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Optimal Grants under Asymmetric Information: Federalism versus Devolution

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Abstract

Economic research has inquired the role of *asymmetric information between central and local governments* in shaping the structure of optimal regional grants. In the mainstream literature, the theoretical setting has been characterized by some basic informational asymmetry between central authority and local government (the informed party) about the state of regional *social and economic fundamentals* (i.e. adverse selection). This setting fits quite well in the stylized facts of *consolidated federalism*, while it is hardly satisfactory in the case of *devolved-powers states*: fiscal systems that were recently reformed in the sense of higher degree of decentralization of policy decision-making and implementation (e.g.: Belgium, Italy, etc.). This paper points out that the situation of newly decentralized public systems is better analyzed under *pure moral hazard*: the only source of asymmetric information is the imperfect *verifiability* of local policy (while the information about social and economic fundamentals is symmetric). Building on a simple model, it is shown that the *sign* of optimal distortion that grants induce on regional fiscal policy is likely to differ between federalism (adverse selection and moral hazard) and devolution (pure moral hazard).

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1 Introduction

Intergovernmental fiscal relations are a traditional topic in economics (Inman and Rubinfeld [16]; Oates [25]). In the symmetric information framework characterizing the traditional literature on fiscal federalism, transfers are devised either as matching grants, compensating for fiscal externalities, or as lump sum grants, equalizing tax bases, public needs and production costs.

The traditional view has been challenged during the last two decades. The starting point of the *new* theoretic approach is the recognition that fiscal relations in multi-tier public sector call for an asymmetric information analytic framework. The reason is quite simple. A general preference for decentralized institutional framework cannot be worked out unless some kind of informational asymmetry between central and local governments is taken into account. Such consideration underlies the fundamental results of the traditional fiscal federalism theory (e.g. Oates [24]).

The inconsistency between a complete information analytical setting and, on the other hand, asymmetric information intuitive argument for fiscal decentralization as well as empirical evidence have brought to a *second generation literature* on intergovernmental fiscal relations (Van Puyenbroeck [28]).

The basic idea of the new approach is that local governments have better information about the status of actual *social and economic fundamentals* (e.g. aggregate production, average individual revenues, aggregate tax base, poverty rate, etc.) of their jurisdiction with respect to central authorities. Moreover, central government is unable to *verify* the actual *structure of local policies.* Asymmetric information creates a scope for opportunistic behavior on the local governments side, thus a trade-off between efficiency and distribution arises.

The mainstream approach to intergovernmental transfers with asymmetric information (Boadway *et al.* [4]; Bordignon *et al.* [7]; Bucovetsky [9]; Cremer *et al.* [10]; Cremer and Pestieau [11]; Lockwood [20]; for a survey, see also Van Puyenbroeck [28]) involves an adverse selection framework (i.e. asymmetric information about *the status of fundamentals*). Moral hazard (i.e. asymmetric information about the structure of policies) is considered only as related to adverse selection.

Is the mainstream approach satisfactory on the theoretical and empirical viewpoints? To answer this question, let the *BMT model* (Bordignon *et al.* [6], [7]) be considered. The BMT model addresses the question of the structure of *optimal regional grants* under asymmetric information in a simple setting. The regional governments of the two regions of a country *privately* know the state of local economic activity. Moreover, regional governments can make an unverifiable effort to extract fiscal resources from the economy.

In the framework of the BMT model, two main results are attained: (a) under pure moral hazard, first best (i.e. lump sum) regional grants are implemented; (b) under both adverse selection and moral hazard, second best regional grants are implemented. The second best optimal regional grants are such that: (1) the rich region pays a lump sum transfer (that does not distort its first best allocation); (2) the poor region receives a grant that affects its fiscal policy.

In the BMT model as well as in other mainstream literature analysis, moral hazard is immaterial for the optimal design of regional transfers. How general is this result? In the considered models, the moral hazard involved in fiscal policy is strictly linked to adverse selection: once adverse selection is removed, moral hazard disappears too. Thus, the result can be suspected not to be extendable to pure moral hazard models.

