Governmental System and Economic Volatility under Democracy*

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Abstract

Economic volatility varies substantially across democracies. We study how the difference between a federal and a unitary system of government can contribute to such variation. We show empirically that federal systems are associated with less volatility in both economic growth and fiscal policy. Motivated by these stylized facts, we develop a macroeconomic model with policy-making at the central and district level. Policy at the central level is uncertain due to uncertainty about the identity of the winning coalition in a legislature containing district representatives. On the other hand, policy at the district level is stable due to homogeneity within districts. We show that, in equilibrium, the decentralization of fiscal power mitigate overall policy uncertainty. This, in turn, implies less volatility in both economic growth and fiscal policy compared to a unitary system.

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1 Introduction

Economic volatility and its determinants are one of the central issues in macroeconomics. In the political economy literature, it has been established that democracies, compared to autocracies, are associated with less volatility in both economic growth and fiscal policy (e.g., Rodrik, 2000; Acemoglu et al., 2003; Henisz, 2004).

However, there exists a substantial variation of volatility *within* democracies. For example, economic growth in Greece is more than twice as volatile as in Austria. Likewise, government spending in Hungary is more than twice as unstable as in Czech Republic.[1] The question to be answered, therefore, is: What accounts for such variation in volatility within democracies? One possible answer lies in the variations of governmental system under democracy. In this paper, we examine the possible effect on economic volatility by the degree of decentralization of policy-making powers.

In a unitary system (e.g., the U.K. and Greece), the central government has the ultimate decision-making power. In contrast, in a federal system (e.g., the U.S. and Germany), the division of powers between the central and sub-national governments is specified in the constitution and, for many federations, the residual powers are retained by sub-national governments (e.g. the Tenth Amendment of the United States Constitution). In this paper, we focus on the division of fiscal powers (e.g. power to levy tax and to invest in public infrastructure). We first show that, across democracies, federal systems are associated with less volatility of economic growth (Figure 1). This relationship is of economic importance: the interquartile range of growth is 4.4% for the median country among unitary states, but only 2.7% for the median country among federations.[2]

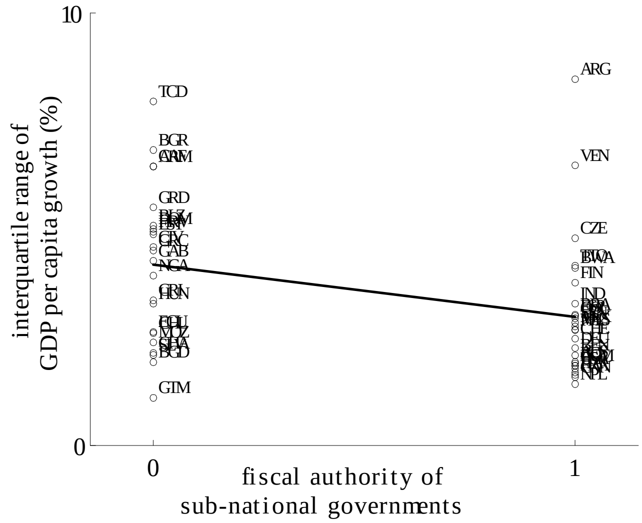
It has been established in the literature that policy volatility contributes to growth volatility (e.g., Fatas and Mihov, 2003). We thus conjecture that federal systems, compared to unitary systems, are associated with less volatility of fiscal policy as well. Figure 2 plots the policy volatility (measured by the interquartile range of government spending) against the governmental system, and it seems to confirm the conjecture. The finding is economically important as well: for the median country, moving from a unitary system to a federal system would reduce the interquartile range of government spending from 4.6% of GDP to 2.6% of GDP.

Motivated by the above stylized facts, we develop a model of fiscal policy-making by the central and district governments. Fiscal policy is used to provide local infrastructure which has a productivity effect on final output. Our model predicts that when allocating greater policy making power to district government leads to lower volatility in both fiscal policy and economic growth.

[1] By our calculation: (i) the interquartile range of growth is 4.5% in Greece, but only 1.8% in Austria; (ii) the interquartile range of government spending is 4.6% of GDP in Hungary, but only 2.1% in Czech Republic.

[2] We address the statistical significance and robustness of this finding in Appendix A.

Figure 1: Volatility of economic growth in 48 democracies, 1990-2013.



(Source: World Bank's *Database of Political Institutions* and *World Development Indicators*.)

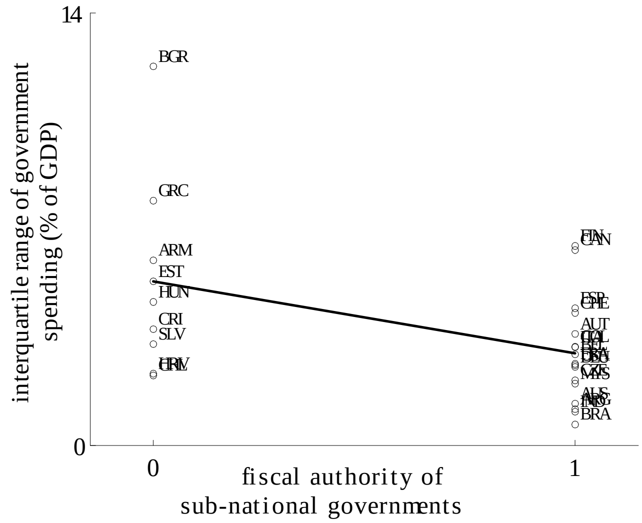
Specifically, the economy consists of two districts and is governed jointly by a central government and district governments. Each district government is identified by an elected legislator from the district, and the assembly of the two legislators characterizes the central government. For each district, both the central government and the respective district government have the ability to provide local infrastructure (transportation, energy supply, etc.) which, in turn, which augments labor and private capital in production.

The provision of local infrastructure by each district government is determined by the respective legislator, while the provision by the central government is determined by the assembly. The policy-making process in the assembly has uncertainty: each legislator is equally likely to dominate the other one and be in charge of the central government's policy.

The interaction between the central and district governments depends on whether the governmental system is federal or unitary. In a *federal* system: (i) the central government (i.e., the legislator in charge) moves first and decides the provision of local infrastructure in each district; (ii) district governments (the respective legislators) move second and provide additional local infrastructure in their own districts. The timing in a *unitary* system is the opposite — the central government moves second and has the final say on fiscal policy. The idea is, unlike in a federal system, the ultimate decision-making power in a unitary system is held by the central government.

One can interpret the timing as capturing the relative policy-making power between the central and local government. In particular, whoever moves second can be considered as having the "residual power". We show that the difference in the timing of the policy-making leads to the difference in the volatility of fiscal policy. In a federal system, legislators decide their district policies *after* the

Figure 2: Volatility of fiscal policy in 26 democracies, 1990-2013.



(Source: World Bank's *Database of Political Institutions* and *World Development Indicators*.)

uncertainty about the assembly's policy-making is resolved. For each legislator: (i) if she is in charge in the first stage, she will use the central government funds to provide a large amount of local infrastructure in her own district, because doing so is in the interest of her constituency; (ii) but even if she is sidelined in the assembly, she still has the opportunity, as a second mover, to provide a modest amount of local infrastructure *ex post*. Therefore, whether the legislator is indeed in charge in the assembly does not make a large difference in the total amount of local infrastructure provided in her district.

