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A Game-Theoretic Analysis of the Spanish System of Regional Finance

Abstract

Recent history has shown the inherent instability in the Spanish system of regional finance. This system is a key element for the design of a fiscal framework aimed at ensuring budgetary stability, debt sustainability and transparency. In this paper we examine issues related to moral hazard and deficit bias from a game-theoretic perspective. We combine classical concepts from game theory (Nash equilibrium, subgame perfection) with concepts derived from modern refinements (Theory of Moves) aimed at introducing dynamic elements in the normal-form game, rendering it more suitable for the study of repeated, recurrent interactions.

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Summary

1 Introduction

The Spanish System of Regional Finance (SRF onwards) plays a key role in the determination of the fiscal policy stance and it is instrumental to ensure the sustainability and stability of public finances. Since its inception in 1978, the system was revised several times and became more complex. Some authors suggest that the frequency of its revisions points out towards the existence of an unstable design[1]. The system currently set in place consists of two government levels (national and subnational) and several agents (one central government, CG, and 17 subnational governments, SNGs) that can be considered as the main players in a multi-agent decision making setting. Given this setting, we use game theory to analyze the stability of the current 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 game, rendering it more suitable for the study of repeated, recurrent interactions. At the same time, this combination provides us with a richer and more robust analysis.

The paper is organized as follows. First, we review the concept of soft budget constraint (SBC), which arises in many economic contexts, including the interaction among several levels of government. Second, we introduce a simplified game model of the Spanish SRF. The subgame perfect equilibrium of this model serves to analyze the role of deficits, non-compliance penalties, interest rate spreads as well as the overall likelihood of the SBC. The model shows how the bilateral interactions between central and regional governments in a sequence of decisions can lead to a form of SBC, thus introducing moral hazard and a deficit bias in the functioning of the system.

In the third section, we use the Theory of Moves (ToM) to introduce explicitly a dynamic dimension in the game and check the robustness of the results.[2] ToM is a powerful technique that highlights the role of path-dependencies and the influence that long-term

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[1] León and Aja (2015) and Monasterio (2016) provide a detailed historical perspective of the Spanish system of regional finance.

[2] Three technical appendices explain ToM basic elements (Appendix A), the detailed output from the computer programs used to apply ToM (Appendix B) and the concept of rational threat used in the paper (Appendix C).

considerations may have in the equilibrium of the game. Specifically, the analysis of the game through the lens of ToM provides a complete study of the role of the CG's preferences, especially the so-called issue of a "weak" vs a "hard" CG. In section four we explore this issue more deeply in the context of a repeated game, exploring the role of rational threats made by the CG. The concepts of sufficiency, fiscal co-responsibility and the role of transfers are considered in section five, linking both concepts to the dynamic analysis of the compliant equilibrium of the game. Section six concludes.

2 Moral Hazard in Regional Finance: The Soft Budget Constraint

Public spending in health, education and social services in Spain is a competence of SNGs. However, the bulk of tax revenue is collected by the CG and only then transferred to SNGs, which autonomously decide how to allocate the funds to the different spending items. The mismatch between tax and expenditure responsibilities, coupled with the fact that the policy objectives of central and regional governments do not necessarily coincide, can be a source of moral hazard. In particular, a SNG whose expenditure exceeds the agreed financing can expect to receive additional funding from the CG. 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 assuming its debt).

2.1 The Spanish System of Regional Finance (SRF)

The current SRF has undergone many reforms since its introduction in 1978, the most important of which were agreed in 1986, 1992, 1996, 2001 and 2009.[3]

In practice, a reform is preceded by a round of bilateral negotiations 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

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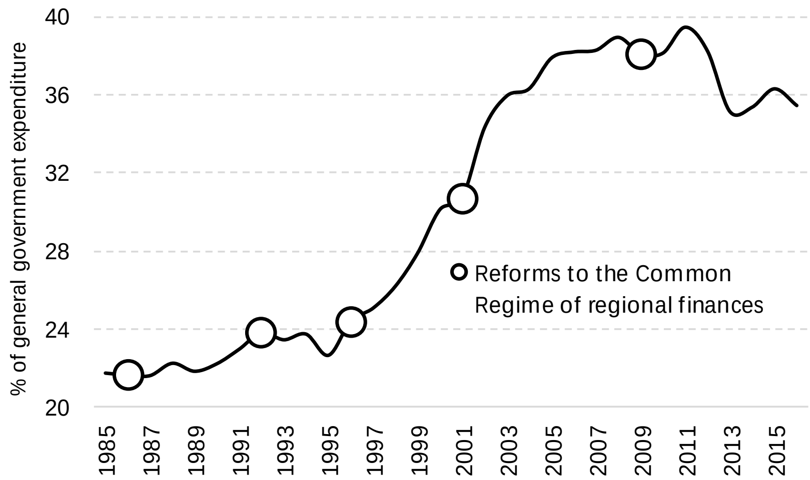
[3] For a comprehensive review of the system see León and Aja (2015), de la Fuente (2015, 2016), Hernández de Cos and Pérez (2015), Lago et al. (2015, 2017), Colegio de Economistas (2016), Bandrés and Cuenca (2016), de la Fuente et al. (2016), Delgado, et al. (2016), Delgado and Pérez (2016), Zabalza (2016), and the references cited therein.

arrangement was that no SNG would end up receiving less fiscal resources than before. Everything else constant, it follows that after each reform the CG would decrease its share in general government revenues. Under the current fiscal arrangement, there are three sources of revenue for SNGs: a) regional taxes, b) shared national taxes and c) interregional funds. SNGs are in charge of setting the rates and collecting the revenue from taxes on property transactions, inheritance, donations, etc. In addition, approximately half of the revenue from income tax[4], 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 special funds are used to cover the difference between SNGs spending needs and revenue received via regional and national shared taxes.

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



Source: IGAE and León and Aja (2015). Note: ESA2010 figures as of 1995. The base 1986 figures from before 1995 were linked by assuming constant the share of local entities expenditure in the general government at the 1995-1996 average.

In the current setup, the funds transferred to each SNG are related to its spending needs. However, spending needs are estimated mainly on the basis of previous "actual" spending. Whatever the underlying reasons (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

[4] In addition, SNGs can set some elements of the income tax, so it can be considered a mixture of shared revenues and own taxes.

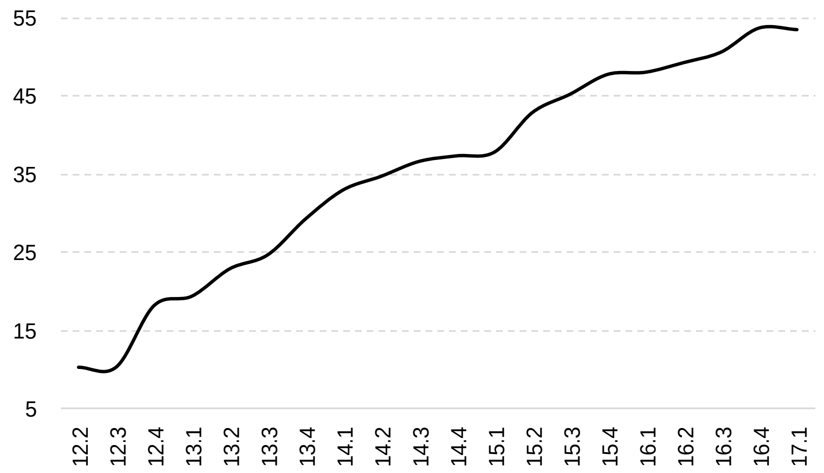
reliable indicators that could be used to measure or compare the quality of the services provided in each region. As the CG is not able to verify precisely the origin of a SNG overspending (or whether the quality of provision is above or below a given target), when a SNG requests additional financing it is more difficult for the CG to behave like a hard player in a negotiation. This feature can provide the incentives to overspend, especially in a context of strong interdependencies as can be seen in figure 1.