Before going ahead in this direction, it is worth asking why this *theoretical gap* could be interesting on the empirical and policy recommendation viewpoints. Without any intention of comprehensiveness, it can be argued that the distribution of information between central and local governments[1] is *path-dependent*. In other terms, informational asymmetries affecting intergovernmental fiscal relations are determined by the historical distribution of powers and functions. The reason is that the information about social and economic fundamentals *sticks "where" it is processed*, both in terms of politics and bureaucracy. This has to do basically with the fact that information (in general, knowledge) is *incorporated* in human capital and in (human resources) organizational patterns.

The above considerations lead us to detect a fundamental difference between *historically consolidated federal systems* (e.g. US, Canada)[2] and states characterized by recent *power-devolution process* (e.g. Belgium, Italy). An adverse selection model fits well in the stylized facts of historically consolidated federations: local political and bureaucratic authorities retain a more accurate information about social and economic fundamentals of their jurisdictions than the central ones. On the other hand, *devolved-powers states* are characterized by a rather symmetric information about fundamentals between central and local authorities, while the former may find it hard to perfectly verify some local policies. In this case, a pure moral hazard model is more appropriate.

As already pointed out, the existing economic literature on intergovernmental fiscal relations has almost neglected the analysis of pure moral hazard, with some remarkable exception. In particular, d'Aspremont and Gérard-Varet [2] find conditions such that, if (a) regional governments are risk-neutral and (b) the central government is not concerned about interregional distribution, a pure moral hazard setting is compatible with first best regional grants. The assumptions, namely the irrelevance of interregional distribution in central government preferences, are quite demanding if the main theoretical concern is to figure out an optimal interregional redistributive system.

Building on the BMT model, the paper analyzes and contrasts optimal regional grants

[1]Indeed, the argument is extendable to other contexts.

[2]In this paper, *federalism* and *devolution* represent respectively historically decentralized and newly decentralized *governmental systems*. This implies that *new federations* are considered, in the terms of the model, as devolved-powers states. Similarly, the European Union has to be viewed, in the terms of this paper, as a consolidated federal (i.e. decentralized) system.

in the two cases of *federalism* and *devolution*. Public powers assignment is exogenous and identical in the two cases (but *institutional history* and, thus, information distribution differs), namely, regional governments are responsible for fiscal policy (tax rate, tax compliance enforcement, and public service provision) and central government is responsible for interregional equalization design and enforcement. The simple two-region setting, described in section 2, is the basis for the analysis. Section 3 addresses the case of symmetric information between central and regional governments as a benchmark for asymmetric information situations. The way adverse selection (and moral hazard) affects intergovernmental fiscal relations is considered in section 4, finding results similar to the ones already discussed by Bordignon *et al.* [7]. Section 5 analyzes optimal regional grants under moral hazard. Section 6 contrasts the results and concludes.

2 The model

The economy is made by private and public sectors. Private sector produces a composite good, x, through either formal or informal (i.e. grey economy) production units. Public sector is made by a local government in each of the two regions and a central government. Local governments provide a public service, g. The production of public and private goods are constant returns to scale and, for the sake of simplicity, the marginal cost of both composite good and public service is assumed to be normalized to unity and equal across the economy.

Households are assumed to be identical up to the productivity of their production factor, y_j, and their *tax residence*, $j \in \{1, 2\}$. Individual productivity is a non-negative, uniformly distributed random variable

$$Prob\{y_j = y_L\} = Prob\{y_j = y_H\} = \frac{1}{2} \tag{1}$$

where, $y_L < y_H$. For the sake of simplicity, household's productivity is identically distributed and perfectly correlated within each jurisdiction but independent across different regions.