In contrast, in a unitary system, each legislator has to decide her district policy *before* knowing whether she will be in charge in the assembly. Since the uncertainty is not resolved yet, each legislator now anticipates the possibility of being in charge and chooses to provide only a smaller amount of local infrastructure *ex ante*. Thus, whether the legislator turns out to be in charge now makes a larger difference in the infrastructure provision in her district.

In other words, when deciding district policies, the legislators in a unitary system are *optimistic* because they might dominate each other in the assembly later on. This optimism will lead to the under-provision of local infrastructure in the event that they turn out to be sidelined. Since the central policy is uncertainty, such under-provision hinders the legislators from mitigating the policy uncertainty facing their districts. Consequently, fiscal policy in a unitary system is more uncertain than in a federal system.

Finally, since local infrastructure has a productivity effect on final output, a larger uncertainty about fiscal policy in a unitary state directly leads to a larger uncertainty about economic growth in a unitary state. The results, therefore, match the two stylized facts.

The rest of the paper is organized as follows. The next subsection reviews the related literature. The model is set up in Section 2. The determination of fiscal policy in each governmental system is analyzed in Section 3. We then compare the volatility of both economic growth and fiscal policy across the two governmental systems in Section 4. Section 5 concludes. The details about the above empirical findings are relegated to Appendix A. The proofs of theoretical results are relegated to Appendix B.

1.1 Related Literature

A sizable literature has shown a negative correlation between the degree of democracy and the volatility of economic growth (Rodrik, 2000; Quinn and Woolle, 2001; Almeida and Ferreira, 2002; Klomp and de Hann, 2009). The causality is also established, with different instruments, in Acemoglu et al. (2003) and Mobarak (2005). Some authors also show that the degree of democracy is negatively correlated with the volatility of fiscal and trade policies (e.g., Henisz, 2004; Dutt and Mobarak, 2007).[3]

The literature that addresses the variation in volatility within democracies is much smaller. The paper closest to our is Wibbels (2000), who looks at 46 developing countries and establishes that federations, compared to unitary states, are associated with *more* volatility in economic policies such as budget balance, inflation, and debt. Although his result seems to be the opposite of ours, there are important differences between his paper and ours. Firstly, the policy variable we focus on is government spending, different from his. Secondly, he focuses on developing countries regardless of their political institutions, whereas we study democratic countries regardless of their levels of economic development.[4]

Democratic governments are also different in aspects other than the federal-unitary dimension. For example, Béjar and Mukherjee (2011) study the difference in electoral systems and show that, within democracies, countries with a proportional-representation system have less volatility of economic growth and fiscal policy than those with a majoritarian system. There is a large literature on political business cycle (reviewed by Drazen (2000)) which claims, empirically and theoretically, that the economic volatility under democracy is in part due to the electoral cycle itself (e.g., pre-electoral manipulation of monetary and fiscal policies). This literature, however, does not focus on the comparison *across* democracies.

In the theoretical literature, our paper is also related to Alesina and Tabellini (1990) and Besley

[3] That the results about growth volatility and policy volatility go in the same direction is not surprising given the finding in the literature that policy volatility increases growth volatility. For example, Jonsson and Klein (1996) find that fluctuations in fiscal policy can account for some key features of business cycles in Sweden. Fatas and Mihov (2003) also show that governments that use fiscal policy aggressively increase the volatility of economic growth.

[4] In addressing the robustness of our results (Appendix A), we also control for the level of economic development in the regressions. The association between federalism and less economic volatility is still present with the control.

and Coate (2003). Alesina and Tabellini study a dynamic model of government debt policy in which policy-makers with different preferences alternate in office as a result of elections. They show that the equilibrium debt level is higher if the disagreement amongst the policy-makers is more pronounced. More closely related to our paper is the model by Besley and Coate. They study the effect of decentralization on the uncertainty of local public goods provision. They model decentralization as a system in which only sub-national governments exist, and they model centralization as a system in which only the central government exists. They show, among other results, that the uncertainty of local public goods provision is smaller in a decentralized system. Our model is built upon theirs by studying an environment in which *both* the central and sub-national governments exist and play a role in the policy-making, and we model the federal and unitary systems as having different timing in the policy-making process.[5]

2 Model

The model is built upon Besley and Coate's treatment (2003) of centralized versus decentralized systems, and we follow the standard treatment of (productive) infrastructure in the macroeconomics literature (e.g., Agénor (2012)).

2.1 Households

The economy is divided into two geographic districts $i \in \{1, 2\}$. Each district has a continuum of households[6] with a unit mass. Households are identical within and across districts, and each derives utility $u(c)$ from consumption c.

Each household is endowed with one unit of labor and some large amount x of a final good. The representative household in district i faces budget constraint

$$c_i + k_i \leq x - \tau_i + r_i k_i + w_i, \tag{1}$$

where c_i and k_i are consumption and capital choices, τ_i is a uniform lump-sum tax levied by the government, r_i is the rate of return to capital, and w_i is the wage rate.

Given the tax τ_i and the factor prices r_i and w_i, each household maximizes the utility $u(c_i)$ subject to (1). The first-order condition with respect to k_i is simply given by

$$r_i = 1. \tag{2}$$

[5] Note that federalism is not equivalent to decentralization. See, for example, Blume and Voigt (2011) for the definitions and different measures of both federalism and decentralization.

[6] Throughout the paper, we use the terms "households" and "citizens" interchangeably.

2.2 Firms

Each district has a continuum of identical firms with a unit mass. Firms produce the final good using local infrastructure, capital, and labor. The production function of an individual firm in district i takes the form

$$\widetilde{y}_i = \left(A_i \frac{g_i}{k_i}\right)^{\beta} \widetilde{k}_i^{\alpha} \widetilde{l}_i^{1-\alpha}, \tag{3}$$

where g_i is the stock of local infrastructure in district i, k_i is the (aggregate) capital stock in district i, $\widetilde{k}_i$ and $\widetilde{l}_i$ are the firm-specific capital and labor, and $A_i > 0$ parameterizes the productivity effect of local infrastructure. The two districts are identical, except that local infrastructure has a larger productivity effect in district 2 than in district 1, i.e., $A_2 > A_1$. We also assume that $\alpha \in (0,1)$ and $\beta > 0$.

Equation (3) implies that local infrastructure g_i is subject to *congestion*: its productivity effect is diminishing in the use by capital stock k_i. Examples include transportation systems, energy and water supply, etc.. As will become clear later on, this setup ensures that, in equilibrium, the indirect utility of households as a function of local infrastructure is strictly concave, and that the problem of finding the optimal level of provision is nontrivial.[7]

Markets are competitive. Each firm's problem is to maximize profits, taking as given the stocks of local infrastructure g_i and capital k_i, and the factor prices r_i and w_i:

$$\max_{\widetilde{k}_i, \widetilde{l}_i} \widetilde{y}_i - r_i \widetilde{k}_i - w_i \widetilde{l}_i.$$

Given that firms are identical, in a symmetric equilibrium, the first-order conditions for the firms are given by

$$r_i = \alpha \frac{y_i}{k_i}, \tag{4}$$

$$w_i = (1-\alpha) y_i. \tag{5}$$

2.3 Policies

The governmental system has two layers: a central government and two districts governments (one for each district).

