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A Game Theoretic Approach to Collaboration in Policy Coordination

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Abstract: Public policies are courses of action by a government in response to public problems in the real world with the aim of meeting the needs of society. Such policies must be coordinated to avoid inefficiencies. Most attempts to model public policy coordination are qualitative and, therefore, do not yield precise conclusions. More accurate modelling attempts are found in game theory, but they are not entirely appropriate as models of policy coordination, because policy coordination involves a high degree of collaboration. There is only one game-theoretic model of collaboration, and it does not model public policy coordination. The aim of this article is to show that a collaboration-based game theory model is not only feasible, but also more realistic than current game theory models of policy coordination. This was performed by adapting Newton's seminal model to a society capable of formulating and coordinating policies. When this adapted game was compared to alternative games used to explain policy coordination, it was found that the adapted game made more realistic assumptions, the modelling process was simpler, and it can be applied to a broader range of contexts. By demonstrating that the adapted model offers a feasible theoretical foundation for the modelling of policy coordination, this paper provides a starting point for future modelling efforts in this area.

Keywords: collaboration; policy coordination; public policy; evolution; mutualistic behaviour

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1. Introduction

Public policies are courses of action by a government in response to real-world public problems with the aim of satisfying the needs of society (Rinfret et al. 2018). Such problems are complex, and few real-world problems that policies try to address are so simple that a single government agency or department can adequately respond to it. Given that most problems are multidimensional and multicausal in nature, a critical mechanism for achieving the objectives of public policies is policy coordination.

Through the coordination of public policies, the specialised contributions of different agencies and departments can be integrated (Peters 2018). Coordination enables the necessary dialogue and consensus among them, which allows them to agree to act according to certain rules or goals (Ghymers 2005). Without coordination there may be a waste of resources, so coordination facilitates the exchange of resources, personnel, and knowledge among agencies (Peters 2018). Peters (2018) also indicates that the coordination of public policies makes it possible to (i) avoid or minimise duplication and overlapping of policies; (ii) reduce policy inconsistencies; (iii) ensure policy priorities and aim for cohesion and coherence among them; (iv) mitigate political and bureaucratic conflict; and (v) promote a holistic perspective that goes beyond the narrow sectoral view of policies.

Even so, as Repetto (2004) explains, coordination is not always an interactive process where everyone involved wins, but a process of seeking new equilibria in which the results tend to be "zero sum": what the person who leads the coordination wins, is usually lost by those who must transfer the goods and/or services to be coordinated and that were previously under their sectoral responsibilities. Coordination is, therefore, a complicated phenomenon that requires careful reasoning.

The preferred method of reasoning in economics is modelling (Morgan 2012), and it enables policymakers to explain past coordination failures and successes, predict the effects of current and proposed coordination efforts, and from that derive recommendations. Because of the complexity of coordination, there is a range of models that focus on it. However, the problem with most current models of policy coordination is that the vast majority of them are qualitative (Bianchi and Peters 2020; Ramírez and Peñaloza 2006; Bouckaert et al. 2010) and present only general patterns supported by narrative explanations.

Qualitative models yield imprecise predictions concerning the directions of change and are often ambiguous, especially when multiple and conflicting cause-and-effect interactions are involved. They are an initial step in reasoning about a phenomenon, but further inquiry can only lead to reliable results if such models evolve into mathematical and quantitative models (Bondavalli et al. 2009). Mathematical models add more precision to predictions of the direction and magnitude of change by discerning which variables and interactions are critical, identifying assumptions and constraints, and defining initial and boundary conditions. Through the use of equations, the consistency and completeness of the reasoning is improved, and so this makes model evaluation more rigorous and lays a sounder basis for quantification and quantitative models. According to Romer (2015), many economists acknowledge that mathematical models allow us to advance knowledge because mathematics, when "used correctly, lends precision to our scientific discourse by linking words tightly to mathematical objects and thereby forcing us to define words clearly and use them consistently". As most models of policy coordination are qualitative and not mathematical, they cannot be the basis for carrying out tests, simulations, and forecasts of variables and their behaviour in the face of different changes in policies.

There are various approaches to the quantitative modelling of policy coordination (Epstein and Axtell 1996; Earnest 2008). Policy coordination occurs in contexts where policymakers pursue different specific objectives, and this creates competition and opportunities for strategic behaviour. As a result, the most promising route to quantitative modelling lies in game theory. Game theory allows for the modelling of how agents behave and how they react to different strategies. Additionally, it can show not only why it can be difficult for people to coordinate, but also how we can achieve optimal results through better communication. The use of game theory can, therefore, lead to more accurate explanations and predictions and to recommendations that are more likely to succeed in achieving coordination (Hill and Hupe 2002).