Household's preferences are represented by the utility function

$$u(x_j, g_j) = v(x_j + r(g_j)) \tag{2}$$

where: $v(.)$ and $r(.)$ are strictly increasing, twice continuously differentiable, and concave[3];

[3] A further restriction ($\partial_g r > \frac{1}{2}$) has to be imposed on $r(.)$ to warrant the concavity of indirect objective function of regional governments in fiscal policy. The following convention is, in general, adopted in this paper:

$$\partial^k_{z_1 \ldots z_k} f(\mathbf{z}) = \frac{\partial^k}{\partial z_1 \ldots \partial z_k} f(\mathbf{z})$$

for any $(z_1, ..., z_k)$ elements of the vector $\mathbf{z}$. The same convention is adopted as regards the operator $d(.)$.

x_j is the household's private consumption, and g_j is the publicly-provided service).

Households are endowed with one unit of a composite production factor (e.g. work, capital) that inelastically supply. When the state of regional (hence, individual) productivity is low, it is assumed that households supply only to the formal (public or private) sectors; whereas, with high productivity, households supply also to the informal sector. This rather stark assumption allows the model to discriminate between low- and high-productivity states of the world. The size of informal sector is assumed more sensitive to government policies when the state of the economy is good, while it is rigid in bad states. In the model, this idea appears in a very simple way: private production is entirely formal in the bad state, and extra production that is possible in the good state may be (partially) informal.

By the above assumptions, *gross income* and household's productivity coincide. But, the *net income* earned by households differs from the gross income and may differ across sectors. Namely, the *formal income* (i.e. the income earned from private formal sector or public sector), m_j, is taxed at a rate t_j, fixed by the regional government. The *informal income* is untaxed but it involves a cost linked to tax sheltering or avoidance (a_j), increasing in the gross informal income, $y_j - m_j$, and in the effort of the regional government to squeeze the informal sector (or, alternatively, to enforce tax compliance), c_j:

$$a(y_j, m_j, c_j) = (y_j - m_j)^2 \cdot c_j \tag{3}$$

In this simple model, the regional government may be aware of individual productivity but it is constrained to tax formal income, m_j. This assumption, as elsewhere in the literature (e.g. Bordignon et al. [7]), is a reduced form of a more complex reality. As remarked by Mayshar [22], the game between taxpayers and tax administration alike the one proposed *does not incorporate the notion that the government has a legal 'right' to impose taxes.*

This shortcut allows the model to take into account tax code *incompleteness* (in the sense of *contract theory*; see Bolton and Dewatripont [5], section IV) that hinders regional government to design optimal rules involving perfect *tax compliance*. It is, thus, assumed that households can exploit taxing *loopholes*, at some cost, and that tax code incompleteness (and loopholes) can be reduced by tax administration (in this model, regional governments) at some cost.

The main effect of the considered game between regional government and households is that taxation determines distortions of private choices and, in turn, a deadweight loss in the economy. In other terms, even in the case of symmetric information between central and local governments, the model is a second best one.

Hence, the household's budget constraint is affected by *regional tax policy* (t_j, c_j) but also by the cost of producing income informally (a_j):

$$y_j - t_j \cdot m_j - a_j - x_j \geq 0 \tag{4}$$

Assuming that the regions have the same population and each household is irrelevant with respect to it[4], each regional government (i.e. the local government ruling on jurisdiction j) maximizes the social welfare of its jurisdiction through tax policy (t_j, c_j) under the local budget constraint[5], given the net grant afforded to the local government j by the *intergovernmental grant system*, G_j:

$$G_j + t_j \cdot m_j - g_j - \frac{c_j^2}{2} - \frac{y_H - y_j}{y_H} \geq 0 \tag{5}$$

for any given $y_j \in \{y_L, y_H\}$; where: $t_j \cdot m_j$ is the regional tax revenue; $\frac{c_j^2}{2}$ is the *cost of tax enforcement*; and $\frac{y_H - y_j}{y_H}$ is a fixed cost associated to the functioning of the regional government, that lowers when the regional productivity grows. The last term catches the positive effect of improvements in regional factor productivity on the public sector production process.