2.2 Conditioning factors

A second characteristic of the current SRF which needs to be pondered due to its potential incentive problems is the large mismatch between ex-ante budgeted and ex-post “adjusted” transfers. Every year at the beginning of the budgetary process, the CG communicates to SNGs next year´s amount of transfers they will receive, estimated with beginning of the year information, about expected tax revenues to be collected from the different national taxes that are shared and the size of the funds to distribute. Although this arrangement aims at providing SNGs with a minimum degree of financial certainty, a problem arises when there is a large divergence between ex-ante budgeted transfers and ex-post final amounts depending on actual revenue collected, since SNGs might be obliged to reimburse the CG afterwards. As an illustration, the amounts effectively transferred from the CG to the SNGs in 2009, when the economy was experiencing a full-blown recession and CG tax collection was plummeting, were associated to budget forecasts prepared in early 2008, when the economy was still growing and tax collection had not started to decrease so dramatically. Thus, SNGs received far more resources than what it was effectively collected by the CG. In 2010 and 2011 though, each SNG had compensate the CG for the excess transfers received in 2009. However, recent experience from the last crisis signals that SNGs spent more than what it was budgeted in 2009 and 2010, since the forecasts on which the transfers were based proved too optimistic. In fact, the excess transfers were so large that many of them have not been returned to the CG.

In 2012, the fiscal effects of the financial crisis became evident in the SNGs, with many of them running large deficits (partly due to the time mismatch between CG revenues and transfers to SNGs). As many SNGs were about to lose 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 (at least in theory) very strict conditionality. At the beginning, CG authorities stated that such a mechanism was temporary, although now its nature has changed. As a matter of fact, after the creation of such a mechanism, SNGs behavior effectively showed that the CG was not able to enforce the compliance of fiscal targets, since most of the SNGs were systematically underperforming. Some SNGs even managed to lower rates in regional taxes or increase their corresponding share in national tax figures. Moreover, as can be seen in figure 2, in only four years the CG took over approximately half of the debt issued by the SNG (and in some cases almost 80%). As the CG is at present the largest creditor by far of the SNG sector, it seems quite difficult for the CG to credibly eliminate expectations of a future debt relief.

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



Source: Bank of Spain.

2.3 Salient features

Most of the literature dealing with fiscal federalism in Spain agrees on the main issues to deal with the current SRF, see León and Aja (2015). Just to mention the most important problems:

- After all the financing sources are taken into account, the results pose serious doubts on the equity and objectivity of the allocation of funds.
- Large mismatch between expenditure responsibilities and revenue rising capacity of SNGs, which do not have enough incentives to rationalize the spending.

- Lack of a mechanism to agree on a vertical balance with a reasonable distribution of resources between the CG and the SNGs.

As regards the issue of moral hazard and overspending, the specialized literature identifies several factors that may worsen the incentives to exploit the SBC, see Treisman (2007).

Overspending commitments and bailouts: There can be two reasons why SNG systematically runs 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 a most costly alternative by central authorities, who cannot really isolate from these issues, at least in the short run or especially 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 reduce even more the common planning 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 SRF 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, see Darby et al. (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 available, 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 SNGs shares the same resource (e.g. a tax base) can give raise to free riding behavior. The experience of local governments (LGs) with property tax rates between 2012-2015 is a clear example of such a situation. In Spain, property tax rates are shared between the CG and LCs. 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, effectively neutralizing the impact of the CG measure. Similar situations of vertical overgrazing can be found at a regional level. Another interesting example is the case in which some SNGs are over-represented in the CG but contribute with relatively few taxes, see Knight, (2003).

Asymmetric information and risk-sharing: The CG can finance relatively inefficient projects due to asymmetric information issues. Moreover, SNGs may exploit such asymmetries which can have, in the long run, a macroeconomic impact due to structural effects. The latter was clear during the last crisis for the case of active labor market policies, which were funded by the CG but implemented by the SNGs under heterogeneous efficiency and supervisory standards, see Cueto and Suárez (2014). 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, mainly through regulation, 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, see Persson and Tabellini (1996a, 1996b) and Baimbridge and Whyman (2005).

3 A Game-Theoretic Model

In this section, we present a simplified formal model of the current Spanish SRF. Although it disregards many of its complexities and subtleties, it clarifies its implications for fiscal stability and sustainability. The model assumes steady-state conditions, thus ignoring shocks linked to business cycles. All variables are expressed on a per capita basis. Firstly, we will introduce the relevant budget constraints for the SNGs and the CG. Then we will explore, by means of a game-theoretic model, the incentive structure of the players and the corresponding outcomes. In particular, we will analyze under which conditions we can find a SBC.

In a nutshell, the SRF can be represented by a set of budget constraints for the SNGs and the CG:

$$\begin{aligned} & T_j + R_j = G_j \\ & T_c + \Delta B = G_c + R + iB_{-1} \qquad R = \sum_j R_j \end{aligned} \qquad [1]$$

Being:

- T=Taxes.
- R=Transfers.
- G=Expenditure.
- B=Debt issued by the CG.
- i=Interest rate paid for the CG.
- SNGs: $j=1..N$, c: CG

The deficit composition, according to [1], is:

$$D = \underbrace{(G_c - T_c)}_{\delta_c} + \sum_j \underbrace{(G_j - T_j)}_{\delta_j} + iB_{-1} = \delta_c + \sum_j \delta_j + iB_{-1} \qquad [2]$$

Being:

- δ_c=Primary deficit of the CG.
- δ_j=Primary deficit of the j-th SNG.

Absent any changes in the fiscal structure (taxes and expenditures) at the subnational and ntral levels, debt dynamics are solely driven by the combination of the subnational and central primary deficits plus the interest burden:

$$D = \Delta B \quad [3]$$

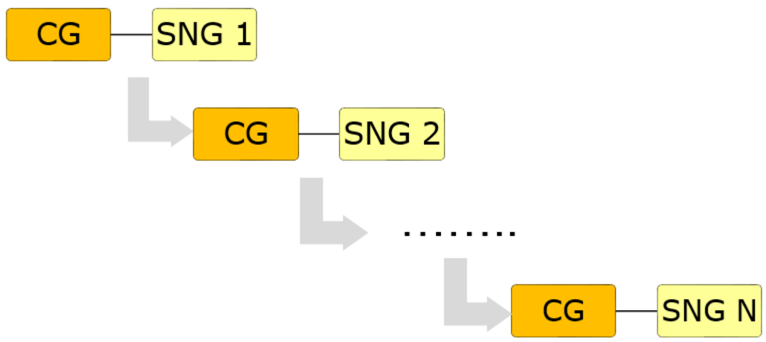
Note that in this model only the CG can issue debt, although it has to finance the deficits of both the CG and the SNGs. In this way, we will consider that the consequence of the SBC (systematic deviation of the SNGs of their budget constraint) is shouldered by the CG, which has to finance the gap through debt issuance.

In the limit, absent any changes in the fiscal structure and if the CG does not run an equivalent compensating fiscal surplus, public finances may become unsustainable, due to the snowball effect introduced by the interest burden. For the moment, we will assume that the CG's debt is sustainable. We will return to this topic later when we will consider a "hard" CG.

Under what circumstances can SNGs "soften" their budget constraints? Why do not force SNGs to compensate past deficits with future surpluses? We will introduce a game model to answer this question.

The model formalizes the interactions between the CG and the SNGs as a sequence of bilateral interactions. This sequence reflects a logical ordering rather than a temporal ordering, emphasizing the bilateral nature of the interactions although they can take place at the same moment in time. The predominance of the bilateral interactions is a well-documented feature of the Spanish SRF, see León (2009) and León and Aja (2015), among others.

Figure 3: Sequential game between the CG and the SNGs



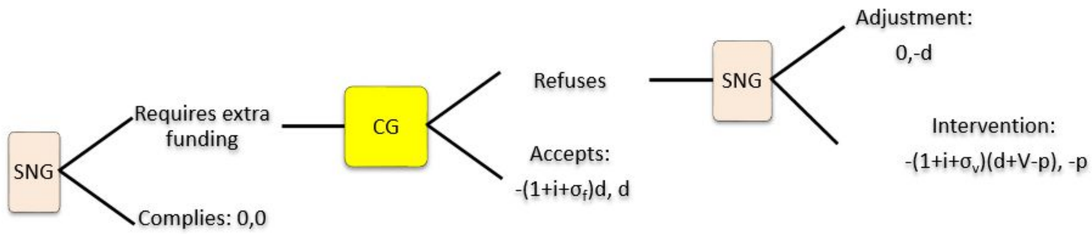
For the sake of simplicity, we will assume a symmetric structure: all the SNGs are equivalent. Hence, the ordering of them in the sequence does not matter.