There are many game-theoretic models of coordination, with the most common ones based on the prisoner's dilemma, but they are not completely appropriate for modelling public policy coordination. This is because public policy coordination involves a large degree of collaboration (Ghymers 2005), yet there is only one game-theoretic model of collaboration (Newton 2017), and it does not model public policy coordination. The objective of this paper is to show that a game-theoretic model based on collaboration is not only feasible but also more realistic than the current game-theoretic models of policy coordination that are based on cooperation.

2. Literature Review

In general, public policy coordination involves attempts to avoid conflicts among the decisions of different government agencies, as well as aligning such decisions and actions to produce solutions that are of mutual benefit to all (Peters 2018). Coordination can, therefore, be approached from the perspective of cooperation as a way to manage conflict (intentional or not), or from the perspective of collaboration, which is defined as a type of decision making (voluntary and peaceful) in which agents adjust their strategies for mutual benefit (Angus and Newton 2020).

The game theoretic literature on the topic frames the problem from the perspective of coordination failure as caused by conflict. Game theory models on this topic, therefore, focus on identifying and avoiding conflict in order to reduce failures. Since game theory focuses on modelling rational approaches to conflict (Rapoport 1974; Myerson 1997), it is well suited to this task.

To model public policy coordination, the game theory literature employs two kinds of games: coordination games and noncooperative games (Cooper 2005; Chen et al. 2019; McCain 2009). Researchers prefer to employ noncooperative games to model policy coordination, and when they do so, we find that they fall into two categories. Firstly, there are those associated with imbalances of incentives for cooperation (i.e., prisoner's dilemma) (Ghymers 2005; Peters 2018), and secondly, those in which personal interest overrides common interest, social conflict over the use of limited resources (i.e., tragedy of the commons) (Escaith and Paunovic 2003; Ghymers 2005; Maas et al. 2017). Within the literature that employs noncooperative games, the models focus on situations where agents have some conflict of interest. By cooperating, they may choose an action that is not optimal for them but superior for society (Ohtsuki 2018). The emerging conflict between self-interest and social welfare leads to a social dilemma (Ostrom 2000; Reyes et al. 2014), and social dilemmas are at the root of many of the complex problems in public policy coordination, such as the efficient use of limited and scarce resources (Maas et al. 2017; Ostrom et al. 2010). The literature regards the need for coordination as the phenomenon that generates conflict, because it is assumed that not all the players will be willing to work together. Desertion is regarded as one of the main causes of such conflict, and this is generated mainly by the lack of confidence in the actions that the other player will or will not carry out (Ghymers 2005; Maas et al. 2017; Ramírez and Peñaloza 2006; Tanimoto 2015). The sanction and punishment of all noncooperative behaviour and defection tendencies is the usual strategy in this type of game (Diekert 2012; Tanimoto 2015).

In contrast to the theoretical treatment of coordination, the coordination of public policy in practice is largely the result of collaboration among agencies of the state in which conflict is not necessarily the predominant element (Ramírez and Peñaloza 2006). Collaboration among decision-makers, based on consensus and collective trust, offers a way out of the problems generated by the "prisoner's dilemma" and other conflicts inherent in coordination (Ghymers 2005). This suggests that, instead of approaching coordination from the perspective of cooperation in the face of conflict, a more fruitful approach would be to look at it from the perspective of collaboration. This shifts the emphasis away from trying to reduce coordination failures towards increasing the likelihood of coordination successes.

Before considering how collaboration can be incorporated in game theory models, one should consider the evolution of thought regarding inter-agent collaboration. While conflict has been prevalent for all of human existence, modern human civilisations were made possible by an earlier evolutionary step in which individuals made a living by coordinating with others in relatively simple acts of collaborative search (Tomasello 2014). Survival of our species depended on finding ways to coordinate activities through collaboration among individuals, but one of the challenges of collaboration is coordinating decisions with others (Duguid et al. 2020). A key skill in collaborative problem solving is the communication and evaluation of proposals to reach a decision that benefits all members of the group (Melis and Tomasello 2019; Domberg et al. 2021).

