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Regional public finances in Spain: a game theoretic perspective

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Regional public finances in Spain: a game theoretic perspective*

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Abstract

Recent history has shown the inherent instability in the Spanish system of regional financing. In this paper we examine issues related to moral hazard and deficit bias that may exist in it from a game-theoretic perspective. This system is a key element for the design of a fiscal framework aimed at ensuring budgetary stability, debt sustainability and transparency. The current system introduces two government levels (national and subnational) and several agents (one central government and 17 subnational governments) whose decisions mostly determine the aggregate fiscal stance of Spain. The use of game theory allows us to examine up to which extent the system is incentive-compatible, guaranteeing that agents´ interactions meet the above mentioned criteria.

Keywords: Fiscal Policy, National and Subnational Interactions, Fiscal Federalism, Game Theory, Theory of Moves, Moral Hazard, Soft Budget Constraint, Credibility.

JEL Codes: H71, H72, H77, C71, C72, C73.

1 Introduction

The Spanish system of regional finance plays a key role in the determination of the stance of the fiscal policy and it is instrumental to ensure the sustainability and stability of public finances. The system has evolved in a complex way and has been revised several times, suggesting that its design is prone to generate some instabilities. The current system introduces two government levels (national and subnational) and several agents (one central government and 17 subnational governments) that can be considered as the main players in a multi-agent decision making setting. Given this setting, we use game theory of analyze the stability of the current system and a proposed reformed system, checking to which extent it is incentive-compatible. We combine classical game-theoretic concepts (Nash equilibrium, subgame perfection) with concepts derived from modern refinements (Theory of Moves) aimed at introducing dynamic elements in the normal form of the game, rendering it more amenable for the study of repeated, recurrent interactions. At the same time, this combination makes the analysis richer and more robust.

The paper is divided in four main sections. First, we review the concept of soft budget constraint that arises in many economic contexts, including the interaction among several levels of government. Second, we analyze the current arrangement in the Spanish regional finance system. Due to its

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complexity, resulting from the interaction of many forces and some path-dependencies, we use a simplified formal model as a workable approximation. The model allows us to explore how a given combination of bilateral interactions between central and regional governments and the sequence of decisions can lead to some form of soft budget constraint, introducing moral hazard and deficit bias in the aggregate functioning of the system.

In the fourth section, we present an alternative model that simplifies the current system and is less reliant on bilateral interactions between the central government (CG) and each subnational government (SNG). This alternative ensures a pre-determined amount of redistribution and introduces a contingency fund as an additional agent. The fund is financed by the CG and the SNGs, and insures regional governments from idiosyncratic shocks and, up to a certain degree, also from common shocks. Section five concludes.

2 The problem of soft budget constraints

Most of the public spending (health, education, social services) in Spain is decided and channeled via the SNGs. However, the bulk of the tax collection is first undertaken by the CG and then distributed to the SNGs. The mismatch between the size of tax collection and expenditure responsibilities, coupled with the fact that many times the policy objectives at central and regional government do not coincide, can be a source of moral hazard. In particular, a SNG can expect to receive additional funding from the CG if need be. Following *Kornai* [1986], we say that we are in the presence of a Soft Budget Constraint (SBC) if such a situation materializes (a situation in which the CG ends up bailing out a SNG either by acting as lender of last resort or condoning its debt).

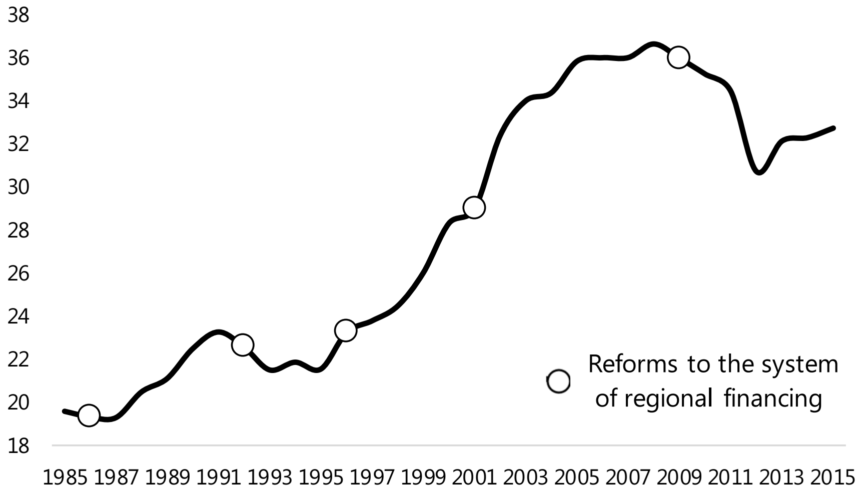
2.1 The Spanish system of regional finances

The current system of regional finance has undergone many reforms since its introduction in 1978, being the most important ones in 1986, 1992, 1996, 2001 and 2009.[1] Most of the time, a reform would be preceded by a round of bilateral negotiation between the CG and each SNG. Most of the studies dealing with the process of decentralization in Spain highlight the fact that a necessary condition to start negotiations related to a new fiscal arrangement was that no SNG would end up receiving less than in the current situation. Everything else constant, it follows that after each reform the CG government would end up decreasing its share of total revenues collected by the general government. Under the current fiscal arrangement, there are three sources of revenue for SNGs: a) regional taxes, b) shared national taxes and c) interregional funds. SNG are in charge of setting the rates and collecting the revenue from taxes on property transactions, inheritance, donations, etc. In addition, approximately half the revenue from income, added value tax (VAT), tobacco and oil tax and excise duties are collected by the CG and transferred to the SNG. Finally, a set of funds are used to cover the difference between spending needs and the revenue received via regional and national shared taxes.[2]

[1] For a comprehensive review see *León* [2015] and the references cited therein.