The central government is able to provide local infrastructure, (g_1^c, g_2^c), for both districts 1 and 2. The spending is financed uniformly by all citizens *across* districts ($(g_1^c + g_2^c)/2$ per capita). In

[7] More generally, one may assume that production takes the form $\widetilde{y}_i = \left(A_i \frac{g_i}{(k_i)^{\gamma}}\right)^{\beta} \widetilde{k}_i^{\alpha} \widetilde{l}_i^{1-\alpha}$, where $\gamma \geq 0$. Under such setup, the households' indirect utility function would be strictly concave if and only if $\gamma > 1 - \frac{1-\alpha}{\beta}$.

addition, each district government i is able to provide local infrastructure g_i^d for its own district, and the spending is financed uniformly by all citizens *within* the district (g_i^d per capita).

Government units cannot issue bonds and, hence, must run a balanced budget. For each district i, the stock of local infrastructure and the amount of lump-sum tax satisfy two equalities, respectively:

$$g_i = g_i^c + g_i^d; \tag{6}$$

$$\tau_i = \frac{g_1^c + g_2^c}{2} + g_i^d. \tag{7}$$

Therefore, for each district, using the central government funds to finance the local infrastructure, if possible, is half as cheap as using the district government funds.

We use the vector $\left(g_1^c, g_2^c; g_1^d, g_2^d\right)$ to denote a policy profile — the provision of local infrastructure across districts by all government unites. For convenience, we also refer to (g_1^c, g_2^c) as the "central policy" and each g_i^d as the "district policy."

2.4 Politics

We model the political process following the citizen-candidate approach. That is: (i) policy-makers are elected citizens who maximize their own utility; (ii) voters elect candidates whose policy preferences they like the most. In each district, citizens elect a single legislator from among themselves. Since citizens are homogeneous, the legislator is simply the representative household in the district. The legislator in district i will be in charge of the district government and decide the district policy g_i^d. The legislator will also be part of the central government.

The central government is characterized by the assembly of the two legislators coming from the two districts, respectively. We model the policy-making process in the assembly following the minimum winning coalition approach in the studies of distributive politics (à la Besley and Coate (2003)). The idea is, under majority rule, a coalition of just more than half of the legislators could be form and be able to concentrate the central government funds on their home districts. In our setup, each of the two legislators constitutes a minimum winning coalition on her own, and there are two equally likely minimum winning coalitions — legislator 1 alone and legislator 2 alone. Each of the two legislators is selected, with probability $\frac{1}{2}$, to be in charge of the central government and choose the central policy (g_1^c, g_2^c).[8]

[8] More generally, one may consider an assembly with $N \geq 2$ legislators representing N districts. Any minimum winning coalition has a size of $\lceil N/2 \rceil$ members. For any single legislator, the probability of being in a minimum winning coalition is given by $\begin{pmatrix} N-1 \\ \lceil N/2 \rceil - 1 \end{pmatrix} \Big/ \begin{pmatrix} N \\ \lceil N/2 \rceil \end{pmatrix} = \frac{\lceil N/2 \rceil}{N}$. We derive our main results using the simplest case: the two-member assembly.

We study two governmental systems: the federal and unitary systems. The two systems differ in the timing of policy-making between the central and district levels:

- In a *federal* system: (i) firstly, the assembly meet and select one member to choose the central policy, denoted by $\left(g_1^{c,F}, g_2^{c,F}\right)$, for both districts; (ii) then, each legislator i simultaneously chooses the district policy, denoted by $g_i^{d,F}$, for her own district.
- In a *unitary* system: (i) firstly, each legislator i simultaneously chooses the district policy, $g_i^{d,U}$; (ii) then, the assembly meet and select one member to choose the central policy, $\left(g_1^{c,U}, g_2^{c,U}\right)$.

The idea behind this formulation is that, in practice, the central government in a unitary state has the ultimate decision-making power. In federations, however, the division of power between the two government levels is outlined by the constitution and, for many federations, the residual powers are retained by sub-national governments. In the model, we formalize the holder of the ultimate power as the second mover in the inter-governmental interaction.

Since the policy-making process in the assembly has uncertainty, the difference in timing between the two systems implies that: (i) in a federal system, the district policies are *contingent* on which legislator is in charge of the assembly; (ii) in a unitary system, however, the district policies have to be made *before* the uncertainty in the assembly is resolved.

2.5 Timeline

For each governmental system, the events unfold according to the following timeline:

1. Policy profile $\left(g_1^c, g_2^c; g_1^d, g_2^d\right)$ is decided by the central and district governments.
2. In each district, the stock of local infrastructure g_i and the lump-sum tax τ_i are determined according to (6) and (7).
3. Households and firms make their individual decisions in the competitive markets.

3 Policy Determination

We examine the policy determination in different governmental systems by backwards induction.

3.1 Competitive Equilibrium

For each district i, given local infrastructure g_i and lump-sum tax τ_i, the competitive equilibrium is characterized by the first-order conditions for households, (2), and firms, (4) and (5). In equilibrium, labor is equal to 1 and capital stock is a function of local infrastructure:

$$k_i(g_i) = (\alpha)^{\frac{1}{1-\alpha+\beta}} (A_i g_i)^{\frac{\beta}{1-\alpha+\beta}}. \tag{8}$$

Since the production function has constant returns to scale in firm-specific inputs, each citizen's gross income, $r_i k_i + w_i$, is equal to the equilibrium output

$$y_i(g_i) = (\alpha)^{\frac{\alpha-\beta}{1-\alpha+\beta}} (A_i g_i)^{\frac{\beta}{1-\alpha+\beta}}, \tag{9}$$

which is also a function of local infrastructure.

From each legislator i's point of view, therefore, a pair (g_i, τ_i) is associated with the indirect utility of the citizens in her district. This indirect utility function is given by

$$\begin{aligned} v_i(g_i, \tau_i) &= x + y_i(g_i) - k_i(g_i) - \tau_i \\ &= x + m_i h(g_i) - \tau_i, \end{aligned}$$

where $m_i \equiv \left(\alpha^{\frac{\alpha-\beta}{1-\alpha+\beta}} - \alpha^{\frac{1}{1-\alpha+\beta}}\right)(A_i)^{\frac{\beta}{1-\alpha+\beta}}$, $h(g_i) \equiv (g_i)^{\frac{\beta}{1-\alpha+\beta}}$, and the second equality uses (8) and (9).[9] Note that h is strictly concave, which is due to the presence of congestion in the use of local infrastructure.

3.2 Policy Determination in a Federal System

In a federal system, the district policies are made after the central policy. By backwards induction, we suppose that legislator i was in charge in the assembly and has made the central policy, $\left(g_i^{c,F}, g_{-i}^{c,F}\right)$. In the second stage, legislator $-i$ (who was not in charge) chooses the district policy, $g_{-i}^{d,F}$, to maximize her objective function

$$\begin{aligned} & v_{-i}\left(g_{-i}^{c,F} + g_{-i}^{d,F}, \frac{g_{-i}^{c,F} + g_i^{c,F}}{2} + g_{-i}^{d,F}\right) \\ = \; & x + m_i h\left(g_{-i}^{c,F} + g_{-i}^{d,F}\right) - \left(\frac{g_{-i}^{c,F} + g_i^{c,F}}{2} + g_{-i}^{d,F}\right). \end{aligned}$$

[9] We omit in the expression the utility function $u(\cdot)$ for the households since, in the point of view of the legislators, maximizing the indirect utility is equivalent to maximizing the equilibrium consumption.