Given its association with conflict, game theory has not sufficiently explored the modelling of collaboration, but more recent developments in game theory (Sandholm 2010; Tanimoto 2015) offer useful tools to do this (especially those found in population games and evolutionary games). Game theory is appropriate to model collaboration (Hill and Hupe 2002), so limited attempts have been made to explore and model collaboration. A first nonformal approximation of collaboration in evolutionary terms is found in Bacharach (2006), where he affirms that both group identification and selection are the fundamentally evolved proximal mechanisms for human collaboration. In Angus and Newton (2015), we find another attempt to model collaboration, specifically with regard to the adoption of technology. However, it was Newton (2017) who offered the first formal model of collaboration. It shows how primitive societies, when exposed to certain conditions, saw the evolutionary need to act in a collaborative way. Some of the most relevant characteristics of this model for the purpose of this paper are the formation of shared intention and mutualistic behaviour, where all participants in the game benefit from participating.

Rusch (2019) built on Newton's (2017) seminal research by showing that collaboration, as an adaptive principle of strategic choice, can be viable and successful in both finite and infinite populations, and that the potential of collaboration for evolutionary success does not require multiple encounters, a particular population structure, or specific information about past behaviour. Angus and Newton (2020) consider the impact of collaboration on coordination in which they observe the impact that mutualistic decisions by small groups can have on cooperative outcomes in structured populations when the results of pairwise interactions are determined using the prisoner's dilemma.

While Newton (2017) demonstrated that game theory is a useful way to model collaboration, it is not possible to use his model in the modelling of public policy coordination without some adaptations. Newton's model contains the basic mechanics for coordinating actions in a primitive society without sophisticated agents or hierarchical institutional structures. He models coordination in a population of individual agents, whereas to model policy coordination we need a society that is composed of m populations that, in turn, consist of groups and individuals. Such a society requires individuals that are more sophisticated than in Newton's model, since they must be able to design public policies and coordinate them. In addition, there a number of minor adaptations that need to be made, as is indicated in the next section. By demonstrating that Newton's adapted model offers a feasible theoretical foundation for the modelling of policy coordination, this paper provides the starting point for future modelling efforts in this area.

3. The Model, Game, and Analysis

3.1. Model Adaptation

The model presented below closely follows the model of Newton (2017). Therefore, all assumptions, theorems, definitions, and corollaries apply. Any adaptation will be explicitly highlighted. Newton's model will be adapted to show the role of collaboration in the coordination of public policies in a more appropriate way. If Newton's model can be adapted, this enables us to conclude whether a game theoretic approach to collaboration in policy coordination is feasible, and from that determine if it is more realistic than the current game-theoretic models of policy coordination that are based on cooperation.

We represent the communities that form our society that face collective problems by Γ, an m-player game with player set $M = \{1, \ldots, m\}$, and a strategy set S_i, $i \in M$.

Communities are formed when individuals come together to pursue common interest. Individuals can be clustered in different groups according to arbitrary clustering criteria.

Let $s_i \in S_i$ and $s = (s_1, s_2, \ldots, s_m)$ be the representative and strategy profiles, respectively, and let $S = X_{i \in M} S_i$ be the set of all strategy profiles.

Let $\pi_i(s)$ be the payoff of player i at strategy profile s. $\pi_i(.) : S \to \mathbb{R}$ payoffs represent fitness.

Let $\underline{x} := (x, \ldots, x)$ be the status quo strategy profile and a Nash equilibrium of the game.

Following Newton, we also assume that actions other than $\times$ exert (weakly) positive externalities (relative to $\times$) on other individuals, so we have the public good condition:

$$(PG)\ \forall\, i, j \in M,\ i \neq j,\ s \in S \text{ we have } \pi_j(s_i, s_{-i}) \geq \pi_j(\times, s_{-i})$$

In Newton's model there are no policies because the agents in his model do not think about the future. They are prehistoric humans whose only concern is hunting and seeking a safe haven for their clan, so they only think about the present. By introducing a collective problem that requires collective action, it becomes possible to make these agents more future oriented.

Unlike Newton's model, we assume that this society is composed of an m unit mass population of individuals, which is divided into two groups: Builders (B) and Warriors (W), with the clustering criteria being their role in society. They have lived together for a long time, and they have mutually benefited from cooperation. But they have reached a point where they face problems that neither of them can solve completely by themselves, and the only option left is to coordinate collective actions that benefit them. This model will not simulate a modern policy environment but rather create a society in which policies can emerge as a result of collaboration.

To introduce the possibility of policies we need to have a third group of agents. Within each group we can define an additional clustering criterion corresponding to a special type of agent who can not only perform previously defined roles but can also solve problems (B_{ps}, W_{ps}). Individuals (B_{ps}, W_{ps}) are more sophisticated than Newton's, which means that they have the ability to share intentions, they have a mutualistic behaviour, think strategically, and choose mixed strategies. Rusch (2019) proves that collaboration can evolve when more sophisticated agents exist.