[2] It is important to mention that there are two regions, Basque Country and Navarre, which are not included in such a scheme. These two regions collect most of the (regional and national) taxes on their own, have a marginal participation in the funds and only transfer a fiscal quota to the CG. Unless stated otherwise, we will always refer to the "common regime" regions when talking about SNG.

Figure 1: Share of regional expenditure in general government (%)



Source: IGAE & *León* [2015] Note: ESA2010 figures as of 1995. The base 86 figures from before 1995 were linked by assuming constant the share of local entities expenditure in the general government at the 1995-1996 average.

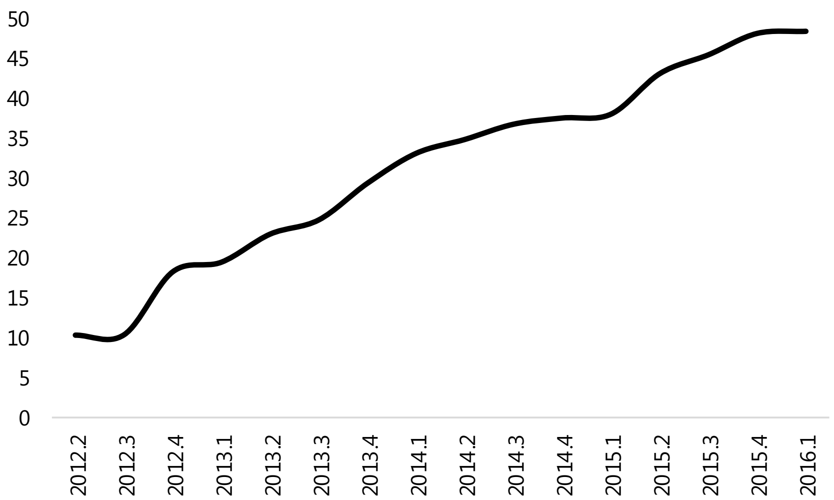
The current setup implies that the size of the funds is going to be related to the size of the spending needs. However, spending needs are estimated mainly based on previous "actual" spending. Regardless the reason behind (e.g. inherent technical difficulties in proposing objective indicators of expenditure, the lack of political will, etc) the evidence suggests that efficiency considerations have been left aside. In addition, there are no reliable indicators that could be used to measure or compare the quality of the services provided in each region. As the CG is not able to verify if a SNG is overspending or not (or whether the quality of provision is above or below a given target), when a SNG requests aid it is more difficult for the CG to behave like a hard player during a negotiation. This feature can provide the incentives to overspend, specially in a context of strong interdependencies as can be seen in figure 1.

2.2 Conditioning factors

A second attribute of the current system of regional finance which needs to be pondered due to its potential incentive problems is the large mismatch between budgeted and "adjusted" transfers. Under the current setup, transfers (i.e. shared national taxes and funds) to regions included in the budget for a given year were those forecasted two years before. For example, the fiscal transfers made by the CG related to shared national taxes and funds in 2009 would correspond to budget forecasts prepared in early 2008. In 2011 though, each SNG would have to compensate the CG if the transfers received in 2009 were above or below what was actually collected in 2009. This arrangement tries to provide to SNG a minimum degree of financial certainty and stability. However, recent experience from the last crisis signals that SNGs spent more than it what it was budgeted in 2009 and 2010, although the forecasts which were used to make the transfers ended up being too optimistic. In fact, the excess transfers were so large that many a large share of them has not been returned to the CG.

In 2012, the fiscal effects of the financial crisis were evident in the regional finances (partly due to the time mismatch between CG revenues and transfers to SNGs) with many SNGs running large deficits. As many SNGs were about to loss market access (or were facing very high rollover costs), the CG established a *de facto* bailout mechanism to provide long-term loans at very low rates under very strict conditionality. At the beginning, CG authorities stated that such a mechanism was temporary, although now its nature has change to permanent. As a matter of fact, after the creation of such a mechanism SNGs behavior showed that the CG was not able to enforce the compliance of fiscal targets, since most of the SNG were systematically underperforming. Some SNG even managed to lower rates in regional taxes or their corresponding share in national tax figures. Moreover, as can be seen in figure 2, in only four years the CG became holder of approximately half the debt issued by the SNG (and in some particular cases 70%). As it is by far the largest creditor of the SNG sector, at the current juncture it seems quite difficult for the CG to credibly eliminate expectations of a future bailout.