The game is solved by backward induction. We determine the solution of the Nth game and, considering this solution as a fixed element, we repeat the process for the (N-1)th game, fix the corresponding solution and so on until the first game is solved.

The Nth game has also a sequential nature and has three stages. The incumbent SNG moves first, then the CG reacts and the last move is made by the SNG, ending the game. The game starts when the SNG departs from its budget constraint by an amount d and faces two possible moves: it requires additional funding by the CG or it complies with its budget constraint, implementing the changes in taxes and expenditure necessary to rebalance its budget.

In the next move the CG can accept or reject the request for extra funding. Finally, if the CG rejects the extra funding, the SNG can make the necessary adjustments to rebalance the budget or can stand firm, thus triggering the intervention of the CG taking over its finances. The next figure depicts the game using a decision tree format:

Figure 4: Bilateral game between the CG and each SNG



Being:

- d=SNG's deficit.
- p=Penalty applied by the CG to the SNG, $p \geq 0$.
- i=Interest rate paid by the CG.
- σ_f=Spread if additional funding is provided.
- σ_v=Spread if intervention is carried out σv>σf.
- V=Cost of intervention.
- $[a,b]$=[Payoff to CG, Payoff to SNG].

Some clarifying remarks: It is assumed that investors perceive that when the CG must provide additional funding to the SNG there is some sort of disruption and hence require an additional compensation σ_f. A fortiori, the spread is higher under the intervention scenario, which may be considered an emergency situation, than in the case of granting additional funding: $\sigma_v > \sigma_f$. The CG can impose a penalty p to the SNG if the intervention is carried out. Finally, the CG faces a fixed cost V when dealing with an intervention. If it is deemed as necessary, both p and V may include a monetary valuation of reputational costs.

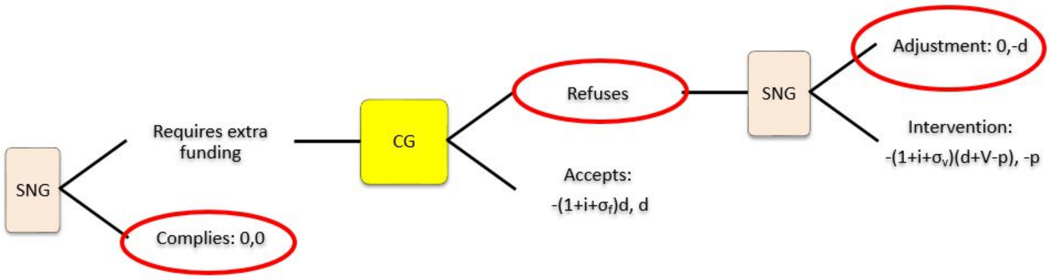
The model extends the one proposed by León (2009), introducing asymmetric financial costs, fixed costs for the intervention and a penalty. Both models are based on the well-known chain-store model proposed by Selten (1978), which is widely used as workhorse for the analysis of reputation and credibility under game-perfectness.[5] The model is solved by backward induction, ensuring a subgame-perfect solution. Starting at the last node, the SNG chooses adjustment or intervention. In the middle node and conditioned on the decision taken by the SNG, the CG rejects or accepts the request made by the SNG for extra funding. Finally, in the initial node, the SNG solves for the complete sequence, taken as fixed elements the decisions made by the CG and by itself in the last node. Two solutions arise depending on the relative sizes of the penalty and the deficit. Let us analyze them separately.

- Case A: p>d.

[5] See Gibbons (1992) or Rasmusen (2006) for a detailed exposition of sequential games.

The next figure shows the subgame perfect solution, circled in red. In this case, the penalty is high enough to deter the SNG from deviating from a balanced budget and the SBC does not arise.

Figure 5: Solution of the game when p>d

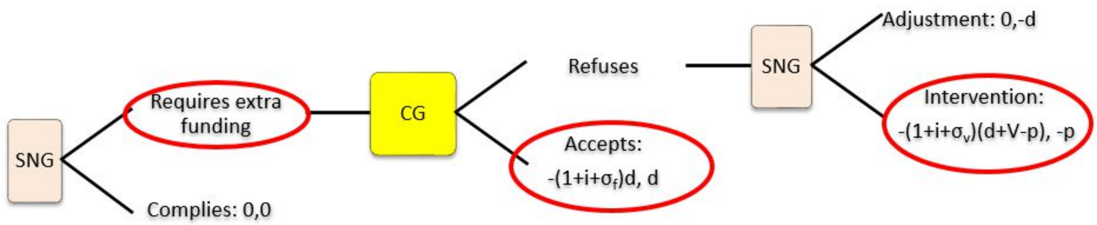


In the final node the SNG compares the payoff linked to the adjustment with the payoff linked to the intervention. Since d<p adjustment is chosen. Moving backward, the CG, knowing that the SNG will choose adjustment, rejects the funding request because its cost *(1+i+σf)d* is greater than zero. Note that zero is the payoff that the CG would receive if it refuses the SNG's request. Finally, in the first node the SNG prefers to comply with the budget since, knowing the decisions to be taken at future nodes, it is in its best interest not to deviate from the budget since the very beginning.

- Case B: p<d.

In this case, we also assume that *V>p*. We believe that this assumption is sensible, once we are in the low-p regime. Using backward induction, the SBC arises as the result of a non-deterrent penalty.

Figure 6: Solution of the game when p<d



The main results can be summarized as follows:

- If the penalty is effectively greater than the deficit, the SBC does not arise.
- The higher the fixed cost *V* is, the more likely is that the SBC arises.
- The higher the spread under intervention, the more likely it is for the SBC to arise. If an intervention is severely penalized by capital markets, the CG may prefer to provide extra funding to the SNG instead of intervention.
- Deterrence of the SNG is based on a credible application of a severe (with respect to the deficit) penalty. Under a cyclical downturn, when $d>0$ is likely to arise, the required action (impose a high penalty *p*) may be severely contested and its application may be diluted.
- Even if the penalty is not high enough to deter the SNG, it may have a role as a bargaining device, prompting the SNG for future corrective action if deviations have materialized.

4 Introducing Dynamics: A Theory of Moves Approach

To check the robustness of the results we analyze the model from a dynamic viewpoint. In particular, do the previous results change if we introduce a dynamic dimension? We use Theory of Moves (ToM) to answer this question, see Brams (1994). ToM is a branch of Game Theory that analyzes the sequential development of the game (extensive form), starting the dynamics on each possible outcome of the game (normal form). In this way, ToM provides an algorithm to find Non-Myopic (or farsighted) Equilibria (NME): a state to which rational players would move (or stay), anticipating all possible rational moves and countermoves from some initial state[6]. Finally, we will also consider the robustness of the results with respect to the "hard" or "soft" nature of the CG.

In order to apply ToM we have to translate the game depicted in figure 4 to a 2x2 ordinal game, represented in normal (strategic) form. To do so, we will consider that each player has two strategies: the CG can penalize or not penalize the SNG and the SNG can comply or not with its budget constraint. The interactions of the strategies give rise to four possible outcomes:

[6] See the Appendix A and the references cited herein for a detailed presentation of ToM basic algorithm.

- *Compliance*: the SNG fulfills its budget constraint and the CG does not penalize it. For short: [NP, C].
- *Soft Budget Constraint (SBC)*: the SNG does not fulfill its budget constraint and the CG does not penalize it. For short: [NP, NC].
- *Intervention*: the SNG does not fulfill its budget constraint and the CG penalizes it. For short: [P, NC].
- *Token*: the SNG fulfills its budget constraint and the CG penalizes it. For short: [P, C]. We have included this outcome only to apply ToM algorithm and we will rank it in order to ensure that it has no role in the results.