The model is designed as a three-stages game. At the first stage, central government fixes the rules for intergovernmental grants implementation[6]. At the second stage, local governments choose tax-expenditure policy mix (tax rate, tax enforcement effort, and local public service levels). At the third stage, households choose taxable income. At the end of the game, the *tax base* (i.e. taxable income) and the tax rate are publicly verifiable and all policies (central and local) are implemented[7].

The distribution of relevant information in the economy is as follows. Households know their productivity (y_j), before choosing taxable income (m_j). Regional and central governments know, at least, the probabilistic distribution of individual productivity. Central government is always able to directly verify the state of tax rate (t_j) and taxable income (m_j), but not the state of other regional policy variables (c_j and g_j). Therefore, in the case in which household's productivity is common knowledge (section 3), regional policies are directly (t_j) or indirectly (i.e. *via* the contract between central and regional governments, c_j and g_j) verifiable, hence the distribution of information between central and regional governments is *symmetric*. If only regional governments are aware of household's productivity (section 4), *adverse selection and moral hazard* characterize intergovernmental relations. Finally, when regional and central governments share the knowledge of individual productivity distribution but are unaware of its actual realization (section 5), *pure*

[4]This assumption justifies household's myopic behavior *vis à vis* the provision of g.

[5]Given the structure of household's preferences (namely, the utility function is increasing in g), the budget constraint holds always with equality.

[6]The assumption underlying the structure of the game is that the central and regional governments *can* commit to implement any given policy for, respectively, interregional transfers and regional taxation. Moreover, no *secession* opportunity is warranted to regional governments (hence, no "participation" constraint will be involved in the analysis).

[7]It is worth to underline that actual tax enforcement effort and provided public good are not directly verifiable.

moral hazard arises.

2.1 Household's optimization program

Following a consolidated approach, the game can be solved by backward induction. It is worth to remark that, the last stage of the model (household's choice of taxable income) is a way to endogenize tax base, m_j, starting from economic fundamentals, y_j, and tax policy, t_j and c_j. This stage remains the same independently of the informational structure of the model affecting the game between central and local governments (the first two stages of the model).

Choosing the share of productive factor to be sold to different sectors amounts to determine the size of taxable income. Given the productivity (i.e. gross income) level[8], y, each household chooses its taxable income (given the structure of *regional fiscal policy*, (t, c, g)), m. The taxable income cannot be lower than y_L, since by assumption, when productivity is low, the production factor is provided only to formal sectors.

By assumption, households are irrelevant with respect to regional population, hence behave myopically with respect to the effect their choices have on public service provision. Therefore, households maximize their welfare by minimizing the sum of tax and non-tax costs associated to the production of their income (given, their productivity):

$$\min_{m \geq y_L} t \cdot m + a(y, m, c) \tag{6}$$

By the necessary and sufficient condition for the minimum, the taxable income is a function of tax rate, tax enforcement effort, and gross income[9]

$$m(y,t,c) = \begin{cases} y_L & \text{if } \frac{t}{2 \cdot c} \geq y - y_L \\ y - \frac{t}{2 \cdot c} & \text{if } \frac{t}{2 \cdot c} < y - y_L \end{cases} \tag{7}$$

3 Optimal regional grants under symmetric information

In the considered model, central and regional objective functions coincide, therefore possible divergence between the interests of the principal (central government) and of the agents (regional governments) could arise only for redistribution or incentive reasons.

The traditional view on intergovernmental fiscal relation points out that optimal equalization grants, in absence of informational asymmetries between central and regional governments, internalize fiscal externalities by matching grants and redistribute by lump sum

[8]Regional index is omitted to keep the notation simpler.

[9]It has to be remarked that, given the assumptions about the structure of the game, household's preferences, and the avoidance expenditure function is the household's *reaction function* (*à la* Stackelberg) to the local government's policies.

transfers. In game-theoretic terms, central government designs *symmetric-information optimal grants* that are conditioned by social and economic fundamentals of different regions and that impose prohibitive costs for opportunistic behaviors of regional governments.