The optimal $g_{-i}^{d,F}$ is obtained from the first-order condition:

$$m_i h'\left(g_{-i}^{c,F} + g_{-i}^{d,F}\right) - 1 = 0$$

That is, not being in charge in the first stage, legislator $-i$ is now on her own in providing local infrastructure. At the optimum, she will provide local infrastructure until the marginal return (proportional to h') equals the marginal cost, 1. Since h' is strictly monotonic, its inverse exists and we can write the optimal $g_{-i}^{d,F}$ as a function of $g_{-i}^{c,F}$:

$$g_{-i}^{d,F}\left(g_{-i}^{c,F}\right) = \left(h'\right)^{-1}\left(\frac{1}{m_i}\right) - g_{-i}^{c,F}. \tag{10}$$

Turning to the selection in the assembly, if legislator i is selected, she will decide not only the central policy, $\left(g_i^{c,F}, g_{-i}^{c,F}\right)$, but also the district policy, $g_i^{d,F}$, later on. The problem the legislator in charge is, hence,

$$\begin{aligned} &\max_{g_i^{c,F}, g_{-i}^{c,F}; g_i^{d,F}} v_i\left(g_i^{c,F} + g_i^{d,F}, \frac{g_i^{c,F} + g_{-i}^{c,F}}{2} + g_i^{d,F}\right) \\ = &\max_{g_i^{c,F}, g_{-i}^{c,F}; g_i^{d,F}} \left\{x + m_i h\left(g_i^{c,F} + g_i^{d,F}\right) - \left(\frac{g_i^{c,F} + g_{-i}^{c,F}}{2} + g_i^{d,F}\right)\right\}. \end{aligned}$$

Two implications are immediate from the maximization problem: (i) it is optimal to set $g_{-i}^{c,F} = 0$ because citizens in district i derive no utility from the local infrastructure provided in district $-i$; (ii) it is optimal to set $g_i^{d,F} = 0$ because, from the point of view of district-i citizens, it is always *half* as cheap to provide local infrastructure using central government funds than using district government funds. Therefore, the problem for legislator i is simplified to

$$\max_{g_i^{c,F}} \left\{x + m_i h\left(g_i^{c,F}\right) - \frac{g_i^{c,F}}{2}\right\}$$

and the solution is given by the first-order condition:

$$m_i h'\left(g_i^{c,F}\right) - \frac{1}{2} = 0 \Leftrightarrow g_i^{c,F} = \left(h'\right)^{-1}\left(\frac{1}{2m_i}\right). \tag{11}$$

By (10) and (11), we establish the policy determination in a federal system as:

Proposition 1 *In a federal system, the equilibrium central policy is*

$$\begin{aligned} g_i^{c,F*}(i) &= (h')^{-1}\left(\frac{1}{2m_i}\right), \\ g_i^{c,F*}(-i) &= 0, \end{aligned}$$

while the equilibrium district policy is

$$\begin{aligned} g_i^{d,F*}(i) &= 0, \\ g_i^{d,F*}(-i) &= (h')^{-1}\left(\frac{1}{m_i}\right), \end{aligned}$$

where $i \in \{1,2\}$, and the arguments of functions $g_i^{c,F*}$ and $g_i^{d,F*}$ specify the identity of the legislator in charge.

Firstly, Proposition 1 shows that whichever legislator in charge in the assembly will provide a large amount $(h')^{-1}\left(\frac{1}{2m_i}\right)$ of local infrastructure in her own district. Moreover, this amount is financed solely by the central government funds. In other words, the central policy is skewed toward the winning legislator.

The proposition also shows that, the district policy is contingent on the identity of the legislator in charge. In particular, the losing legislator will provide some amount $(h')^{-1}\left(\frac{1}{m_i}\right)$ of local infrastructure using her district government funds. This decision is made in response to *the lack of* infrastructure provision when the other legislator was in charge of the central policy. Therefore, district governments as the second move in the game mitigate the skewness of central policy to some extent.

3.3 Policy Determination in a Unitary System

In a unitary system, the district policies are made *before* the central policy. Working backwards again, we suppose the district policies, $\left(g_1^{d,U}, g_2^{d,U}\right)$, have already been made by the respective legislators. In the assembly, each legislator is selected with probability 1/2 to decide the central policy. If in charge, the objective of legislator i is to maximize

$$\begin{aligned} & v_i\left(g_i^{c,U} + g_i^{d,U}, \frac{g_i^{c,U} + g_{-i}^{c,U}}{2} + g_i^{d,U}\right) \\ = \;& x + m_i h\left(g_i^{c,U} + g_i^{d,U}\right) - \left(\frac{g_i^{c,U} + g_{-i}^{c,U}}{2} + g_i^{d,U}\right) \end{aligned}$$

by choosing $g_i^{c,U}$ and $g_{-i}^{c,U}$. Since citizens in district i derive no utility from the local infrastructure provided in district $-i$, it is optimal for legislator i to set $g_{-i}^{c,U} = 0$. Furthermore, the optimal $g_i^{c,U}$, as a function of $g_i^{d,U}$, is given by the first-order condition:

$$m_i h'\left(g_i^{c,U} + g_i^{d,U}\right) - \frac{1}{2} = 0 \Leftrightarrow g_i^{c,U}\left(g_i^{d,U}\right) = \left(h'\right)^{-1}\left(\frac{1}{2m_i}\right) - g_i^{d,U}. \tag{12}$$

Thus, legislator i provides local infrastructure in (and only in) her own district until the marginal return equals the marginal cost, $\frac{1}{2}$. As in a federal system, doing so is half as cheap as using the district government funds.

Turning to the determination of district policies in the first stage, note that the two legislators are equally like to be selected in the assembly later on. When deciding the district policy, therefore, each legislator i's objective is to maximize the expected utility:

$$\max_{g_i^{d,U}} \frac{1}{2}\left\{v_i\left(g_i^{c,U}\left(g_i^{d,U}\right) + g_i^{d,U}, \frac{g_i^{c,U}\left(g_i^{d,U}\right)}{2} + g_i^{d,U}\right)\right.$$
$$\left. + v_i\left(0 + g_i^{d,U}, \frac{g_{-i}^{c,U}\left(g_{-i}^{d,U}\right)}{2} + g_i^{d,U}\right)\right\},$$

where the first part inside the parenthesis corresponds to the scenario of being in charge in the assembly. By substituting (12) into the objective, we derive from the first-order condition the optimal $g_i^{d,U}$:

$$-\frac{3}{2} + m_i h'\left(g_i^{d,U}\right) = 0 \Leftrightarrow g_i^{d,U} = \left(h'\right)^{-1}\left(\frac{3}{2m_i}\right). \tag{13}$$

By (12) and (13), hence, we establish the policy determination in a unitary system.