Figure 2: Share of regional public debt held by the central government (%)



Source: Banco de España

2.3 Salient features

Most of the literature dealing with fiscal federalism in Spain have highlighted the following problems as the main issues to deal with the current system of regional finances, see *León* [2015]. Just to mention the most important ones:

1. After all the transfers are made, the results pose serious equity and objectivity considerations.
2. Large mismatch between expenditure responsibilities and revenue capacity. Lack of correct incentives to rationalize the spending.
3. Lack of a mechanism to ensure a vertical balance (i.e. a reasonable distribution of resources among the CG and subnational governments).

As regards the issue of moral hazard and overspending, the specialized literature identify several factors that may worsen the incentives to exploit the SBC, see *Treisman* [2007]):

Overspending commitments and bailouts: According to the literature, there can be two reasons why SNG systematically run deficits larger than originally planned. First, there are not enough institutional arrangements to prevent SNG from setting (explicit or implicit) spending levels over their capacity to raise taxes (i.e. vertical imbalances). The relatively low correspondence between spending responsibilities and taxation capabilities can reinforce this issue. Second, SNG might set higher spending levels ex-ante partly due to their expectations on future aid from the CG. The latter is of particular importance if CG authorities fear substantial political and economic costs in the case of a large SNG default, in particular if there is a high probability of contagion to other regions.

Convergence of policy objectives and political costs: In many situations SNG can efficiently transfer to the central government the political costs of reducing spending (in health or education) or raising taxes. In these cases, not bailing out a SNG can be seen as most costly alternative by central authorities, who cannot really isolate from these issues, at least in the short run or specially during the electoral period. In particular, when government authorities must face elections every four years (which in turn reduces the incentives to be a hard player during bailout negotiations). In addition, the asynchronous electoral calendars at the national and sub-national level reduces even more the common planing horizon of the negotiations between SNGs and the CG.

Lack of simplicity, transparency and legal enforcement: The relatively high level of complexity and opacity inherent in the current system of regional finance can prevent a more efficient spending. In this respect, horizontal transfers aimed to guarantee a minimum provision of public services can be a worsening factor, since they are not conditioned to the compliance of accountability standards in terms of quality or efficiency. The latter can eventually raise serious equity considerations by eventually financing relatively inefficient governments (*Darby* [2002]). The case of health is a very illustrative example since there is a "basic set" of services that needs to be provided by each SNG but at the same time it is not strictly defined (the responsibilities are far from being clear in terms of waiting lists, quality of the materials used, preventive medicine policies such as the use of vaccines, etc). In fact, it is extremely difficult to compare efficiency indicators between SNGs since they are not easily accessible, which makes even more difficult to establish an optimal spending level given a defined set of services.

Free riding situations: The case in which more than one level of government or more than one SNG share the same resource (e.g. a tax base) can give raise to free riding behaviour. The experience of local governments (LGs) between 2012-2015 is a clear example of such a situation. During that period, the CG intended to follow a strong fiscal consolidation strategy. As part of this strategy it was decided to increase the property tax rate. However, LGs responded (on average) by reducing their share of the tax and neutralizing the impact of the CG measure. Similar situations of vertical overgrazing can be found at a regional level. Other interesting example are those SNG which are over-represented in the CG but contribute with relatively few taxes (*Knight*, 2003)

Asymmetric information and risk-sharing: As it is the case in corporate finance, the CG can finance relatively inefficient projects due to asymmetric information issues. Moreover, SNGs can exploit such asymmetries which can have, in the long run, a macroeconomic impact due to the lack of structural reforms. The latter is clear in the case of active labour market policies, which are funded by the CG but implemented by the SNGs under heterogeneous efficiency and supervisory standards. The problem of risk-sharing also arises in the case of unemployment benefits. As the SNGs are not responsible for funding them, their incentive in investing or undertaking institutional reforms is lower (*von Hagen*, 1998). Moreover, as these type of transfers increase in case of negative shocks, SNGs have lower incentives to invest in projects that would decrease structural unemployment (e.g. spending in education, attract the most productive workers, etc.) or in the pursue of structural reforms (*Persson and Tabellini* [1996a, b]; *Baimbridge and Whyman* [2005])

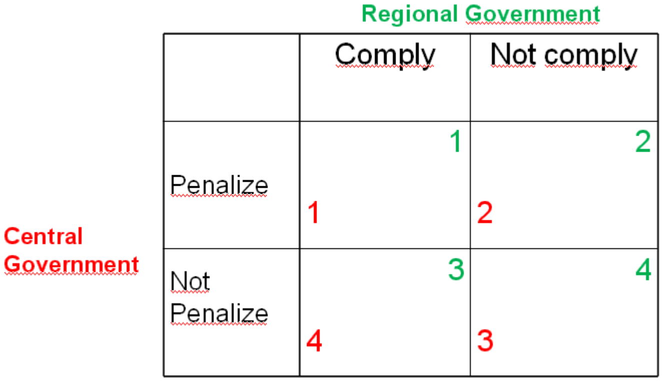
3 Regional Finance in Spain: a game model

In this section we will present a simplified formal model of the current Spanish system of regional finance. Representing in a reduced set of equations the complexities and subtleties of this system is of course a daunting task but we believe that, although much simpler, it can help providing a useful guide to shed some light about the implications for fiscal stability and fiscal sustainability. The model operates under steady-state conditions, that is, abstracting from shocks linked to the business cycle. To reinforce the steady-state analysis, all the variables are expressed on a per capita basis. Firstly, we will introduce a very stylized model to highlight some of the issues that will be explored using a more complete game model. This exploratory analysis will be carried on using the Theory of Moves (ToM), a dynamic extension of game theory. Later on, the model will be expanded and analyzed using classical game theory to check if it is stable from an incentive-compatible perspective.