In this section, optimal transfer rules under symmetric information are considered to work out a benchmark for the asymmetric information analysis. The information about regional income is assumed to be complete, namely, central and local authorities know regional productivity. In this case, central government is able to (indirectly) verify the status of all regional policies. Moreover, the capacity of central government to design transfers is unconstrained, hence *lump sum* grants are implementable[10].

3.1 Optimal regional policy

The assumed structure of household's preferences (namely, the utility is increasing in g) imply that the local public budget (5) holds always with equality. Thus, the (indirect) objective function of the local government can be written as

$$W(y,t,c,G) = u\left(y - t \cdot m(y,t,c) - a(y, m(y,t,c), c), G + t \cdot m(y,t,c) - \frac{c^2}{2} - \frac{y_H - y}{y_H}\right) \tag{8}$$

for any $y \in [y_L, y_H]$ and $G \in \Re_+$.

In the Appendix A, sufficient conditions for the concavity of the regional government's objective function (8) are considered.

[10]In contract theory terms, central government policy is characterized by *completeness*: there are no costs to design and enforce such policy. The latter assumption, though consistent with perfect commitment involved in the Stackelberg's structure of the model, is potentially inconsistent with incompleteness of tax code, underlying the tax game between regions and households. A *reconciliation* between these two parts of the model can be found in the following argument. Tax code, applying to the relationship between state and individuals, has to regulate a huge number of situations and issues in a relatively simple way. On the other side, a granting system is characterized by a better balance between complex situations to be tackled and suitable (i.e. complicated) mechanisms that can be designed and managed. Empirically, it can be observed that a huge political debate points at reducing complexity of taxing rules, while complexity and technicalities often characterize equalization formulas.

The Kuhn-Tucker conditions for the maximum of (8)[11] are

$$\begin{aligned} \partial_t W &= -\partial_x u \cdot m + \partial_g u \cdot (m + t \cdot \partial_t m) \leq 0 \\ \partial_c W &= -\partial_x u \cdot \partial_c a + \partial_g u \cdot (t \cdot \partial_c m - \partial_c e) \leq 0 \end{aligned} \tag{9}$$

the first addend of conditions (9) - determined by Roy's identity - is the marginal disutility (in terms of private consumption) of an increase of tax rate (first condition) or tax collection effort (second condition), while the second addend is the marginal utility of the same change in regional policy (in terms of public service provision).

Excluding corner solutions, the following optimization conditions are obtained

$$\begin{aligned} MRS = \frac{\partial_g u}{\partial_x u} &= \frac{1}{1 + \frac{t}{m} \cdot \partial_t m} = MCPF_t \\ MCPF_t = \frac{1}{1 + \frac{t}{m} \cdot \partial_t m} &= \frac{\partial_c a}{t \cdot \partial_c m - \partial_c e} = MCPF_c \end{aligned} \tag{10}$$

The economic intuition underlying the optimal regional policy, conditions (10), is:

1. the *"public" marginal willingness to pay* (or marginal rate of substitution between private and public consumption - MRS) for an increase in the local service level is equal to the *marginal cost of public service provision*[12] - condition (10);

2. the *marginal cost of public funds* raised through different *policy instruments* (tax rate - $MCPF_t$ - or tax enforcement - $MCPF_c$) is equalized - condition (10).

It has to be remarked that, if $y = y_L$, then $MCPF_t = 1$ and $MCPF_c = 0$; therefore, in the case of low productivity, the regional taxation does not entail deadweight losses (hence, the first best allocation is attained) and it is easy to check that the optimal tax enforcement effort is zero. Moreover, when $y = y_H$, if the optimal tax rate is such that $\frac{t}{2 \cdot c} \geq y_H - y_L$, then taxable income collapses to $m = y_L$ whatever the tax enforcement level. Then, taxation is nondistorsive and the optimal enforcement effort becomes zero.