Proposition 2 *In a unitary system, the equilibrium district policy is*

$$g_i^{d,U*} = \left(h'\right)^{-1}\left(\frac{3}{2m_i}\right),$$

while the equilibrium central policy is

$$\begin{aligned} g_i^{c,U*}(i) &= \left(h'\right)^{-1}\left(\frac{1}{2m_i}\right) - \left(h'\right)^{-1}\left(\frac{3}{2m_i}\right), \\ g_i^{c,U*}(-i) &= 0, \end{aligned}$$

where $i \in \{1, 2\}$, and the argument of function $g_i^{c,U*}$ specifies the identity of the legislator in charge.

Proposition 2 shows that, firstly, the *total* stock of local infrastructure provided by the legislator in charge (say, i) will be a large amount $g_i^{c,U*}(i) + g_i^{d,U*} = (h')^{-1}\left(\frac{1}{2m_i}\right)$, financed jointly by the central and district government funds. The central policy is still skewed toward the winning legislator, as in a federal system.

Secondly, note that the district policy in a unitary system has to be made *before* the uncertainty of the assembly's policy-making is resolved. Therefore, for each legislator (say, $-i$), the district policy $g_{-i}^{d,U*}$ partially mitigates the skewness of central policy only in the event that the other legislator, i, turns out to be winning in the assembly. If the legislator in charge is $-i$ herself, then the earlier provision $g_{-i}^{d,U*}$ will be a waste of money because the infrastructure could have been financed solely by the central government funds.

4 Comparing Governmental Systems

We have shown that the policy-making process in the assembly generates uncertainty in the equilibrium policy for both governmental systems. In what follows, we compare across the two systems the *magnitude* of uncertainty in both policy and output.

We first examine the policy uncertainty. For each governmental system (say, a federal system), we are interested in the uncertainty in three policy variables: (i) the stock of local infrastructure in each district i, i.e.,

$$g_i^{F*}(\cdot) \equiv g_i^{c,F*}(\cdot) + g_i^{d,F*}(\cdot);$$

(ii) the stock of local infrastructure *in the economy*, i.e.,

$$g^{F*}(\cdot) \equiv g_1^{F*}(\cdot) + g_2^{F*}(\cdot).$$

All three are random variables dependent on which legislator is in charge in the assembly. We measure the magnitude of policy uncertainty by the range of values each of the three random variables could take when the legislator in charge changes. For example, the magnitude of policy uncertainty for district i is given by the absolute value $\left|g_i^{F*}(i) - g_i^{F*}(-i)\right|$. The three policy variables in a unitary system are defined in the same way.

The following proposition is the first main result of the paper. It establishes that the policy uncertainty, for any of the three variables, is smaller in a federal system.

Proposition 3 *The uncertainty in the provision of local infrastructure, nationally or sub-nationally, is smaller in a federal system than in a unitary system. Formally,*

$$\left|g^{F*}(i) - g^{F*}(-i)\right| < \left|g^{U*}(i) - g^{U*}(-i)\right|,$$

and, for each $i \in \{1,2\}$,

$$\left|g_i^{F*}(i) - g_i^{F*}(-i)\right| < \left|g_i^{U*}(i) - g_i^{U*}(-i)\right|.$$

The part of the result about sub-national policies delivers the following intuition. For each district i, the stock of local infrastructure attains two possible values. The higher value corresponds to the case of the legislator being in charge, and the total provision is a large amount $(h')^{-1}\left(\frac{1}{2m_i}\right)$ regardless of the governmental system. The lower value, however, is dependent on the governmental system. Compared to a federal system, legislators in a unitary system are *optimistic* when they decide their district policies, because the uncertainty about who will be in charge is not resolved yet and they are both likely to win. This optimism, in turn, will result in the *under*-provision of infrastructure if, when the uncertainty is resolved, the legislator turns out to be losing. The possibility of under-provision, therefore, leads to a larger magnitude of policy uncertainty in the district.

In addition, the first part of the proposition amounts to showing that the above intuition holds up as well when we look at the policy uncertainty at the national level. Therefore, the policy in the entire economy is less uncertain in a federal system than in a unitary system. If we interpret policy uncertainty in the model as *policy volatility* in the data, then this result matches the second stylized fact.

Next, we next study how the uncertainty in policy affects the uncertainty in output. Similar to the above, we define, for a federal system, three output variables: (i) the output in each district i, i.e., $y_i\left(g_i^{F*}(\cdot)\right)$, where the output function y_i is given by (9); (ii) the output *in the economy*, i.e.,

$$y^{F*}(\cdot) \equiv y_i\left(g_i^{F*}(\cdot)\right) + y_{-i}\left(g_{-i}^{F*}(\cdot)\right).$$

The counterpart for a unitary system are defined similarly.

Analogous to Proposition 3, the second main result of the paper shows that the output uncertainty, for any of the three variables, is smaller in a federal system as well:

Proposition 4 *The uncertainty in output, nationally or sub-nationally, is smaller in the federal system than in a unitary system. Formally,*

$$\left|y^{F*}(i) - y^{F*}(-i)\right| < \left|y^{U*}(i) - y^{U*}(-i)\right|,$$

and, for each $i \in \{1,2\}$,

$$\left|y_i\left(g_i^{F*}(i)\right) - y_i\left(g_i^{F*}(-i)\right)\right| < \left|y_i\left(g_i^{U*}(i)\right) - y_i\left(g_i^{U*}(-i)\right)\right|.$$

Proposition 4 can be understood as a direct consequence of Proposition 3. For each district i, given any equilibrium stock of local infrastructure g_i, the equilibrium output y_i is as given in equation (9):

$$y_i(g_i) = (\alpha)^{\frac{\alpha-\beta}{1-\alpha+\beta}} (A_i g_i)^{\frac{\beta}{1-\alpha+\beta}},$$

which is an increasing function of g_i. Proposition 4 shows that, given the simple economic environment of the model, the uncertainty in policy g_i is directly passed on to the uncertainty in output y_i. Again, with the interpretation of output uncertainty in the model as *growth volatility* in the data, this result matches the first stylized fact as well.

5 Conclusion

This paper contributes to the literature by being the first to explore the relationship between governmental system (federal versus unitary systems) and economic volatility within democracies. Two stylized facts are established: both economic growth and fiscal policy are less volatile in federal systems than in unitary systems. We have developed a theory to match these facts. In our theory, the policy stipulated by the central government is more volatile because who is in power is more uncertain than that of district governments. Fiscal policy is less volatile in a federal system because district governments have more power to overcome the volatility of policy made by the central government. Lastly, policy volatility leads to growth volatility because fiscal policy affects the provision of infrastructure which has a productive effect on final output.

The current analysis is more than just positive — it has interesting implications on institutional design as well. It suggests that when we consider whether a governmental system should be federal or unitary, in addition to factors that have already been suggested by previous literature (e.g., externality versus diversity considerations), we need to take into account that being unitary might lead to more economic volatility. Alternatively, when a unitary state devolves into a federation, our theory would suggest that a volatile economic condition might be a contributing factor.