3.1 A preliminary game-theoretic analysis

Just to introduce game-theoretic models to represent the interactions between the CG and the SNGs, let us consider a simple 2x2 game defined by two players (the CG and a SNG). Both players have two strategies: the SNG has to decide whether to comply or not (with a pre-defined fiscal target) and the CG has to decide whether to penalize or not (with a fine or any other kind of instrument) the SNG. The ordinal preferences of both players are represented in the following matrix of payoffs[3]:

Figure 3: Matrix of (ordinal) payoffs for the basic game



In this game both players have a dominant strategy: the SNG not to comply and the CG not to penalize. Consequently, in a static setting the determination of the (unique) Nash equilibrium is immediate and corresponds to the lower right entry of the matrix of payoffs: the SNG does not comply and the CG does not penalize. In this way, the SNG achieves its more preferred outcome and the CG its second best.

Since the interactions between the central and the SNGs evolve along the time dimension, one important question arises: does the equilibrium of the game change if we introduce a dynamic perspective? To answer this question we have used the concept of Non-Myopic Equilibria (NME) and the Theory of Moves (ToM) algorithm to identify the set of NME.

The basic idea of the ToM algorithm is that both players make moves projecting sufficiently ahead into the future and looking ahead taking into account backward induction to decide whether moving will be beneficial or not. The players consider the strategic form of the game, as opposed to the normal form, and take decisions (stay or move) alternatively, starting from the four possible outcomes of the game. Additional information about the ToM algorithm is provided in the Appendix A.

The application of the ToM algorithm to the game yields the following correspondence between initial and final outcomes[4]

Figure 4: Basic game: dynamics according to the Theory of Moves (ToM)

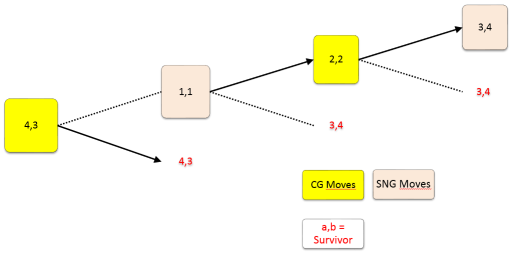
```
*********************************
***  INITIAL AND FINAL OUTCOMES ***
-----------------------------------------
  Initial            Final
-----------------------------------------
  1    1   --->    3    4
  4    3   --->    4    3
  2    2   --->    3    4
  3    4   --->    3    4
-----------------------------------------
```

[3]According to León (2009) this ordinal ranking defines a weak CG.
[4]Appendix A provides a detailed accounting of the results provided by ToM.

The ToM algorithm identifies two NME: [3,4] and [4,3]. The first one coincides with the Nash equilibrium and dominates the dynamic solution according to ToM, since it is the final outcome in all of the cases except when the game starts at [4,3]. This sort of path-dependency indicates that, if the game starts at [4,3] it will remain there, irrespective of the dominant nature of the strategies "not to penalize" and "not to comply". In this way, the CG achieves its most preferred outcome and the SNG its second best, reversing the results of the Nash equilibrium. How can this happen?

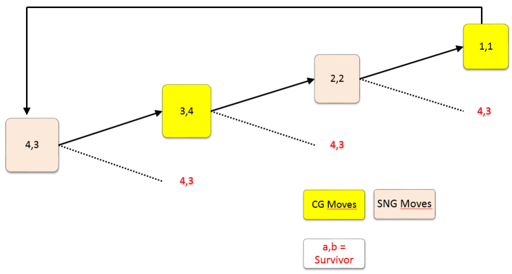
The following tree graph provides the answer, analyzing the sequence of moves and their corresponding survivor outcomes[5]:

Figure 5: Basic game: path dependency on [4,3] according to ToM. Starting player: CG



In this case it is fairly evident that the CG blocks any move, keeping it at its most preferred outcome [4,3]. Considering the SNG as the starting player, the results are depicted in the next tree graph:

Figure 6: Basic game: path dependency on [4,3] according to ToM. Starting player: SNG



This case yields the same outcome [4,3] but trough a more circuitous route. The first decision of the SNG is to move away from [4,3] in order to reach its most preferred outcome [3,4]. But this move is countered by the following sequence of moves that, initiated by the CG and using backward induction, ends at [4,3]. This sequence introduces the possibility that both players may transit for some time through their less preferred outcomes ([2,2] and [1,1]) and depends implicitly on the willingness of the CG to visit those states.