4.1 The "weak" Central Government

Let us assume that the SNG ranks the four outcomes, from best to worst (with normalized pay-offs in parenthesis), as follows: SBC (4), Compliance (3), Intervention (2) and Token (1). Moreover, the CG ranks the four outcomes as follows: Compliance (4), SBC (3), Intervention (2) and Token (1).

Those preferences are in close correspondence with the results derived in the sequential game when the penalty is lower than the deficit (case B: $p<d$). In this case, the CG is reluctant to act, due to the high costs of the intervention, and the SNG is prompt to deviate, due to reduced costs of the penalty with respect to the deficit. Hence, the SBC arises.

Do the results change if we introduce a dynamic dimension in the game? The application of ToM to this game yields the following results[7]:

[7] A detailed accounting of the sequence of moves-countermoves of both players starting at the four possible outcomes is presented in the Appendix B.

Table 1: CG and SNG game. Matrix of payoffs (ordinal form): "Weak" CG

CG SNG→	Comply	Not Comply
Penalize	Token (1 1) [3 4]	Intervention (2 2) [3 4]
Not Penalize	Compliance (4 3) [4 3]	Soft Budget Constraint <u>(3 4)</u> <u>[3 4]</u>

Key: (x,y) = (payoff to CG, payoff to SNG) in the original game.
[x, y] = [payoff to CG, payoff to SNG] in preplay game[8].
4=Best; 3=Next best; 2=Next worst; 1= worst.
Nash equilibrium in original game and preplay game underscored.
Non-myopic equilibria (NMEs) are highlighted in grey.

On the one hand, if we solve the game simultaneously, both CG and SNG have a dominant strategy: Not Penalize and Not Comply, respectively. Therefore, the Nash equilibrium corresponds to the SBC outcome [NP, NC], ranked as (3 4) for the CG and the SNG, respectively.

On the other hand, when we apply ToM as a dynamic approach to solve the game, two NME are obtained. The first outcome corresponds to the SBC, as in the Nash analysis. Moreover, the second NME that this algorithm suggests is the Compliance one. However, this outcome is unstable: the players will remain at Compliance only if they start there, otherwise they will finish in the SBC outcome [3 4]. To shed additional light on the Compliance outcome, we can check the sequence of moves starting from the Compliance outcome according to ToM rules, represented in the next table.

[8] A game, described by a payoff matrix, whose entries, which are given in brackets, are the Non-Myopic Equilibria (NMEs) into which each state of the original game goes.

Table 2: Table of the sequence of moves starting at Compliance

	Outcome										
	1			2			3			4	
	CG			SNG			CG			SNG	
CG starts	4	3	→ |	1	1	→	2	2	→	3	4
Survivor	4	3		3	4		3	4		3	4
	1			2			3			4	
	SNG			CG			SNG			CG	
SNG starts	4	3	→ |	3	4	→	2	2	→	1	1
Survivor	4	3		4	3		4	3		4	3

Key: The symbol → and →| means move and blocked move (stay), respectively.
Note: The 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 the play of the game returns to the initial outcome (outcome 1).

If the CG starts, it prefers to stay at [4 3] because it is its most preferred outcome. Provided that the SNG starts the game, it also prefers to remain at [4 3]. This is due to the fact that the SNG knows that the movement from [4 3] to its most preferred outcome [3 4] may trigger the CG to initiate a sequence of moves and countermoves that will end up in [4 3]. This sequence of moves implies a "transit through hell", i.e. through the Intervention outcome [2 2] which both players want to avoid. However, the CG could intervene as it expects to end up in the compliance outcome [4 3]. Hence, the SNG, knowing that it will anyways end in [4 3], prefers to stay at [4 3] and to avoid the retaliatory "transit through hell" risk. According to ToM rules and its reliance on the concept of backward induction, the CG can credibly commit to this "transit through hell" in order to improve its payoff. Finally, the Nash equilibrium of the preplay game is the same as the Nash equilibrium of the original game, increasing the likelihood of the SBC outcome as the final result of the game.

4.2 The "hard" Central Government

The dominance of the SBC outcome that arises in the previous game prompts the following question: is the SBC the dominant outcome if the CG has a "hard" stance with respect to the SNG's deviations from a balanced budget? A simple way to answer this question is swapping the preferences of the CG with respect to the outcomes SBC and Intervention and recalculating the Nash equilibria and ToM's NME of the new game.

Now the "hard" CG ranks the four outcomes as follows: Compliance (4), Intervention (3), SBC (2) and Token (1). The preferences of the SNG remain constant: SBC (4), Compliance (3), Intervention (2) and Token (1).

The corresponding analysis of the new game is summarized in the next table:

Table 3: CG and SNG game. Matrix of payoffs (ordinal form): "Hard" CG

CG SNG→	Comply	Not Comply
Penalize	Token (1 1) [4 3] / [3 2]	Intervention (3 2) [4 3]
Not Penalize	Compliance (4 3) [4 3]	Soft Budget Constraint (2 4) [2 4]

Key: (x,y) = (payoff to CG, payoff to SNG) in the original game.
[x, y] = [payoff to CG, payoff to SNG] in preplay game[9].
4=Best; 3=Next best; 2=Next worst; 1= worst.
Nash equilibrium in original game and preplay game underscored.
Non-myopic equilibria (NMEs) highlighted in grey.

In the new game, the SNG has a single dominant strategy (Not Comply). The CG hinges around the Not Comply strategy of the SNG and its best choice now is to penalize the SNG. Thus, the Nash equilibrium is Intervention: the SNG does not comply and the CG punishes its deviation from a balanced budget. ToM detects two Non-Myopic Equilibria (NME), the same ones as in the case of the "weak" CG, but now none of them are Nash equilibrium in the original game: the SBC outcome and the Compliance outcome both emerge as NME but their features are now reversed. Now the SBC is a NME if, and only if, the players start the game there. Otherwise, they will end up in the Compliance outcome.

The fact that the Nash equilibrium does not belong to the set of NMEs when the CG is "hard" suggests a quite different story to the one that arises when the CG is "weak".

9 A game, described by a payoff matrix, whose entries, which are given in brackets, are the Non-Myopic Equilibria (NMEs) into which each state of the original game goes.

According to the preplay game, if the players can choose before the game starts, they will choose [Penalize, Not Comply], generating an Intervention, which is the basic Nash equilibrium. Note that the SNG has a dominant strategy (Not Comply) and will try to end up in its most preferred outcome [Not penalize, Not Comply]. However, the “hard” CG does not accommodate and penalizes the SNG, ending both in the [Penalize, Not Comply] outcome.

According to ToM (i.e. assuming a forward looking, farsighted view) both players will move to the compliant NME [Not Penalize, Comply], materializing a Pareto improvement. In the same vein, they will not move to the SBC outcome [Not penalize, Not comply], if they start at Intervention. Although the SBC is less likely now than in the case of a “weak” CG, it is still a NME. According to ToM, if the players are forward looking and start at the SBC outcome, they will remain there. In any case, an alternative path may happen if the CG has deterrent power (it can endure better than the SNG a costly state), because then the CG can apply Penalize, moving from the SBC outcome to the Nash equilibrium Intervention [Penalize, Not comply]. Once there, and assuming that the players are farsighted, the SNG can move from Not Comply to Comply in exchange of the CG moving from Penalize to Not penalize, materializing a Pareto improvement for both players.

Finally, if the CG is perceived as a hard[10]player by the SNG, this perception can exert an autonomous deterrent role, making the NME Compliance=[Not Penalize, Comply] more attractive to both players than the NME SBC=[Not Penalize, Not Comply] because of the possibility commented above that both players may end up in the Nash equilibrium Intervention=[Penalize, Not Comply]. In this way the CG can be “weak” rather than “hard”. The critical issue is how the SNG perceives the game, rather than the true game. In practice, we believe that the role of imperfect information is fairly limited due to the fact that learning about the preferences of the other player can be very fast and that reputation without a real exhibition of hardness and threat power is ineffective.

[10] In this case “hard” refers to the preferences of the CG as well as the CG having threat power.

4.3 The role of threats

The Theory of Moves (ToM) introduces a dynamic dimension in the analysis of games by means of the use of the backward induction technique and the path dependencies that may arise as the result of starting the game in a predetermined initial state.