Some extensions of the paper are worth pursuing further. For example, the paper focuses on democratic countries; it would be interesting to extend both the empirical and theoretical exploration to autocratic countries. Furthermore, the current analysis is done in a static model for tractability reasons, but it could be extended to a fully dynamic version. We leave these extensions to future work.

A Empirics

A.1 Data Sources

Fiscal authority of sub-national governments

The data are from the World Bank's Database of Political Institutions created by Beck at al. (2001). We use the "federalism_author" indicator from the database to measure the fiscal authority of sub-national governments. The indicator takes value 1 if sub-national governments have the local authority over taxing, spending, or legislating. It takes value 0 if none of the three authorities is present. Unfortunately, the database does not separate legislative authority from fiscal authority which is what we focus on. In Figures 1 and 2, for each country, we average the data over the period 1990-2013 and assign the country value 1 (the group on the right-hand side) if its sub-national governments have such authority during the entire period, and value 0 otherwise.

Volatility of economic growth

The data are from the World Bank's World Development Indicators database. In Figure 1, for each country, we calculate the interquartile range of the growth rate of GDP per capita (i.e., the difference between the 75th percentile growth rate and the 25th percentile growth rate) over the period 1990-2013.

Volatility of fiscal policy

The data are from the IMF's Government Finance Statistics database. In Figure 2, for each country, we calculate the interquartile range of government spending (% of GDP) over the period 1990-2013.

List of democracies

We use the "eiec" indicator in the Database of Political Institutions to select the sample of democracies. The indicator measures the electoral competitiveness for the chief executive. We include a country in the sample if it has the highest score, 7, for at least 10 years during the period 1990-2013. The full sample is listed as follows.

Unitary systems: Armenia, Bangladesh, Belize, Bulgaria, Central African Republic, Chad, Chile, Costa Rica, Cote d'Ivoire, Croatia, Dominican Republic, Ecuador, El Salvador, Estonia, Gabon, Ghana, Greece, Grenada, Guatemala, Hungary, Mozambique, Nigeria.

Table 1: Effect of fiscal authority on volatility of economic growth.

Dependent variable: interquartile range of GDP per capita growth.

	(1)	(2)	(3)	(4)	(5)
fiscal authority	-1.203^{**}	-1.408^{***}	-1.008^{**}	-1.174^{**}	-1.049^{**}
	(0.019)	(0.005)	(0.046)	(0.025)	(0.042)
GDP per capital, PPP, log-scaled		-0.018			0.168
		(0.929)			(0.528)
GDP, PPP, log-scaled			-0.201^{*}		-0.239
			(0.081)		(0.120)
trade (% of GDP)				0.003	0.003
				(0.697)	(0.741)
constant	4.178^{***}	4.335^{**}	9.096^{***}	3.941^{***}	8.338^{**}
	(0.000)	(0.020)	(0.002)	(0.000)	(0.010)
observations	48	47	47	48	47
R-squared	0.114	0.187	0.242	0.117	0.259

p-values in parentheses

$^{***}p < 0.01,\ ^{**}p < 0.05,\ ^{*}p < 0.1$

Federal systems: Argentina, Australia, Austria, Belgium, Benin, Botswana, Brazil, Canada, Colombia, Comoros, Czech Republic, Finland, France, Germany, India, Italy, Malaysia, Mexico, Nepal, Philippines, Senegal, Spain, Switzerland, Trinidad and Tobago, United States, Venezuela.

A.2 Robustness of Stylized Facts

We first address the robustness of the negative relationship established in Figure 1. We run linear regressions on the volatility of economic growth against the fiscal authority of sub-national governments, with the consideration of three control variables: the level of economic development (measured by GDP per capita, PPP, log-scaled), the size of economy (measured by GDP, PPP, log-scaled), and trade openness (measured by trade as a percentage of GDP).[10] These controls are meant to address the concern that less volatility in a country may be due to being at a higher development level, having a larger economy, or being less open to international trade (i.e., less susceptible to external shocks).

All regression results are reported in Table 1. The coefficient of the fiscal authority is significant with the controls, separately or simultaneously. Besides, a larger economy is indeed associated with less volatility (regression (3)), confirming the conjecture. However, such effect is not significant with the presence of other controls (regression (5)).

Secondly, we address the robustness of the negative relationship established in Figure 2. Similar

[10] All the control variables are from the World Development Indicators, averaged over the period 1990-2013.

Table 2: Effect of fiscal authority on volatility of fiscal policy.

Dependent variable: interquartile range of government spending (% of GDP).

	(1)	(2)	(3)	(4)	(5)
fiscal authority	-2.330^{**}	-2.783^{**}	-1.459	-2.183^{**}	-1.830
	(0.021)	(0.016)	(0.329)	(0.036)	(0.252)
GDP per capital, PPP, log-scaled		0.825			0.949
		(0.248)			(0.222)
GDP, PPP, log-scaled			-0.295		-0.426
			(0.494)		(0.418)
trade (% of GDP)				0.008	-0.003
				(0.529)	(0.825)
constant	5.309^{***}	-2.479	12.681	4.642^{***}	7.282
	(0.000)	(0.711)	(0.246)	(0.002)	(0.598)
observations	26	25	25	26	25
R-squared	0.203	0.237	0.206	0.217	0.265

p-values in parentheses

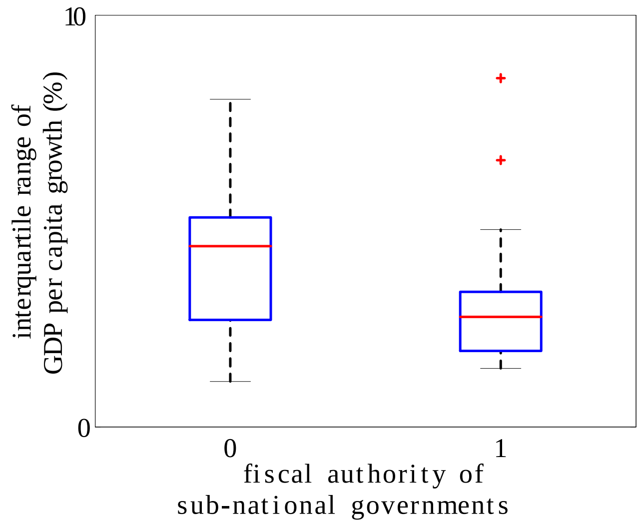
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

to the above, we run linear regressions on the volatility of fiscal policy against the fiscal authority of sub-national governments, with the same set of control variables: the level of economic development, the size of economy, and trade openness.

Table 2 reports all regression results. This negative relationship is less pronounced than the earlier one about the volatility of economic growth. Here, the coefficient of the fiscal authority is significant, except for the cases in which the size of economy is also controlled for (regressions (3) and (5)). However, the (negative) effect of the size of economy on the volatility of fiscal policy is itself insignificant in regressions (3) and (5).