Thus, starting at [4,3], the CG can ensure it as a NME if it is the first mover or if it can credibly threat to move from [3,4] in order to achieve the result derived from the application of backward induction. In this way, credible threats come into action. Notably, this result can be achieved even when the CG is labeled as "weak". On the other hand, ToM suggests that if the initial state is not [4,3] it will never be achieved, becoming the Nash outcome [3,4] the resulting NME.

3.2 A simplified model of regional finance

Let us now formalize the previous ideas. In this model each SNG obtains funding combining their own taxes T with transfers from the CG, R. This funding covers the total expenditure of the SNG, G.

[5]According to Brams (1994), survivor is "the payoff selected at each state as the result of backward induction. It is determined by working backward, after a cycle has been completed and play returns to the initial state".

$$T_j + R_j = G_j \tag{1}$$

The budget constraint (1) can be labeled as hard since it does not consider a way to deviate from it. Own taxes are levied applying an effective tax rate τ that can vary across regions to a regional tax base Y :

$$T_j = \tau_j Y_j \tag{2}$$

The budget constraint for the CG is:

$$T_c + \Delta B = G_c + R \tag{3}$$

$$R = \sum_j R_j$$

CG's tax revenues are:

$$T_c = \tau_c Y \tag{4}$$

$$Y = \sum_j Y_j$$

In this model only the CG can issue debt. The model (1)-(4) can be solved in many ways. The solution of this system is at the core of any system of regional financing. As an approximation to the current Spanish system we will assume the following algorithm:

1. Output is exogenous at the regional level.
2. For each SNG, the effective tax rate and the level of expenditure are determined by the SNG.
3. To balance each regional budget, transfers must equate for each SNG the difference between its own taxes and its expenditure:
$$R_j = G_j - \tau_j Y_j \tag{5}$$
4. Assuming that the CG does not issue debt, the CG has to determine its effective tax rate and its level of expenditure in order to accommodate total transfers:
$$\tau Y - G_c = R = \sum_j R_j \tag{6}$$

This algorithm reflects a temporal ordering in which the SNGs move first and the CG moves second, assuming the decisions taken at the subnational level.

3.3 Game-theoretic analysis

Under plausible assumptions concerning the form of the utility function of the regional decision maker , this procedure generates a sort of overbidding behavior that reduces the CG to be the ultimate tax collector:

$$\left\{ \begin{array}{c} \tau_j \to 0 \\ G_j \to \infty \end{array} \right\} \Longrightarrow \left\{ \begin{array}{c} \tau_c \to 1 \\ G_c \to 0 \end{array} \right\} \tag{7}$$

Of course, several constraints are imposed on the algorithm to avoid (7). These constraints act like caps and floors, limiting the freedom of the SNGs in step a. The constraints can be formalized as follows. First, regional expenditure has a cap determined in practice by inherited competencies:

$$Ge_j = min(Gb_j, G_j) \tag{8}$$

Second, a common notional (or normative) effective tax rate is considered to compute the fiscal space for each SNG. This notional tax rate introduces a floor on the computation of the regional revenues:

$$\tau e_j = max(\tau^b, \tau_j) \tag{9}$$

The introduction of those constraints modify accordingly the transfers level to:

$$R_j^e = G_j^e - \tau^b Y_j \leq G_j - \tau_j Y_j \tag{10}$$

Note that (10) introduces a potential deficit whose size depends on the difference between the effective tax rate and the normative tax rate and also on the gap between the effective expenditure and the warranted expenditure:

$$\delta_j = (G_j - G_j^e) - (\tau_j - \tau_j^b)Y_j \geq 0 \tag{11}$$

To ensure a null deficit, the SNG has to set the effective tax rate and/or the level of expenditure accordingly generating a sort of "possibility frontier" (i.e. a higher expenditure requires a higher effective tax rate). As an example, if the expenditure is used as the adjustment variable, its level evolves according to:

$$G_j = G_j^b + (\tau_j - \tau^b)Y_j \tag{12}$$

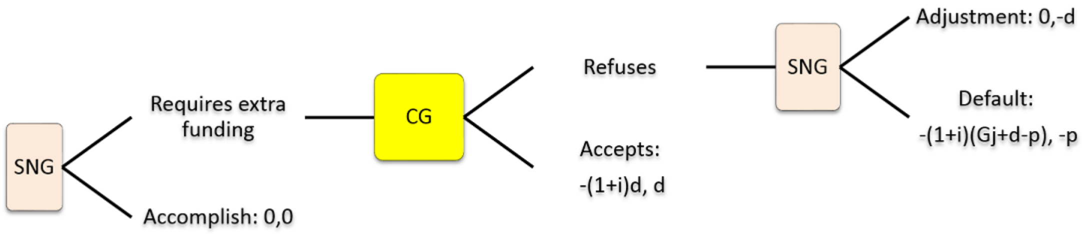
Note that, according to (12), if the SNG sets a very low effective tax rate it will have to compensate the lack of funding by means of a level of expenditure lower than the basic expenditure.

But providing a level of expenditure lower than the level guaranteed by the CG is a risky decision since it can be punished by the electorate. This risk forces the SNG to set the effective tax rate close to or in excess to the notional (or normative) tax rate. Combining both elements, the autonomy of the SNG is limited.