[11] The optimization program is

$$\begin{aligned} &\max_{t,c} W(t,c) \\ &\quad s.t. : \\ &t \geq 0 \quad (\mu_t) \\ &c \geq 0 \quad (\mu_c) \end{aligned}$$

By the strict concavity of the optimization program, the first order conditions are necessary and sufficient for the global maximum (Beavis and Dobbs [3]). In the Appendix A, the existence of the solution is discussed.

[12] The marginal cost of public service provision is given by the product of the *marginal cost of public production* (that in this paper is assumed to be one) and the *marginal cost of public funds* ($MCPF_t$ and $MCPF_c$).

3.2 Optimal interregional grants

When the productivity of both regions is publicly verifiable, intergovernmental relations are characterized by *symmetric information.* Indeed, if the productivity of region j is publicly verifiable, then its regional policy, (t_j, c_j, g_j), is completely verifiable *via* taxable income function, $m(y_i, t_j, c_j)$, (given that the tax rate is always verifiable).

Regional productivity is *ex ante* a random variable taking two possible values: good, y_H, and bad, y_L (with $y_H > y_L$). The probability distribution is identical and independent across regions and uniform. Thus, there are four equally probable states-of-the-world: both regions are poor, region 1 is poor and region 2 is rich, region 1 is rich and region 2 is poor, both regions are rich. It has to be underlined that, in terms of central public budget, the cases in which one region is poor and the other is rich are identical. Hence, the central budget constraint can be simplified by representing the transfer from rich to poor region as G. Assuming that the central government chooses its policy *ex ante* with respect to the revelation of regional productivity, but that it is *ex post* able to verify it (which amounts to write the central government problem in terms of *pure utilitarian* social welfare function), central and local objective functions perfectly correspond as regards the optimal regional policy.

Thus, the central government will maximize its objective function[13] by choosing an optimal (horizontal) system of lump sum grants (G)[14]

$$\max_{\{G^*\}} W_{HH}(t^*_{HH}, c^*_{HH}, 0) + W_{HL}(t^*_{HL}, c^*_{HL}, -G^*) + \\ W_{LH}(t^*_{LH}, 0, G^*) + W_{LL}(t^*_{LL}, 0, 0) \tag{11}$$

where: $W_{HH}(t^*_{HH}, c^*_{HH}, 0)$ is the welfare of the rich region, when the other region is rich; $W_{HL}(t^*_{HL}, c^*_{HL}, -G^*)$ is the welfare of the rich region, when the other region is poor; $W_{LH}(t^*_{LH}, 0, G^*)$ is the welfare of the poor region, when the other region is rich; and $W_{LL}(t^*_{LL}, 0, 0)$ is the welfare of the poor region, when the other region is poor. As already pointed out, the optimal tax collection effort is zero when the region is poor.

This way of writing the program of the central government amounts to consider that regional tax policy is decided after regional incomes are revealed (or communicated), this is part of the very logic of the centralization of information involved in the principal-agent scheme (also under asymmetric information).

By the *Envelope Theorem*, $d_G W_{sz} = \partial_G W_{sz}$ for any $s, z \in \{L, H\}$, hence, the first

[13]The strict concavity of $B(y, t, c, G)$ is a sufficient condition for concavity of the central government's objective function (see Appendix A).

[14]The optimization program of central government does not incorporate any *participation constraint*, given the "no secession" assumption.

order conditions[15] are

$$G: \qquad -\partial_G W_{HL} + \partial_G W_{LH} = 0 \tag{12}$$

Given that $\partial_G W_{sz} = \partial_g u_{sz}$, conditions (12) imply

$$\partial_g u_{HL} = \partial_g u_{LH} \tag{13}$$

The solution of central government optimization program bring to the following statement

Proposition 3.1 *Under symmetric information*[16] *between central and local governments, optimal regional grants determine the equalization of the* social marginal utility of public service *across regions.*

The allocation given by the set of conditions (10) and (13) can be, trivially, obtained in a *centralized* institutional framework where the central government chooses (through its optimization program) the set of local policies for all the regions, $\{(t_j, c_j, g_j)\}_{j=1}^{2}$, determining either *deficit* or *surpluses* with respect to the (*notional*) local public budget. Notional surpluses and deficits compensate each other at aggregate level (central public budget). The *equivalence* between centralized and the decentralized framework is crucially linked to the absence of any *uniformity constraint* (as the one assumed by Oates [24]) to central policy.