Under the premise that there are opportunities for coalitions of players to share their interests and adjust their strategies collectively in order to obtain higher payoffs, Newton establishes the following set of collaborative opportunities under the following parameters:

Let $T \subseteq M$

$$C(T) = \left\{ s \in S : \begin{matrix} \forall\, i \in T,\ s_i \neq\ x\ \wedge\ \pi_i(s) > \pi_i(x) \\ \forall\, i \notin\ T,\ \mathrm{s}_i = x \end{matrix} \right\}$$

Bear in mind that our communities face collective problems that need to be solved by collective action. In other words, our communities need to collaborate in order to find a solution to a common problem by implementing some policy-like solutions.

In our model we need to widen that window of opportunity. In order to make the model more realistic and generate the need for policymakers, this window should be permanently open. So, unlike Newton's model, we assume that there is always the opportunity of collaborating; that is, $C(T) > 0$.

We have a set of collective problems to be solved through collaboration $\widetilde{C}(T) = \{\widetilde{s} \subseteq S,\ \forall\, i \in T\ \}$; $S = (\widetilde{s}, s)$, $\widetilde{s} \neq \varnothing$; that is, there will always be problems to solve. With the above criteria, we guarantee that there will always be an opportunity to collaborate and that there will always be collective problems to solve.

Newton established the following rules of behaviour: individuals who collaborate improve their payments with respect to the status quo, and the strategies of those individuals who do not cooperate remain fixed.

(C) (i) If for all $T \subseteq M_{PS}$, $C(T) = \varnothing$; then, $s^* = \underline{\times}$;

(ii) If there exists T $\subseteq M_{PS}$ such that $C(T) \neq \varnothing$; then, select a set of PS-type individuals, $T \subseteq M_{PS}$;

$\mathrm{C}(T) \neq \varnothing$, according to the probability measure $\mathrm{F}_{M_{PS},\Gamma}(.)$. Then, let $s^* \in C^*(T)$ be chosen according to the probability measure $G_{M_{PS},T,\Gamma}(.)$.

To ensure that no individual adjusts their strategies to reduce their own benefits, Newton established the following criteria:

(R)
If $s^* \in$ supp $G_{M_{PS},T,\Gamma}(.),\ i \notin T,\ s_i^* \neq \times,$
then, let s be unique
$s \in C(T)$
corresponding to
$s^* \in C^*(T)$
$R\ \subseteq M \backslash T,$ such that $i \in R$
and either
$\pi_j(s_R^*, \underline{\times}_{-R}) > \pi_j(\underline{\times})\ \forall\, j \in R$ or $\pi_j(s_R^*, s_{-R}) > \pi_j(s)\ \forall\, j \in R$

Newton's (2017) balance condition implies that collaborative-type individuals will find themselves in groups in which collaboration occurs much more frequently. We must bear in mind that Newton deals with individuals who do not contemplate communities.

For our case, we need to adapt Newton's (2017) balance condition as follows:

A. Extend the scope of Newton's balance condition (2017) model:
   i. A society consists of multiple communities;
   ii. Each community consists of multiple groups of individuals;
   iii. All individuals in a community share the same set of grouping criteria;
   iv. Each community has at least one problem solver (Ps) and one person who is not a problem solver (NPs);
   v. There is a "type or representative" individual, *Ps* $X_{PS}Pr_x[Z = k - 1|PS]$, and a "representative" individual, *NPs* $X_{NPS}Pr_x[Z = k|NPS]$, in each community who can represent the set of individuals of his type in that community. Those "representative" individuals, for our purposes, are called a unit of mass.

B. A society with j communities will have $2j$ units of mass (i, vi, and v);

C. A society with $2j$ units of mass will have j units of mass of type *Ps* and j units of mass NPs;

D. The proportion k (proportion of *Ps*) = $\frac{1}{2}$.

Therefore, Newton's balance condition equation can be preserved in its same form with $m = 2j \wedge k = \frac{1}{2}$ (particular case of the model), which means that the analysis of communities is a particular case of the generality presented by Newton (2017).