The constraints (8) and (9) are a stylized version of several restrictions actually implemented in the Spanish regional finance system. Are they sufficient to induce stability from a fiscal view? The answer is no.

The basic reason relies on a problem of asymmetric information. Let us assume that, ex-ante, the SNG wants to accomplish a null deficit, setting the effective tax rate and the level of expenditure accordingly. Then, an adverse shock that increases expenditure takes place. This shock requires extra funding. This situation generates a sequential game situation that can be depicted in the following decision tree:

Figure 7: Sequential game between the CG and each SNG



Note that this situation is, from the point of view of the CG, observationally equivalent to one in which the SNG has deceived, declaring ex-ante to accomplish a null deficit although it never really wanted to do so. In case of non-compliance, the CG can penalize the SNG by a fixed amount ρ. By means of backward induction we can derive the solution of the game as a function of the penalty ρ:

• If $\delta \leq \rho$ the penalty is high enough to deter the SNG to break its budget constraint.

• On the other hand, if $\delta > \rho$ the penalty does not play its role as deterrent and the budget constraint become soft.

• Finally, is $\rho=0$ we get the case considered by *León* [2009]in which the Nash equilibrium is uniquely associated with a soft budget constraint, corresponding to the so called "chain store model" described in *Selten* [1978].

In some sense, the actual regional finance system includes this type of penalties. To be effective, they have to be high enough to inflict a net cost on the SNG for not accomplishing its budget constraint and credible enough to be properly taken into account by the SNG when making its decisions.

Note that, if they are not credible, they are equivalent to deleting the penalty, that is $\rho=0$, making the model unstable in a fiscal sense since all the constraints are soft and the CG has to compensate the deviations.

How can the CG achieve credibility? There are two ways to enhance credibility, both costly in one way or another. The first one relies on generating a reputation of hard player, allowing the SNGs to default (*Sargent* [2012]). The second way introduces a third actor that surrogates the CG whenever a SNG asks for funding. This third actor may be a supranational entity (e.g. the European Commission) or a national entity (e.g. a Fiscal Council with executive powers). Note that delegation, to be effective, must be complete. Otherwise, the essence of the game remains constant and so its equilibrium. The use of an additional player plays a similar role to the use of uncontrollable decision devices in deterrence theory (*Brams* [1988]).The actual system relies greatly on the reputation of the CG as hard player and does not discriminate appropriately between true unforeseen shocks and noncompliant behaviors. For these reasons, among others, we will analyze in the next section some alternative systems.

4 Regional Finance in Spain: a revised game model

In recent years, Spanish regional finance system has been subjected to detailed scrutiny, including various proposals aimed at its reform.[6] In this section we explore one alternative system that introduces a third actor that may enhace the stability of the system.

[6]see *Cosano and Abenza* [2012], *Álvarez and Rubio* [2018], *de Economistas* [2016], *de la Fuente* [2016] and *Zabalza* [2016]

4.1 A modified system of regional finance

We will introduce some modifications to the system presented in the previous section that will enhance its stability and increase its degree of regional equalization. As we will see, the modified system is more incentive-compatible but is not a silver bullet. The first key element is the introduction of a uniform level of expenditure on a per capita basis, valued at constant prices:

$$Gc_j = p_j q \qquad \forall j \tag{13}$$

The second element is the explicit guarantee that this expenditure will be finance by the CG through transfers:

$$R_j = Gc_j \qquad \forall j \tag{14}$$

The combination of (13) and (14) ensures a maximum level of regional equalization and the sufficiency of its financing, taken into account observable differences in their cost of provision. The Achilles heel of the system rests on the determination of the common expenditure level q and its monitoring on an ongoing basis. Let us postpone for the moment those important issues and continue with the revised system.

Each SNG has the option to increase, but never decrease, the basic level of expenditure using their own tax revenues, determining the combination of taxes and discretionary expenditure according only to their own preferences:

$$Gd_j = T_j = \tau_j Y_j \qquad \forall j \tag{15}$$

We will introduce an additional player that consists of a contingency fund, financed by all the SNGs and the CG . This fund acts as the first stance in case of trouble. Note that the relevant budget constraint for the SNG becomes:

$$T_j + f_j = Gd_j \qquad \forall j \tag{16}$$

The dynamics of the fund are described according to:

$$F = (1+i)F_{-1} + \sum_j f_j \qquad \forall j \tag{17}$$

The budget constraint for the CG is:

$$T_c + \triangle B = G_c + R + f_c \tag{18}$$

$$R = \sum_j R_j \tag{19}$$

CG's tax revenues are:

$$T_c = \tau_c Y \tag{20}$$

$$Y = \sum_j Y_j$$

Again, in this revised model only the CG can issue debt.