This is a special case of the *decentralization principle* investigated by asymmetric information literature[17]. The decentralization principle is *robust* against the relaxation of symmetric information assumption. Both adverse selection and moral hazard leave unaffected the *equivalence between centrally commanded and locally determined policies*, though (as argued below) the structure of *decentralizable policies* is, generally speaking, affected by the peculiar distribution of information that shapes intergovernmental relations.

4 Optimal regional grants in federal states

Asymmetric information is introduced in the above setting by assuming that household's productivity, y_j ($\forall j \in \{1, 2\}$), is *not* verifiable by all public authorities. The relaxation of the assumption about the verifiability of y_j implies that also the tax enforcement effort, c_j, is no more verifiable (via taxable income function).

[15] Conditions (12) are necessary and sufficient for the maximum given the concavity of the objective functions of the local governments.

[16] This statement is valid also under *incomplete* (but symmetric) information as we will see in the following.

[17] See for all Myerson [23], Poitevin [26].

The introduction of *incomplete information* determines two possible information asymmetries between central and local governments. If regional governments are still able to verify the state of regional productivity, asymmetric information is due to both *adverse selection and moral hazard* (where moral hazard is given by the non-observability of the tax collection effort, c). If, on the contrary, regional governments are not able to *ex ante* verify the state of regional productivity, then a *pure* moral hazard setting is relevant for the analysis.

This section focuses on the case of asymmetric information in consolidated federal systems, that is characterized by adverse selection and moral hazard. Section 5 will study optimal regional grants in devolved-powers states. In section 4.1, conditions under which complete information grants fail to be optimal are inspected. In particular, it will be argued that moral hazard is not a qualifying characteristic of the model considered in this section; thus, it can be analyzed as a *pure adverse selection* one. Then (section 4.2), the features of optimal regional grants under adverse selection are explored in a simple two-states-of-regional-productivity model.

4.1 Incentive-compatibility of symmetric information grants

The distribution of information between central and regional authorities under federalism could bring the latter ones to perform opportunistic behavior on the basis of their *private* capacity to verify regional productivity. It is, consequently, worth to examine the structural conditions (on preferences and technologies) effecting incentive incompatibility of complete information grants under adverse selection and moral hazard.

As first, let us point out the *irrelevance of moral hazard* in the specified framework (as in the bulk of adverse-selection literature on intergovernmental grants). The reason is quite simple and, in the following, a standard textbook argument (by Mass-Colell *et al.* [21], p. 502) is recalled. As shown in section 2.1, the tax game between households and regional government determines a regional tax base function: $m(y, t, c)$. For any given regional tax policy (t and c), regional productivity, y, is an invertible function of tax base m. By assumption, regional tax rate is publicly known and verifiable. Hence, if a regional government cheats about its fundamentals (the value of y), it has to choose an adequate level of tax collection effort (c) to *sustain its deviation.* In other terms, there is only *one degree of freedom* in possible deviations of regional governments. This allow to treat the situation under consideration as *pure adverse selection.*

We now consider the incentive compatibility of symmetric-information intergovernmental grants, determined by the central government's optimization program (11). The complete information grant system is written as a *complete contract* between central and regional governments. Indeed, under complete information, regions cannot deviate from their optimal regional policy (10) to manipulate interregional grants. But, under adverse selection, a *safe* manipulation of the grant mechanism may arise.