In addition, ToM can be used to examine repeated games and, in particular, the role that threats may have in this type of games. When a player makes a threat it tries to modify the behavior of the other player in order to get better results than under the normal solution of the game. According to Brams (1994), threats can be compellent (aimed at inducing the threatened player to stay) or deterrent (aimed at inducing the threatened player to choose a more preferred outcome according to the threatener preferences).

Let us assume that Player 1 (P1) is the threatener and Player 2 (P2) is the threatened player. According to ToM, a threat to be credible must be real (when the threat is carried out, it worsens the payoff of P1) and rational (when successful in deterring P2, it improves P1's own payoffs). An algorithm to identify threats that hinges on the existence of Pareto-inferior states is presented in the Appendix C.

Once we have defined what a threat is, the immediate question is whether it is in the interest of the players to formulate them. The SNG has a dominant strategy (Not Comply, NC), so its optimizing strategy does not depend at all on the other player's choices and it does not need to make any threat to improve its results. On the contrary, the CG does not have a dominant strategy and its optimizing strategy hinges on the choices of the SNG. So, is it in the interest of the CG to make a threat? Does the answer depend on the "weak" or "hard" nature of the CG?

Using the algorithm described in Appendix C, we can find that the CG has a deterrent threat (Penalize) that sustains its most preferred outcome (Compliance=[NP C]), irrespective of whether it is "weak" or "hard". In both cases, the threat outcome is Intervention=[P NC], that is Pareto-inferior to Compliance. In this way, the multiplicity of NME that ToM suggests (Compliance and Soft Budget Constraint) can be reduced by means of threats. This is especially relevant in the case of a "weak" CG, ensuring the stability of the otherwise unstable Compliance NME.

In the case of a "hard" CG, the role of threats is less critical because the Compliance NME is stable and only has a clear role if the game starts in the SBC outcome. In fact, the deterrent threat induces a rational switch of the SNG from the Not Comply strategy to the Comply strategy.

5 The Right Square: Transfers and the Tax-Expenditure Balance

According to the Theory of Moves (ToM) the Compliance outcome [NP C] is a Non-Myopic Equilibrium (NME). This NME can be supported by means of deterrent threats made by the CG, irrespective of whether it is a "weak" or a "hard" player but, once this NME has been reached and apart from the threats, how can it be preserved? Note that, even if the CG can be labeled as "weak", once Compliance is achieved the players will remain there indefinitely. To answer this question we have to make a small detour. First, we assume a linear structure for the SNG's own taxes:

$$T_j = \tau_j Y_j \qquad [4]$$

Being:

- T=Taxes.
- τ=Effective tax rate set by the SNG.
- Y=Regional GDP, the tax base.

Let us assume that the SNG's constraint is binding when the economy is on its steady state. This assumption implies that the SRF is sufficient: when the economy is at its steady state, the combination of own taxes and transfers provides enough funding for the SNG's expenditure. Thus, there are no structural fiscal imbalances.

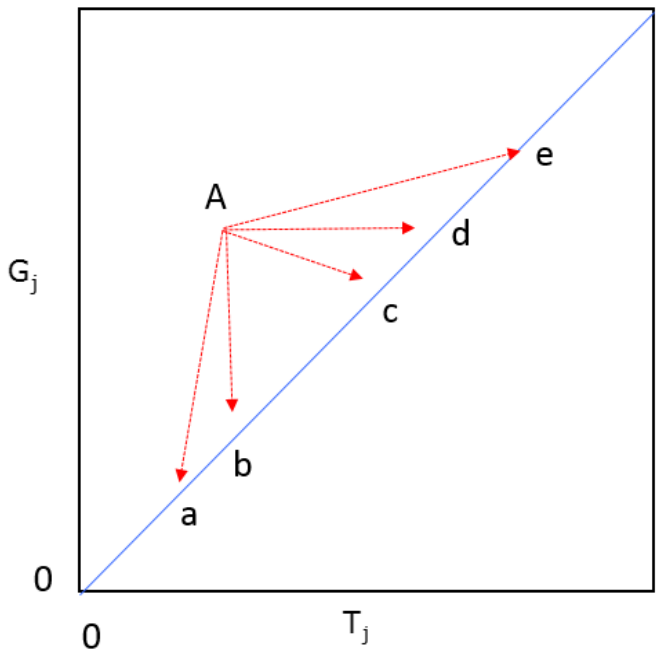
Differencing the SNG's budget constraint [1], the tax structure defined by [4] and assuming that the system is on its steady state we get:

$$\Delta\tau_j Y_j = \Delta G_j - \Delta R_j \qquad [5]$$

Equation [5] allows transfers to play a potential, permanent role to compensate deviations induced by discretionary changes made by the SNG. This link explains why is so tempting to deviate: transfers are always there and its increase does not require the implementation of new funding channels, as may be the case of a bail-out. The conclusion is immediate: setting $\Delta R_j=0$ forces taxes and expenditures to be dynamically balanced. An interesting limiting case is when transfers are not in the system: $R_j=0$. In this case, a full co-responsible fiscal system has been enacted. Of course, this is a limiting case but the message is clear: reducing the role of transfers as much as possible increases the Compliance NME likelihood.

This move towards a co-responsible fiscal system is compatible with many final fiscal structures, as can be seen in the next figure:

Figure 7: The transition towards a balanced fiscal structure



Moving from a fiscal structure reliant on transfers (A) to a new fiscal structure less reliant on transfers depends on the preferences of the SNG[11]. Many combinations are feasible, ranging from a reduction of the size of the SNG (case a) to an increase of its size (case

[11] Of course, in a democratic setting, the preferences of the voters that elect the SNG.

e). If the SNG wants to keep constant its level of expenditure (case d), an increase of taxes has to be enacted. This increase can be made through higher tax rates or by means of an expansion of the tax base (i.e., transferring taxes like VAT from the CG to the SNG). This “federal” system has been criticized on the basis that it does not guarantee the same provision of public services for all the citizens[12], which is considered a normative feature for the country as a whole.

Several changes can be introduced in order to ameliorate the lack of equalization. The first one is the introduction of a uniform level of expenditure[13]that ensures equalization at a minimum. The second alternative is to issue an explicit guarantee stating that such additional expenditure will be funded by the CG through transfers, avoiding unfunded mandates. Finally, each SNG has the option to increase, but never to 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. The new equation that define the modified system is:

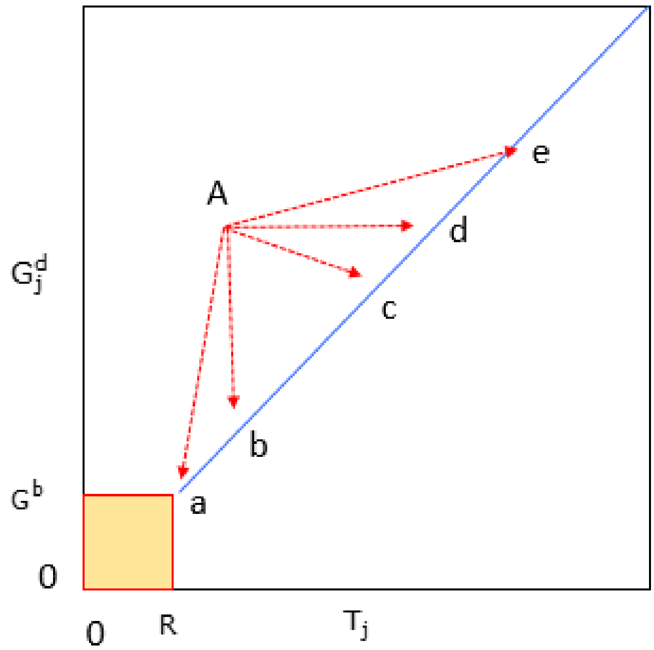
$$G_j = \overbrace{\underbrace{G^b}_{\text{Basic}} + \underbrace{G_j^d}_{\text{Discretionary}}}^{\text{Uses}} = \overbrace{\underbrace{R}_{\text{Transfers}} + \underbrace{\tau_j Y_j}_{\text{Own Taxes}}}^{\text{Funding}} \quad [6]$$

This system combines equalization (by means of a common floor on expenditure), preserves autonomy (because each SNG can improve the provision of public services on their own) and is budget-compliant (because the eventual increase in expenditure has to be funded by the corresponding increase in taxes). Using figure 7, these changes are equivalent to the introduction of a square area determined by R and the same principles of co-responsibility apply as before but on a reduced scale. The next figure represents the modified system.