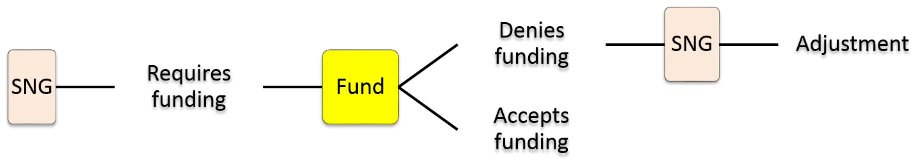
4.2 A modified system: a game theoretic analysis

Let us now analyze the revised model under the lens of game theory. Under steady-state conditions (i.e. absence of shocks) the structure of the model prevents the type of overgrazing that arises in the previous model and that required the introduction of additional stabilizing clauses like (8) and (9).

Let us assume that the SNG j deviates from its budget constraint by an amount δ. This deviation may be the result of an adverse shock that reduces the tax revenues or by a deliberate increase in the discretionary expenditure. Although the final result is the same, a budget deficit, the origin is completely different and the likely response of the remaining players is likely to be also different.

The next figure depicts the structure of the ensuing game.

Figure 8: Revised system: Game tree under idiosyncratic shocks



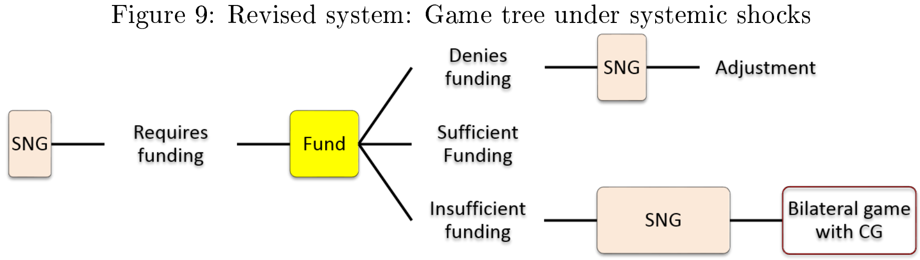
First of all, note that the presence of the new player (the Fund) is a game changer because it makes redundant the presence of the CG. The critical node of the game is the Fund's decision.

Assuming perfect information, the players can discriminate between a deficit generated by an unforeseen adverse shock or by a deliberate decision to increase spending. In the latter case, the Fund will deny funding. To ensure stability and to avoid pushing the players back to square one (the SNG and the CG playing the game depicted in figure 7) the next step must be automatic: the SNG has to adjust its budget by the usual combination of increased taxation and reduced spending. Note that now the culprit of the deficit can be clearly stated, providing an automatic reason to the Fund to deny the extra funding. Otherwise, the modified system is not stable: the SNG will deliberately overspend, will ask for funding and, when denied, will enter in the bilateral game knowing in advance the result: the CG financing its funding requirements.

When the deficit is due to an adverse shock, the Fund provides funding and automatically eliminates the need to interact with the CG.

The ideal conditions for the system to work are similar to those on an insurance: transitory and idiosyncratic shocks. Otherwise they will eventually exhaust the Fund, forcing again the SNGs to interact with the CG in the same way as depicted in figure 7. The corresponding extensive form of the game is depicted in figure 9.

Figure 9: Revised system: Game tree under systemic shocks



The original game emerges again but with a lower probability than under the current system and under stressed circumstances that strengthen the bargaining power of the CG. Those stressed circumstances arise as the result of the systemic nature of the shocks that reduce the fiscal space of the CG .

5 Conclusions

Regional finance systems are evaluated according to several criteria: sufficiency, regional equalization, regional autonomy and sustainability. The proposed revision of the current system is sufficient on the steady-state (i.e., absence of shocks), under idiosyncratic shocks and, to a lower extent, under systemic shocks. At the same time, it ensures regional equalization in a high degree since any citizen will receive the same minimum amount of public service irrespective of the territory in which she is demanding the service. Regional autonomy is also preserved, granting each SNG the right to increase its level of spending on a steady-state basis but always constrained to a sufficiency condition. Finally, the system is sustainable because the introduction of the fund as an additional player internalizes the individual decisions of each subnational government and ensures an adequate hedging against unfavorable riks.

The common level of per capita expenditure q poses a serious challenge for the revised model. First, its initial determination requires an agreement between all the players of the game. This agreement may be difficult to achieve and its absence precludes the complete system. Second, monitoring q requires that all the players (including the fund) can observe it without error. This requirement tries to avoid possible informational asymmetries that may induce each SNG to inflate it. With the modern systems of cost accounting and the computerization of audit procedures this monitoring seems feasible.

6 Appendix A: Theory of Moves (ToM)

The Theory of Moves (ToM) combines both forms of game modeling: the normal form and the extensive form. The normal form, usually represented in matrix form, is used for the strategic, simultaneous analysis of game models. On the other hand, the extensive form, usually represented as a graph (decision tree), is used for the sequential, dynamic analysis of game models.

The combination of both forms enriches notably the analysis of game models, introducing dynamic elements (extensive form) in an otherwise static representation (normal form) in a simple and intuitive way. In this way, ToM can cope with path-dependencies, misperception, asymmetric power, and other advanced modeling features without requiring the introduction of probabilistic elements (e.g. including Nature as a third player).[7]

The basic idea of ToM is that both players make moves projecting sufficiently ahead into the future but assuming that cycles should be avoided in order to avoid blocking the game. To make his decision, the player looks ahead and uses backward induction to decide whether moving will be beneficial or not.