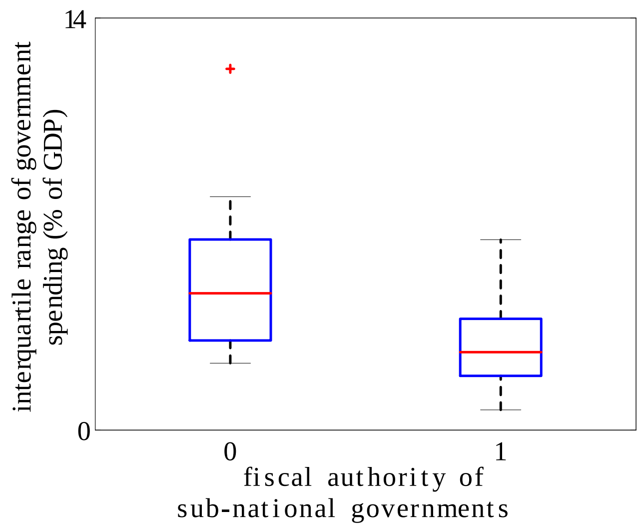
Another way to see the negative relationship between sub-national governments' fiscal authority and economic volatility is to use box plots (Figure 3 for growth volatility and Figure 4 for policy volatility). In each box, the central mark is the median, the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points not considered outliers which, in turn, are plotted individually. In both figures, the box for the group of unitary states have a higher position than the box for the group of federations, consistent with the stylized facts.

Figure 3: Box plot of the volatility of economic growth in 48 democracies, 1990-2013.



(Source: World Bank's *Database of Political Institutions* and *World Development Indicators*.)

Figure 4: Box plot of the volatility of fiscal policy in 26 democracies, 1990-2013.



(Source: World Bank's *Database of Political Institutions* and IMF's *Government Finance Statistics*.)

B Proofs

Proof of Proposition 3.

Part 1: We first show the inequality $\left|g^{F*}(i)-g^{F*}(-i)\right|<\left|g^{U*}(i)-g^{U*}(-i)\right|$. Using Propositions 1 and 2, we rewrite $g^{F*}(i)$ and $g^{U*}(i)$ as

$$\begin{aligned} g^{F*}(i) &= (h')^{-1}\left(\frac{1}{2m_i}\right)+(h')^{-1}\left(\frac{1}{m_{-i}}\right), \\ g^{U*}(i) &= (h')^{-1}\left(\frac{1}{2m_i}\right)+(h')^{-1}\left(\frac{3}{2m_{-i}}\right). \end{aligned}$$

For a federal system, the magnitude of policy uncertainty is given by

$$\begin{aligned} & \left|g^{F*}(i)-g^{F*}(-i)\right| \\ = & \left|\left[(h')^{-1}\left(\frac{1}{2m_i}\right)+(h')^{-1}\left(\frac{1}{m_{-i}}\right)\right]-\left[(h')^{-1}\left(\frac{1}{2m_{-i}}\right)+(h')^{-1}\left(\frac{1}{m_i}\right)\right]\right| \\ = & \left|\left[(h')^{-1}\left(\frac{1}{2m_i}\right)-(h')^{-1}\left(\frac{1}{2m_{-i}}\right)\right]-\left[(h')^{-1}\left(\frac{1}{m_i}\right)-(h')^{-1}\left(\frac{1}{m_{-i}}\right)\right]\right|, \end{aligned}$$

where the second equality follows by rearranging terms. Similarly, the magnitude of policy uncertainty in a unitary system is given by

$$\begin{aligned} & \left|g^{U*}(i)-g^{U*}(-i)\right| \\ = & \left|\left[(h')^{-1}\left(\frac{1}{2m_i}\right)+(h')^{-1}\left(\frac{3}{2m_{-i}}\right)\right]-\left[(h')^{-1}\left(\frac{1}{2m_{-i}}\right)+(h')^{-1}\left(\frac{3}{2m_i}\right)\right]\right| \\ = & \left|\left[(h')^{-1}\left(\frac{1}{2m_i}\right)-(h')^{-1}\left(\frac{1}{2m_{-i}}\right)\right]-\left[(h')^{-1}\left(\frac{3}{2m_i}\right)-(h')^{-1}\left(\frac{3}{2m_{-i}}\right)\right]\right|. \end{aligned}$$

To compare the two magnitudes, we first claim that, for any $z>0$, $(h')^{-1}(z)$ is positive and strictly decreasing. This is because

$$h'(g)=\frac{\beta}{1-\alpha+\beta}g^{-\frac{1-\alpha}{1-\alpha+\beta}}\Leftrightarrow (h')^{-1}(z)=\left(\frac{1-\alpha+\beta}{\beta}z\right)^{-\frac{1-\alpha+\beta}{1-\alpha}}.$$

Next, we define for any $t_2>t_1>0$ a new function

$$H(z;t_1,t_2)\equiv (h')^{-1}(t_1 z)-(h')^{-1}(t_2 z).$$

We claim that: (i) $H(z;t_1,t_2)$ is positive, which is due to $(h')^{-1}$ being strictly decreasing; (ii)

$H(z;t_1,t_2)$ is strictly decreasing in z, because

$$\begin{aligned}
& \frac{\partial H}{\partial z}(z;t_1,t_2) \\
= & -\frac{1-\alpha+\beta}{1-\alpha}\left(\frac{1-\alpha+\beta}{\beta}\right)^{-\frac{1-\alpha+\beta}{1-\alpha}} z^{-\frac{1-\alpha+\beta}{1-\alpha}-1}\left[(t_1)^{-\frac{1-\alpha+\beta}{1-\alpha}}-(t_2)^{-\frac{1-\alpha+\beta}{1-\alpha}}\right]<0,
\end{aligned}$$

where the inequality is due to $(t_1)^{-\frac{1-\alpha+\beta}{1-\alpha}} > (t_2)^{-\frac{1-\alpha+\beta}{1-\alpha}}$. Therefore, we can rewrite the two magnitudes as

$$\begin{aligned}
\left|g^{F*}(i)-g^{F*}(-i)\right| &= H\left(\frac{1}{2};\frac{1}{m_2},\frac{1}{m_1}\right)-H\left(1;\frac{1}{m_2},\frac{1}{m_1}\right), \\
\left|g^{U*}(i)-g^{U*}(-i)\right| &= H\left(\frac{1}{2};\frac{1}{m_2},\frac{1}{m_1}\right)-H\left(\frac{3}{2};\frac{1}{m_2},\frac{1}{m_1}\right),
\end{aligned}$$

where the absolute value notation is removed due to $m_2 > m_1$ and H being strictly decreasing. It follows immediately that $\left|g^{F*}(i)-g^{F*}(-i)\right| < \left|g^{U*}(i)-g^{U*}(-i)\right|$ if and only if

$$H\left(\frac{3}{2};\frac{1}{m_2},\frac{1}{m_1}\right) < H\left(1;\frac{1}{m_2},\frac{1}{m_1}\right)$$

which holds because H is strictly decreasing.