[12] Note that the same critique applies to the system defined by [1], unless additional constraints are enforced.

[13] Remember that the variables are on a per capita basis.

Figure 8: The transition towards a balanced fiscal structure with equalizing transfers



This system can be considered as a simplified version of the current Spanish SRF.[14] As we have mentioned above, the system defined by equation [6] ensures equalization, sufficiency, preserves autonomy[15]and is budget-compliant. Nevertheless, it reintroduces the transfers from the CG to the SNGs, moving the players back to the square one of the game: soft budget constraints, especially if the CG is "weak" and, in general, the need to use threat power by the CG to preserve the Compliant NME as the unique NME of the model.

According to this view, there is a trade-off between sustaining budget-compliance and equalization. This trade-off can be lessened if the equalization process is made directly by the SNGs, without the intervention of the CG. In this way, the direct channel between deficit and transfers is absent and equalization is achieved.

[14] See León and Aja (2015) and the references cited therein.

[15] Although in a lesser degree as the original system. This reduction can be considered as the price to pay in order to ensure equalization.

This trade-off is the main problem of the system defined by equation [6]. However, two other problems can be mentioned: The first one is related to the difficulty to disentangle basic and discretionary expenditure, which generates an incentive to transform the later into the former. As a consequence, SNGs are tempted to avoid raising regional taxes and promoted to embark into an overgrazing process through the request of increased transfers. The second additional problem is related to the determination of the level of basic expenditure that serves as a common floor for all SNGs. If this level is too high, it may reduce substantially SNGs fiscal autonomy whereas if it is too low, it can also exacerbate the fiscal overgrazing phenomenon.

6 Conclusions and future research

Classical Game Theory and the Theory of Moves (ToM) suggest that the SBC is more likely when:

- The (expected) penalty is relatively low (compared to the size of the deficit).
- The costs of intervention are relatively high (compared to the cost of accommodation).
- The spreads under intervention are higher than under accommodation. There is a “weak” CG.

Although the NMEs identified by ToM are the same irrespective of whether the CG is "hard" or "weak", the SBC is more likely in the second case than in the first one. In particular, if the CG is “hard” the corresponding (unique) Nash[16] equilibrium is not a NME[17], indicating a divergence between short and long run calculations. This gap can be filled by means of rational threats made by the CG (intervention in case of non-compliance by the SNG).

The role of threats is robust with respect to the “weak” or “hard” nature of the CG and it becomes clear when the game is repeated over time. In both cases, the threat to intervene solves the indeterminacy linked to the multiple NMEs, thus ensuring

[16] The Nash equilibrium is Intervention (SNG does not comply and the CG intervenes).

[17] ToM identifies two NME: Compliance (SNG complies and the CG does not intervene) and SBC (SNG does not comply and the CG does not intervene).

Compliance as the unique outcome of the game. ToM also allows us to analyze path-dependencies. Specifically, it suggests that starting at the compliant NME helps to sustain it over time. Otherwise, the use of threat power by the CG is required to bring the game to this outcome.

Analyzing the compliant NME in order to keep hard the SNG's budget constraint suggests the convenience to greatly reduce the role of transfers[18]in the system and to balance tax and expenditure (shared fiscal responsibility). This decentralized system may generate a trade-off between equalization and budgetary stability, if the former is ensured by means of a reintroduction of transfers.

Finally, there are many extensions for the framework used in this paper. The first one is the introduction of additional players[19] that can reduce the dominant bilateral nature of the system. In this way, a stability fund owned only by the SNGs can reduce the likelihood of the SBC by means of a process of peer-review and the corresponding pressure to keep the budget balanced. In addition, the fund can easily absorb idiosyncratic shocks and (under "normal" business cycle conditions) common shocks.

A stability fund can complement the use of penalties, introducing conditions for its accession[20]: funding is quasi-automatic and non-conditional if the SNG has a proven record of fiscal responsibility. This record can be endorsed by an independent agency or fiscal council. This external validation is very important to reduce "permissive behaviors": in the end, the fund is backed by the SNGs. Note that, in case of request by the other SNGs, the game is an n-person Prisoners' Dilemma. Thus, repeated interaction prompts the SNGs to be more prone to accept the demands placed by the other SNGs, hence the convenience to reinforce the majority rule and the assessment of an external agency.

The model can also be extended to include debt issuance by the SNGs, see Cottarelli et al. (2016) and Strauch et al. (2016) for an analysis of the recent international experience.

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[18] Especially the system of deferred transfers ("pagos a cuenta").

[19] Quoting Brams and Kilgour (2003): "Third parties may play an important role in attenuating conflict. Their presence, it seems, can ease the desperation one often finds in two-player conflicts, which often becomes wars of attrition. The third player, in essence, provides a balancing mechanism that helps to sustain hope, whether the future is murky or clear".

[20] An example is the Flexible Credit Line provided by the International Monetary Fund (IMF).

Although this extension does not change the basic conclusions of the model it introduces an additional layer that has important practical consequences. We should consider two different implications of the debt issued by a SNG. First, the role that the existing level of debt may have on the game and, second, its role as a regular financing mechanism.

The first one can be easily grasped by the model presented in the paper, stretching the definition of deficit to encompass debt financing. The second one requires an explicit modeling of the interest rate spread that the SNG faces with respect to the CG. This modeling is outside the limits of this paper but our preliminary research suggests that it is extremely convenient to ensure the compliant equilibrium of the game and the overall sufficiency of the system before a regular issuance program is expected to be successful, see Geli and Quilis (2017). Note that success means both reasonable spreads and not contributing to make the SBC a sensible choice for the players, thus endangering the budgetary stability of the system.

Finally, another line of research consists of extending the model to include the relationship of the CG with a supranational entity (e.g. the European Commission) at the same time as the interaction of the CG with the SNGs. Using this extension, we can check the robustness of the results and, specially, the role of the CG's compliance, see Molina-Parra and Martínez-López (2017).

7 Appendix A: The 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 the 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), see Brams (1994) for a detailed exposition of ToM.

The basic idea of ToM is that both players make moves projecting sufficiently ahead into the future but assuming that cycles should be passed up in order to avoid blocking the game. To make his decision, each 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 a 2x2 bi-matrix that reflects 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 first is called player 1 (P1).
- 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 implement 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 for the other player not to move, then the player who moves overrides the player who stays.

The application of the six ToM rules to all the possible initial outcomes, controlling also for the starting player, generates the set of NME. 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.).

We have written a program in MATLAB to easily apply ToM to a variety of game models, see Quilis (2017). The program takes into account the so-called Two-Sidedness Convention (TSC), which modifies the rules described above in order to consider certain cases in which the overriding rule must be modified. Those cases give rise to a specific type of games (Magnanimity Games), including among them the famous Prisoners' Dilemma and the Chicken game. When the TSC is called by the program, the analyst must check carefully the results in order to ascertain the relevant NMEs of the game.

The program also considers the solution of the Anticipation (or preplay) Game (AG) derived from swapping the original payoffs by the NME into which each original outcome goes. The AG is then solved by searching for its Nash equilibria. Indeterminacies preclude the automatic solution of the AG and may require additional assumptions regarding what player has order power.

8 Appendix B: Output from the MATLAB ToM Calculator

We present here the complete output from the MATLAB ToM calculator, for the "weak" CG as well as for the "hard" CG. In both cases, Player 1 is the CG and Player 2 is the SNG.