ToM players alternate in making moves: preserve current decision (stay or pass) or switch decision (move). They think ahead not just to the immediate consequences of making moves but also to the consequences of counter-moves, counter counter-moves, and so on.

Basic ToM modeling assumes 2x2 ordinal games with complete information about the payoffs structure and the rules of the game. So, the basic input of ToM is 2x2 bi-matrix that reflect the ordinal preferences of the players over the four possible outcomes derived from the implementation of their two fundamental strategies.

To find the Non-Myopic Equilibria (NME) of the game, ToM considers six rules. Rules 1 to 4 define the evolution of the game according to ToM and rules 5 to 6 define the optimality conditions that ensure that the outcome defines a point of rest (equilibrium).

- Rule 1: The game starts at a given outcome, i.e. a fixed element of the bi-matrix of (ordinal) payoffs.
- Rule 2: Either player can unilaterally switch his strategy (i.e. make a move). The player who switches is called player 1 (P1).

[7] See *Brams* [1993, 1994] for a detailed exposition of ToM and Willson (1998) for an extension of its basic framework.

- Rule 3: The other player, player 2 (P2), responds by unilaterally switching his strategy, thereby moving the game to a new state.
- Rule 4: The alternating responses continue until the player (P1 or P2) whose turn it is to move next chooses not to switch his strategy. When this happens, the game terminates in a final state, which is the outcome of the game.

Note that rules 2 and 3 imply a sequential implementation of ToM and that the payoffs are accrued only at the final outcome. Note also that the rule 1 is a simple yet effective way to introduce path-dependencies in game-theoretic analysis.

The next two rules implements rationality (optimization) in the search for NME:

- Rule 5: Termination rule: If the players return to the initial state, the initial state becomes the final outcome.
- Rule 6: Two-sidedness rule: Each player takes into account the consequences of the other player's rational choices, in deciding whether or not to move from the initial state or any subsequent state. Each player uses backward induction to decide if it is in his best interest to move or not. If it is rational for one player to move and the other player not to move, then the player who moves overrides the player who stays.

The application of the six rules of ToM to all the possible initial outcomes, controlling also for the starting player, generates a set of NME. An indeterminacy may arise when both players want to move but differ in their preferred final outcome. In this case, additional information is required to solve the game (e.g. moving precedence, asymmetric power, etc.).

To apply ToM we have developed a MATLAB Calculator (*Quilis* [2016]). In this way, we can easily explore the strategic landscape through the lens provided by ToM as well as the sensitivity of the results to different payoff structures. The ToM Calculator determines the set of NME and possible indeterminacies; the initial and final outcomes and a detailed analysis of each one of the four possible cases, considering both players as starting players. The ToM Calculator presents the sequence of moves with their corresponding survivors and the stage at which stoppage occurs. The global results of its application to the game interaction described in section 3 are:

Figure 10: Analysis of the basic game between CG and SNG using ToM: Summary

```
*************************************************************
 *** THEORY OF MOVES CALCULATOR ***
*************************************************************
Game -> CENTRAL &  REGIONAL GOVERNMENTS
*************************************************************
 Player 1: Payoff matrix (ordinal preferences):
     1      2
     4      3
----------------------------------------------------------------------
 Player 2: Payoff matrix (ordinal preferences):
     1      2
     3      4
*************************************************************
*** NON-MYOPIC EQUILIBRIA ***
    0     0
    1     1
*************************************************************
***  INITIAL AND FINAL OUTCOMES ***
***  Note: -9 => Indeterminacy.
----------------------------------------------------------------------
   1     1   --->      3     4
   4     3   --->      4     3
   2     2   --->      3     4
   3     4   --->      3     4
----------------------------------------------------------------------
```

The detailed analysis of the game starting at [4,3] is:

Figure 11: Analysis of the basic game between CG and SNG using ToM: Analysis from [4,3] onwards

```
-------------------------------------------------------------------------------
***  POTENTIAL MOVES AND SURVIVORS FROM BACKWARD INDUCTION ***
***  Note: First row = CG; second row = SNG
-------------------------------------------------------------------------------
 Initial outcome ->    4     3
 Starting player ->    CG
 Stage ->         1     2     3     4     5
-------------------------------------------------------------------------------
 Potential moves:
                  4     1     2     3     4
                  3     1     2     4     3
-------------------------------------------------------------------------------
 Survivors:
                  4     3     3     3     0
                  3     4     4     4     0
-------------------------------------------------------------------------------
 Stoppage:
                  1     0     0     0     0
-------------------------------------------------------------------------------
 Starting player ->    SNG
 Stage ->         1     2     3     4     5
-------------------------------------------------------------------------------
 Potential moves:
                  4     3     2     1     4
                  3     4     2     1     3
-------------------------------------------------------------------------------
 Survivors:
                  4     4     4     4     0
                  3     3     3     3     0
-------------------------------------------------------------------------------
 Stoppage:
                  1     0     0     0     0
-------------------------------------------------------------------------------
```

To save space, the remaining analysis of the game starting at [1,1], [2,2] and [3,4] are skipped although they are available on request.

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