Parts 2: In a federal system, the magnitude of policy uncertainty in district i is rewritten as

$$\begin{aligned}
\left|g_i^{F*}(i)-g_i^{F*}(-i)\right| &= \left|(h')^{-1}\left(\frac{1}{2m_i}\right)-(h')^{-1}\left(\frac{1}{m_i}\right)\right| \\
&= (h')^{-1}\left(\frac{1}{2m_i}\right)-(h')^{-1}\left(\frac{1}{m_i}\right),
\end{aligned}$$

where the absolute value notation is removed due to $(h')^{-1}$ being strictly decreasing. Similarly, the magnitude of policy uncertainty in a unitary system is given by

$$\begin{aligned}
\left|g_i^{U*}(i)-g_i^{U*}(-i)\right| &= \left|(h')^{-1}\left(\frac{1}{2m_i}\right)-(h')^{-1}\left(\frac{3}{2m_i}\right)\right| \\
&= (h')^{-1}\left(\frac{1}{2m_i}\right)-(h')^{-1}\left(\frac{3}{2m_i}\right).
\end{aligned}$$

It follows that $\left|g_i^{F*}(i)-g_i^{F*}(-i)\right| < \left|g_i^{U*}(i)-g_i^{U*}(-i)\right|$ if and only if

$$(h')^{-1}\left(\frac{3}{2m_i}\right) < (h')^{-1}\left(\frac{1}{m_i}\right)$$

which, in turn, holds because $(h')^{-1}$ being strictly decreasing. ■

Proof of Proposition 4.

Part 1: We first show inequality $\left|y^{F*}(i) - y^{F*}(-i)\right| < \left|y^{U*}(i) - y^{U*}(-i)\right|$. Using Propositions 1 and 2, we rewrite $y^{F*}(i)$ and $y^{U*}(i)$ as:

$$\begin{aligned}
y^{F*}(i) &= y_i\left(g_i^{c,F*}(i) + g_i^{d,F*}(i)\right) + y_{-i}\left(g_{-i}^{c,F*}(i) + g_{-i}^{d,F*}(i)\right) \\
&= y_i\left((h')^{-1}\left(\frac{1}{2m_i}\right)\right) + y_{-i}\left((h')^{-1}\left(\frac{1}{m_{-i}}\right)\right), \\
y^{U*}(i) &= y_i\left(g_i^{c,U*}(i) + g_i^{d,U*}(i)\right) + y_{-i}\left(g_{-i}^{c,U*}(i) + g_{-i}^{d,U*}(i)\right) \\
&= y_i\left((h')^{-1}\left(\frac{1}{2m_i}\right)\right) + y_{-i}\left((h')^{-1}\left(\frac{3}{2m_{-i}}\right)\right).
\end{aligned}$$

By (9) and the functional form of $(h')^{-1}$ (derived in the proof of Proposition 3), we derive the expression of $y^{F*}(i)$ as:

$$\begin{aligned}
y^{F*}(i) &= \alpha^{\frac{\alpha-\beta}{1-\alpha+\beta}}\left(A_i\,(h')^{-1}\left(\frac{1}{2m_i}\right)\right)^{\frac{\beta}{1-\alpha+\beta}} + \alpha^{\frac{\alpha-\beta}{1-\alpha+\beta}}\left(A_{-i}\,(h')^{-1}\left(\frac{1}{m_{-i}}\right)\right)^{\frac{\beta}{1-\alpha+\beta}} \\
&= \alpha^{\frac{\alpha-\beta}{1-\alpha+\beta}}\left(\frac{1-\alpha+\beta}{\beta}\right)^{-\frac{\beta}{1-\alpha}}\left[\left(A_i\,(2m_i)^{\frac{1-\alpha+\beta}{1-\alpha}}\right)^{\frac{\beta}{1-\alpha+\beta}} + \left(A_{-i}\,(m_{-i})^{\frac{1-\alpha+\beta}{1-\alpha}}\right)^{\frac{\beta}{1-\alpha+\beta}}\right] \\
&= \Gamma \times \left[(2A_i)^{\frac{\beta}{1-\alpha}} + (A_{-i})^{\frac{\beta}{1-\alpha}}\right],
\end{aligned}$$

where $\Gamma \equiv \alpha^{\frac{\alpha-\beta}{1-\alpha+\beta}}\left(\frac{1-\alpha+\beta}{\beta}\right)^{-\frac{\beta}{1-\alpha}}\left(\alpha^{\frac{\alpha-\beta}{1-\alpha+\beta}} - \alpha^{\frac{1}{1-\alpha+\beta}}\right)^{\frac{\beta}{1-\alpha}}$ is a constant. Therefore, the magnitude of output uncertainty in a federal system is given by

$$\begin{aligned}
&\left|y^{F*}(i) - y^{F*}(-i)\right| \\
&= \Gamma \times \left|\left[(2A_i)^{\frac{\beta}{1-\alpha}} + (A_{-i})^{\frac{\beta}{1-\alpha}}\right] - \left[(2A_{-i})^{\frac{\beta}{1-\alpha}} + (A_i)^{\frac{\beta}{1-\alpha}}\right]\right| \\
&= \Gamma \times \left(2^{\frac{\beta}{1-\alpha}} - 1\right) \times \left|(A_i)^{\frac{\beta}{1-\alpha}} - (A_{-i})^{\frac{\beta}{1-\alpha}}\right|.
\end{aligned}$$

Similarly, we derive $y^{U*}(i) = \Gamma \times \left[(2A_i)^{\frac{\beta}{1-\alpha}} + \left(\frac{2}{3}A_{-i}\right)^{\frac{\beta}{1-\alpha}}\right]$, and the magnitude of output uncertainty in a unitary system is given by

$$\left|y^{U*}(i) - y^{U*}(-i)\right| = \Gamma \times \left(2^{\frac{\beta}{1-\alpha}} - \left(\frac{2}{3}\right)^{\frac{\beta}{1-\alpha}}\right) \times \left|(A_i)^{\frac{\beta}{1-\alpha}} - (A_{-i})^{\frac{\beta}{1-\alpha}}\right|.$$

It follows immediately that $\left|y^{F*}(i) - y^{F*}(-i)\right| < \left|y^{U*}(i) - y^{U*}(-i)\right|$.

Part 2: Similar to Part 1, for each district i, we rewrite and simplify the magnitude of output uncertainty as:

$$\begin{aligned}\left|y_i\left(g_i^{F*}(i)\right)-y_i\left(g_i^{F*}(-i)\right)\right| &= \left|y_i\left(\left(h'\right)^{-1}\left(\frac{1}{2m_i}\right)\right)-y_i\left(\left(h'\right)^{-1}\left(\frac{1}{m_i}\right)\right)\right| \\ &= \Gamma\times\left(2^{\frac{\beta}{1-\alpha}}-1\right)\times\left(A_i\right)^{\frac{\beta}{1-\alpha}}\end{aligned}$$

for a federal system, and

$$\begin{aligned}\left|y_i\left(g_i^{U*}(i)\right)-y_i\left(g_i^{U*}(-i)\right)\right| &= \left|y_i\left(\left(h'\right)^{-1}\left(\frac{1}{2m_i}\right)\right)-y_i\left(\left(h'\right)^{-1}\left(\frac{3}{2m_i}\right)\right)\right| \\ &= \Gamma\times\left(2^{\frac{\beta}{1-\alpha}}-\left(\frac{2}{3}\right)^{\frac{\beta}{1-\alpha}}\right)\times\left(A_i\right)^{\frac{\beta}{1-\alpha}}\end{aligned}$$

for a unitary system. It follows that $\left|y_i\left(g_i^{F*}(i)\right)-y_i\left(g_i^{F*}(-i)\right)\right|<\left|y_i\left(g_i^{U*}(i)\right)-y_i\left(g_i^{U*}(-i)\right)\right|$. ■

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