8.1 "Weak" Central Goverment

```
*****************************************************************
*** THEORY OF MOVES CALCULATOR ***
*****************************************************************
Game -> SOFT BUDGET CONSTRAINT
*****************************************************************
 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
----------------------------------------------------------------------------------
 Note: -9 => Indeterminacy. Check tables of moves and survivors.
*****************************************************************
***  INITIAL AND FINAL OUTCOMES ***
----------------------------------------------------------------------------------
   1     1   --->       3     4
   4     3   --->       4     3
   2     2   --->       3     4
   3     4   --->       3     4
----------------------------------------------------------------------------------
***  INITIAL AND UNILATERALLY MOST PREFERRED OUTCOMES ***
***  Note: First pair = Initial outcome; second pair =player 1; third pair = player 2
***
***  Note: Discrepancies between the players may indicate the need to use the Two-
Sidedness Convention,
***          represented below as TSC=1. Check tables of moves and survivors to refine
the results.
----------------------------------------------------------------------------------
   1     1   -->      3     4     or        3     4        TSC=0
   4     3   -->      4     3     or        4     3        TSC=0
   2     2   -->      3     4     or        3     4        TSC=0
   3     4   -->      3     4     or        3     4        TSC=0
----------------------------------------------------------------------------------
***  POTENTIAL MOVES AND SURVIVORS FROM BACKWARD INDUCTION ***
***  Note: First row = player 1; second row = player 2
----------------------------------------------------------------------------------
 Initial outcome ->     1     1
```

```
 Starting player ->    1
 Stage ->          1     2     3     4     5
-----------------------------------------------------------------------------------
 Potential moves:
                   1     4     3     2     1
                   1     3     4     2     1
-----------------------------------------------------------------------------------
 Survivors:
                   3     3     3     2     0
                   4     4     4     2     0
-----------------------------------------------------------------------------------
 Blockade:
                   0     0     1     1     0
-----------------------------------------------------------------------------------
 Starting player ->    2
 Stage ->          1     2     3     4     5
-----------------------------------------------------------------------------------
 Potential moves:
                   1     2     3     4     1
                   1     2     4     3     1
-----------------------------------------------------------------------------------
 Survivors:
                   3     3     3     4     0
                   4     4     4     3     0
-----------------------------------------------------------------------------------
 Blockade:
                   0     0     1     1     0
-----------------------------------------------------------------------------------
*****************************************************************
 Initial outcome ->    4     3
 Starting player ->    1
 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
-----------------------------------------------------------------------------------
 Blockade:
                   1     0     0     1     0
-----------------------------------------------------------------------------------
 Starting player ->    2
 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
-----------------------------------------------------------------------------------
 Blockade:
                   1     0     0     0     0
-----------------------------------------------------------------------------------
```

```
*****************************************************************
 Initial outcome ->     2      2
 Starting player ->     1
 Stage ->          1      2      3      4      5
-----------------------------------------------------------------------------------
 Potential moves:
                   2      3      4      1      2
                   2      4      3      1      2
-----------------------------------------------------------------------------------
 Survivors:
                   3      3      4      2      0
                   4      4      3      2      0
-----------------------------------------------------------------------------------
 Blockade:
                   0      1      1      0      0
-----------------------------------------------------------------------------------
 Starting player ->     2
 Stage ->          1      2      3      4      5
-----------------------------------------------------------------------------------
 Potential moves:
                   2      1      4      3      2
                   2      1      3      4      2
-----------------------------------------------------------------------------------
 Survivors:
                   3      3      3      3      0
                   4      4      4      4      0
-----------------------------------------------------------------------------------
 Blockade:
                   0      0      0      1      0
-----------------------------------------------------------------------------------
*****************************************************************
 Initial outcome ->     3      4
 Starting player ->     1
 Stage ->          1      2      3      4      5
-----------------------------------------------------------------------------------
 Potential moves:
                   3      2      1      4      3
                   4      2      1      3      4
-----------------------------------------------------------------------------------
 Survivors:
                   3      3      3      3      0
                   4      4      4      4      0
-----------------------------------------------------------------------------------
 Blockade:
                   1      0      0      0      0
-----------------------------------------------------------------------------------
 Starting player ->     2
 Stage ->          1      2      3      4      5
-----------------------------------------------------------------------------------
 Potential moves:
                   3      4      1      2      3
                   4      3      1      2      4
-----------------------------------------------------------------------------------
 Survivors:
                   3      4      3      3      0
                   4      3      4      4      0
-----------------------------------------------------------------------------------
 Blockade:
                   1      1      0      0      0
-----------------------------------------------------------------------------------
*****************************************************************
```

8.2 “Hard” Central Goverment

We present now the complete output from the MATLAB ToM calculator, for the “hard” CG.

```
*****************************************************************
*** THEORY OF MOVES CALCULATOR ***
Game -> HARD CG
*****************************************************************
 Player 1: Payoff matrix (ordinal preferences):
     1      3
     4      2
-----------------------------------------------------------------------------------
 Player 2: Payoff matrix (ordinal preferences):
     1      2
     3      4
*****************************************************************
*** NON-MYOPIC EQUILIBRIA ***
   -9     0
    1     1
-----------------------------------------------------------------------------------
 Note: -9 => Indeterminacy. Check tables of moves and survivors.
*****************************************************************
***  INITIAL AND FINAL OUTCOMES ***
-----------------------------------------------------------------------------------
   1     1   --->     -9    -9
   4     3   --->      4     3
   3     2   --->      4     3
   2     4   --->      2     4
-----------------------------------------------------------------------------------
***  INITIAL AND UNILATERALLY MOST PREFERRED OUTCOMES ***
***  Note: First pair = Initial outcome; second pair =player 1; third pair = player 2
***
***  Note: Discrepancies between the players may indicate the need to use the Two-
Sidedness Convention,
***          represented below as TSC=1. Check tables of moves and survivors to refine
the results.
-----------------------------------------------------------------------------------
   1     1   -->      4     3     or        3     2        TSC=1
   4     3   -->      4     3     or        4     3        TSC=0
   3     2   -->      3     2     or        4     3        TSC=0
   2     4   -->      2     4     or        2     4        TSC=0
-----------------------------------------------------------------------------------
***  POTENTIAL MOVES AND SURVIVORS FROM BACKWARD INDUCTION ***
***  Note: First row = player 1; second row = player 2
-----------------------------------------------------------------------------------
 Initial outcome ->    1     1
 Starting player ->    1
 Stage ->         1     2     3     4     5
-----------------------------------------------------------------------------------
 Potential moves:
                  1     4     2     3     1
                  1     3     4     2     1
-----------------------------------------------------------------------------------
 Survivors:
                  4     4     3     3     0
                  3     3     2     2     0
-----------------------------------------------------------------------------------
 Blockade:
                  0     1     0     1     0
```

```
----------------------------------------------------------------------------------
 Starting player ->    2
 Stage ->         1     2     3     4     5
----------------------------------------------------------------------------------
 Potential moves:
                  1     3     2     4     1
                  1     2     4     3     1
----------------------------------------------------------------------------------
 Survivors:
                  3     3     2     4     0
                  2     2     4     3     0
----------------------------------------------------------------------------------
 Blockade:
                  0     1     1     1     0
*****************************************************************
 Initial outcome ->    4     3
 Starting player ->    1
 Stage ->         1     2     3     4     5
----------------------------------------------------------------------------------
 Potential moves:
                  4     1     3     2     4
                  3     1     2     4     3
----------------------------------------------------------------------------------
 Survivors:
                  4     3     3     2     0
                  3     2     2     4     0
----------------------------------------------------------------------------------
 Blockade:
                  1     0     1     1     0
----------------------------------------------------------------------------------
 Starting player ->    2
 Stage ->         1     2     3     4     5
----------------------------------------------------------------------------------
 Potential moves:
                  4     2     3     1     4
                  3     4     2     1     3
----------------------------------------------------------------------------------
 Survivors:
                  4     4     4     4     0
                  3     3     3     3     0
----------------------------------------------------------------------------------
 Blockade:
                  1     0     0     0     0
----------------------------------------------------------------------------------
*****************************************************************
 Initial outcome ->    3     2
 Starting player ->    1
 Stage ->         1     2     3     4     5
----------------------------------------------------------------------------------
 Potential moves:
                  3     2     4     1     3
                  2     4     3     1     2
----------------------------------------------------------------------------------
 Survivors:
                  3     2     4     3     0
                  2     4     3     2     0
----------------------------------------------------------------------------------
 Blockade:
                  1     1     1     0     0
----------------------------------------------------------------------------------
 Starting player ->    2
 Stage ->         1     2     3     4     5
----------------------------------------------------------------------------------
 Potential moves:
                  3     1     4     2     3
                  2     1     3     4     2
----------------------------------------------------------------------------------
 Survivors:
                  4     4     4     3     0
                  3     3     3     2     0
----------------------------------------------------------------------------------
```

```
 Blockade:
                   0      0      1      0      0
-----------------------------------------------------------------------------------
*****************************************************************
 Initial outcome ->     2      4
 Starting player ->     1
 Stage ->          1      2      3      4      5
-----------------------------------------------------------------------------------
 Potential moves:
                   2      3      1      4      2
                   4      2      1      3      4
-----------------------------------------------------------------------------------
 Survivors:
                   2      2      2      2      0
                   4      4      4      4      0
-----------------------------------------------------------------------------------
 Blockade:
                   1      0      0      0      0
-----------------------------------------------------------------------------------
 Starting player ->     2
 Stage ->          1      2      3      4      5
-----------------------------------------------------------------------------------
 Potential moves:
                   2      4      1      3      2
                   4      3      1      2      4
-----------------------------------------------------------------------------------
 Survivors:
                   2      4      3      3      0
                   4      3      2      2      0
-----------------------------------------------------------------------------------
 Blockade:
                   1      1      0      1      0
-----------------------------------------------------------------------------------
*****************************************************************
```