This results in a new balance condition (B):

$$(B)\frac{X_{PS}Pr_x[Z = k - 1|PS]}{X_{NPS}Pr_x[Z = k|NPS]} = \frac{X_{PS}Pr_x[Z = k - 1|PS]}{(1 - X_{PS})Pr_x[Z = k|NPS]} = \frac{k}{m - k}$$

The process of seeking solutions to collective problems occurs in a collaborative environment. Since collaboration is a mutualistic act, not an altruistic act (Newton 2017), our group of problem solvers adjust their strategies and improve their payoffs, as well as the payoffs of their communities (solving common problems). Additionally, it is guaranteed that those who for some reason cannot solve problems (NPs) do not adjust their strategies against themselves or their communities. The balance condition guarantees that at least $\frac{1}{2}$ of individuals are capable of solving problems in each community.

Since, a complex community is simplified as to be modelled by representative unit mass individuals, the fundamental individual structure presented by Newton (2017) is preserved. Therefore, theorem 1 in Newton (2017) is also maintained in its same form which states that if C, R, B, and PG hold, then $X_{PS} > 0$ in any evolutionary stable state. Since Newton's (2017) generality presents stability, the particular case is also in an evolutionarily stable state. So, in this society groups of problem solvers evolve into institution-like organizations dedicated to improving the quality of life of their communities by solving collective problems and implementing policy-like solutions. When they collaborate in solving collective problems, they reach an evolutionary stable state, and the society evolves.

3.2. Model Analysis

In this section, the proposed game, as adapted from Newton (2017), is compared against the alternative (noncooperative game-theoretic models of public policy coordination) in order to determine if the game proposed in this paper offers advantages over alternative games. It will be argued that this game offers advantages in three areas: (1) realism of assumptions; (2) manageability of the modelling process; and (3) versatility of the game.

While the proposed game adds assumptions compared to alternative models, such as mutualistic behaviour and bounded rationality, it eliminates the need for other assumptions, such as punishment and self-enforcing (Escaith and Paunovic 2003; Ghymers 2005). Overall then the proposed game, therefore, has a comparable level of simplicity, even while its assumptions are more realistic. As already mentioned, the assumption of conflict is implicit in noncooperative games (Axelrod and Hamilton 1984; Aumann 1959), and this makes it difficult for alternative games to explain or model collaboration in policy coordination. In practice, policy coordination involves a large degree of collaboration, which games like Prisoner's dilemma will not be able capture. In contrast, the proposed game is able to model both conflict and collaboration and so offers a more general approach to policy coordination.

By virtue of being based on evolutionary game theory, the proposed model makes more realistic assumptions about the behaviour of agents and the equilibrium. Alternative games, being based on noncooperative games, assume that agents are hyperrational, agreements need to be self-enforcing, and that there is no possibility of collective agency (Aumann 1959; Axelrod and Hamilton 1984), whereas the proposed game can accommodate bounded rationality and mutualistic behaviour by agents. It is also more dynamic, since it allows for the equilibrium, behaviour, and strategies to change over time.

Whereas the proposed game is of comparable simplicity in terms of assumptions, the modelling process is simpler than alternative games. Alternative games represent policy coordination as the interactions among individuals. For example, games based on the stochastic iterated prisoner's dilemma (Press and Dyson 2012) will have difficulty modelling policy coordination, because the number of interactions that need to be modelled will increase exponentially as the number of individuals increase and form societies. The proposed game circumvents this complexity by grouping individuals into a representative unit mass, thus significantly reducing the number of interactions that need to be modelled. This also adds to the realism of the model, since policy coordination in reality occurs not between individuals, but rather between groups.

Finally, the proposed game is more versatile because it can be applied to a wider range of contexts. Alternative games (Maas et al. 2017; Ostrom et al. 2010) can only model coordination at the level of individuals. The proposed game, however, can model coordination at different hierarchical levels—from individuals to groups of individuals, and to society as a whole. This is evident from the fact that collective problems need collective actions, and this requires collective agency at different levels of a society.

4. Conclusions

The objective of this paper was to show that a game-theoretic model of policy coordination based on collaboration is not only feasible but also more realistic than the current game-theoretic models of policy coordination that are based on cooperation. This was achieved by adapting Newton's (2017) seminal model to a society capable of policy formulation and coordination. When this adapted game was compared to alternative games used to explain policy coordination, it was found that the adapted game made more realistic assumptions, the modelling process was simpler, and it can be applied to a wider range of contexts.

The resulting model, therefore, offers a solid foundation for modelling collaboration in policy coordination. For this model to further the understanding of policy coordination, it has to be extended to include actions related to communication and enforcement. While Herrera-Medina and Riera Font (2023) has already extended this model to include aspects of communication, the incorporation of a reinforcement mechanism remains for future research.

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