularity by publicly downplaying the gravity of the pandemic and inviting people not to comply with precautionary measures, such as Italy, most scientists agreed on the need to follow strict emergency rules (e.g., Farina and Lavazza, 2020).

4.2.3 Cyclic homeostatic policymaker dynamic regime

This scenario may be representative of socio-cultural contexts where policymakers have an incentive to go "against the current", i.e., to raise consensus by taking a distinctive positioning even at the cost of clashing with experts. As in the *bi-stable dissenting dynamic regime*, this adversarial behavior may be rewarding when scientific populism and anti-intellectualism bias the political debate (Mede and Schäfer, 2020; Merkley and Loewen, 2021). In this context, political leaders can exploit the contrast with scientists to gain consensus by appearing as a champion of the common people against cultural elites (McKee et al., 2021). On the other hand, experts may prefer avoiding conflicts with the political power, for example to safeguard the well-functioning of institutions for the common good or because they fear retaliation, as in the *bi-stable concurrent dynamic regime.* This combination of incentives is consistent with the behavior of political leaders oscillating between hard and soft mitigation measures in many countries and regions. For example, the *cyclic homeostatic policymaker dynamic regime* could trace the evolution of the pandemic policy response enacted in the Italian region of Veneto.[8] In February 2020, the Veneto Governor Luca Zaia distinguished himself by opting for a tough policy response that stood in stark contrast with the skepticism with which most political leaders met experts' early warnings on the virus threat. At the onset of the pandemic, the governor's advisors were rather endorsing soft mitigation measures. Instead, Zaia was inclined to adopt a tougher stance, and entrusted the head of the Department of Microbiology at the University of Padua, Andrea Crisanti, with the responsibility to design the response strategy. As a result, the regional policy response involved massive testing of asymptomatic individuals, treatment of infected patients in isolation, and the systematic tracing of their contacts (Toth, 2021). Such an approach defied the conventional wisdom of the time and the central government's guidelines, positioning Veneto as an outlier at the frontier of the policy response to the pandemic

[8] Given the high decentralization of the healthcare system in Italy, the Italian COVID policy response differed across regions (Bosa et al., 2021).

(Starr, 2020).[9] However, as the first wave of the outbreak began to decline in Veneto, Zaia ignored Crisanti's recommendation to keep up with tight distancing measures and stood again in contrast with most political leaders by shifting to an extremely soft policy response aimed to support tourism and the local economy (Toth, 2021). As Crisanti resigned from office, the new experts in charge for the crisis management agreed on a soft approach. After a few months, when Veneto was heavily struck by a second wave of the outbreak, Zaia contradicted his advisors again, asking for more restrictive measures to the national government (Starr, 2020). Although caution is mandatory in drawing general implications from a specific regional case, the *cyclic homeostatic policymaker dynamic regime* could help make sense of the cyclical oscillation between different policies, with many public administrations toggling between strict lockdown measures and lighter, voluntary restrictions, generally following the evolution of the levels of contagion with an eye to the mood of the public opinion.

4.2.4 Cyclic homeostatic expert dynamic regime

This regime could reflect a culture where the media tend to hype scientific personalities, giving experts an incentive to build themselves as media characters. This situation recalls to some extent the early pandemic policy debate in Italy, where a few experts took positions in stark contrast with most of their peers to gain media exposure and popularity. However, it would be difficult to identify a society in which scientists systematically develop an incentive structure that makes the S_E strategy (respectively, H_E) the best reply to the policymaker's H_E (S_P) strategy, with Italy making no exception. In the Italian pandemic debate, the scientific community almost entirely agreed on cautious policy stances and supported compliance with emergency measures during the most severe stages of the outbreak (Lavazza and Farina, 2020). More generally, experts do not necessarily need to go against the current to garner media attention. Instead, there is evidence that the most prominent motivations for scientists to engage in public communication and get news media visibility generally relate to commitment to the public good and deontological obligation (Besley et al., 2018).

4.3 Conclusions

The examples of different socio-cultural contexts that correspond to the various regimes should be taken as mere illustrations to fix ideas. Calibrating model parameters with reference to a specific socio-cultural context is a difficult exercise that likely requires extensive fieldwork. However, the simple model presented in this paper is able to reproduce some key features of a broad spectrum of observed policy scenarios, and with all the caveats raised above, this is of some interest. Despite that realistic scenarios in their full detail are clearly more complicated than the ones presented here, it is intriguing to realize that so many stylized facts can fit into a very simple model. This suggests that the basic underlying structure of incentives that drives experts and policymakers in their interaction might span a significant portion of the actual motivations at play. Our model could therefore serve as an useful basis to design experimental trials and possibly natural experiments to explore in a more finely grained fashion what are the single contextual and cultural factors that has determined, or is likely to determine in the future, the main features of the extant pandemic response

[9] To support such a massive testing campaign, Crisanti chose the daring strategy of ordering enough reagent to process half a million swabs in a moment in which very little cases had yet been observed, bearing the risk of being charged with public finance misdemeanor. Then, he even acquired the equipment and certifications to produce reagents on his own. As a result, when the need for massive testing finally became apparent with the escalation of cases, Veneto had a surplus of reagents while the other regions were running short (Toth, 2021). Crisanti's defiance of institutional recommendations and procedures played a fundamental role in Veneto's exceptional performance in the early phase of the COVID-19 pandemic, which stood in stark contrast with the catastrophe that hit the neighboring region of Lombardy (Starr, 2020).

strategy of a given country. And such insights could in turn be of relevance in improving our capacity of designing and testing them.

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