9 Appendix C: An Algorithm to Identify Rational Threats

Let us consider a 2x2 game with players Row (R) and Column (C), whose ordinal preferences are stored in matrices A:2x2 and B:2x2, respectively. In both matrices: 4=best, 3=next best, 2=next worst, 1= worst.

In order to make operational the definition of compellent and deterrent threats, Brams (1994), p. 147-8, proposes the following algorithm to identify the threats available to Row:

- Step 1: Select i and j such that A(i,j)=4. Select R’s best outcome (target).
- Step 2: If B(i,j)=4, stop: no threats are necessary to implement [A(i,j),B(i,j)].
- Step 3: If B(i,j)=1, go to 8: no threats can induce [A(i,j),B(i,j)].
- Step 4: Select [A(m,n),B(m,n)] such that [A(m,n),B(m,n)] < [A(i,j),B(i,j)]. Search for Pareto-dominated outcomes. If the search fails, go to 7.
- Step 5: If m=i, [A(i,j),B(i,j)] is R's compellent threat state.
- Step 6: If m≠i and B(m,n)=2, stop: [A(i,j),B(i,j)] is R's deterrent threat state.
- Step 7: If A(i,j)=3, stop: R has no threat states.
- Step 8: Select i and j such that A(i,j)=3. Downgrade Row’s target. Go to 2.

The identification of the threats available to player C can be implemented just swapping A and B and repeating the algorithm.

10 References

Baimbridge, M. and Whyman, P. (2005), *Fiscal Federalism and European Economic Integration*, Routledge.

Bandrés, E. and Cuenca, A. (2016), "Las reformas de la financiación autonómica: elementos para una aproximación desde la economía política", *Revista de Estudios Regionales*, 105: 165-194.

Bassanetti, A., Cottarelli, C. and Presbitero, A. (2016) "Lost and Found: Market Access and Public Debt Dynamics", IMF, Working Paper n. 16/253.

Brams, S. (1994), *Theory of Moves*, Cambridge University Press.

Brams, S. and Kilgour, M. (2003), "Truels and the Future", *Math Horizons*, 10(4): 5-8.

Colegio de Economistas (2016), *Financiación autonómica de régimen común: una reforma necesaria*, Colegio General de Economistas de España.

Cueto, B. and Suárez, P. (2014), "A Review of Active and Passive Labor Market Policies in Spain, MPRA paper 60648

Darby, J., Muscatelli, A. and Roy, G. (2002), "Fiscal Federalism and Fiscal Autonomy", *Scottish Affairs*, 41: 26-55.

Delgado, M., Lledó, V.D. and Pérez, J. (2016), "On the Determinants of Fiscal Non-compliance: An Empirical Analysis of Spain's Regions", Bank of Spain, Working Paper n. 1632.

Delgado, M. and Pérez, J. (2016), "La financiación de las comunidades autónomas: más allá del sistema de financiación autonómica", *Mediterráneo Económico*, 30: 465-482.

de la Fuente, A. (2016), "La evolución de la financiación de las comunidades autónomas de régimen común, 2002-2012", *Papeles de Economía Española*, 143: 28-50.

de la Fuente, A. (2016), “La reforma del sistema de financiación de las comunidades autónomas de régimen común: una propuesta específica”, FEDEA Policy Papers.

de la Fuente, A. (2016), Thöne, M. and Kastrop, M. “Regional Finances in Germany and Spain: Comparative Reform Perspectives”, BBVA Research, Working Paper n. 16/04.

Geli, F. and Quilis, E.M. (2017), “Regional Debt Issuance: A Game-Theoretic Preliminary Analysis”, AIReF Internal Presentation.

Gibbons, R. (1992), *A Primer in Game Theory*, Harvester-Wheatsheaf.

Hernández de Cos and Pérez, J, (2015), “Reglas fiscales, disciplina presupuestaria y corresponsabilidad fiscal”, *Papeles de Economía Española*, 143: 174-184.

Knight, B. (2006), “Common Tax Pool Problems in Federal Systems,” in *Democratic Constitutional Design and Public Policy: Analysis and Evidence*, R. Congleton, and Swedenborg, B. (Eds.) p. 229-250. MIT Press.

Kornai, J. (1986), “The Soft Budget Constraint”, *Kyklos*, 39(1): 3-30.

Lago, S., Fernández, X. and Vaquero, A (2015), “El sistema de financiación autonómica: ¿Quo vadis?”, *Papeles de Economía Española*, 143: 2-14.

Lago, S., Fernández, X. and Vaquero, A (2017), “¿Por qué incumplen fiscalmente las Comunidades Autónomas?”, *Investigaciones Regionales*, forthcoming.

León, S. (2009), “¿Por qué el sistema de financiación autonómica es inestable?”,*Revista Española de Investigaciones Sociológicas*, 128: 57-87.

León, S. y Aja, E. (2015), *La financiación autonómica*, Alianza Editorial.

Molina-Parra, A. and Martínez-López, D. (2017), “Do Federal Deficits Motivate Regional Fiscal (Im)Balances? Evidence for the Spanish Case”, *Journal of Regional Science*, Forthcoming.

Monasterio, C. (2016), "Bajo el síndrome de la mujer de Lot. Un ensayo sobre la descentralización en España", *Mediterráneo Económico*, 30: 23-39.

Persson, T. and G. Tabellini, G. (1996a), "Federal Fiscal Constitutions: Risk Sharing and Redistribution", *Journal of Political Economy*, 104: 979-1009.

Persson, T. and G. Tabellini, G. (1996b), "Federal Fiscal Constitutions: Risk Sharing and moral hazard", *Econometrica*, 64: 623-646.

Quilis, E.M. (2016), "Theory of Moves: a MATLAB Calculator", MATLAB Central File Exchange.

Rasmusen, E. (2006), *Games and Information: An Introduction to Game Theory*, John Wiley & Sons.

Selten, R. (1978), "The Chain Store Paradox", *Theory and Decision*, 9: 127-159.

Strauch, R., Rojas, J., O'Connor, F., Casalinho, F., Ramón, P. and Kalozois, P. (2016) "Accessing Sovereign Markets: the Recent Experiences of Ireland, Portugal, Spain, and Cyprus", European Stability Mechanism, Discussion Paper Series n. 2.

Treisman, D. (2007), *The Architecture of Government*, Cambridge University Press.

Von Hagen, J. (1998), "Fiscal Policy and Intranational Risk-sharing", ZEI Working Paper, n. B 13-1998.

Zabalza, A. (2016), "Equidad y responsabilidad en la financiación autonómica: una propuesta de reforma", FEDEA Policy Papers.