Now, we observe that under adverse selection low-productivity regions cannot deviate. Indeed, by the structure of the taxable income function - expression (7) - when the regional productivity is low, whatever tax policy parameters are, taxable income is $m = y_L$ and, as pointed out, this makes useless the enforcement effort (that is optimally fixed to zero). Only high productivity regions are able to deviate by declaring a low income and, consistently, fix tax enforcement effort to zero. In the following, it is assumed that symmetric information optimal central and regional policies are not implementable under adverse selection; therefore, it is assumed that

$$\begin{aligned} W_{HH}(t^*_{HH}, c^*_{HH}, 0) + W_{HL}(t^*_{HL}, c^*_{HL}, -G^*) < \\ < \hat{W}_{HH}(t^*_{LH}, 0, G^*) + \hat{W}_{HL}(t^*_{LL}, 0, 0) \end{aligned} \tag{14}$$

where: $\hat{W}_{HH}(t^*_{LH}, 0, G^*)$ is the welfare of the rich region mimicking the poor region, when the other region is rich; $\hat{W}_{HL}(t^*_{LL}, 0, 0)$ is the welfare of the rich region mimicking the poor region, when the other region is poor; (t^*_{HH}, c^*_{HH}), (t^*_{HL}, c^*_{HL}), $(t^*_{LH}, 0)$, $(t^*_{LL}, 0)$, and G^* are the regional and central optimal policies under symmetric information.

The structure of the incentive incompatibility condition (14) highlights the timing of the very incentive problem: the region uncovers its own productivity, y, while it does not know the other region's one. Condition (14) insures that the incentive problem, in this case, is actually relevant. As argued before, the considered structure of the incentive problem is consistent with the differentiation of tax regional policies in the four eventual states of the regional productivity. Indeed, consistency between incomplete information suffered by each region (*vis vis* the other region) and regional tax policies taking into account all (truthfully revealed) information is regained through the centralization of information underlying the application of the revelation principle.

4.2 Optimal regional grants in federal states

In this section, optimal regional grants features and effects are examined in a simple adverse selection framework similar to the BMT model (Bordignon *et al.* [7]). Now, the central government is unable to verify regional productivity (that is *privately* known by each regional government), hence its optimization program has to incorporate an incentive compatibility constraint:

$$\begin{aligned} W_{HH}(t_{HH}, c_{HH}, 0) + W_{HL}(t_{HL}, c_{HL}, -G) \geq \\ \geq \hat{W}_{HH}(t_{LH}, 0, G) + \hat{W}_{HL}(t_{LL}, 0, 0) \end{aligned} \tag{15}$$

the expected value of complying has to be as high as the expected value of cheating for the regional government; where: $W_{HH}(t_{HH}, c_{HH}, 0)$ is the welfare of the rich region choosing the truth-telling regional policy, when the other region is rich; $W_{HL}(t_{HL}, c_{HL}, -G)$ is the welfare of the rich region choosing the truth-telling regional policy, when the other region is poor; $\hat{W}_{HH}(t_{LH}, 0, G)$ is the welfare of the rich region cheating, when the other region is rich; and $\hat{W}_{HL}(t_{LL}, 0, 0)$ is the welfare of the rich region cheating, when the other region is poor.

The central government's program under adverse selection entails the maximization of the expected regional welfare under the incentive constraint.

$$
\begin{aligned}
\max_{\{t_s, c_s\}_{s\in\{HH,HL,LH,LL\}}, G} \quad & W_{HH}(t_{HH}, c_{HH}, 0) + W_{HL}(t_{HL}, c_{HL}, -G) + \\
& W_{LH}(t_{LH}, 0, G) + W_{LL}(t_{LL}, 0, 0) \\
& s.t.: \\
W_{HH}(t_{HH}, c_{HH}, 0) + W_{HL}(t_{HL}, c_{HL}, -G) \geq & \qquad (\theta) \\
\geq \hat{W}_{HH}(t_{LH}, 0, G) + \hat{W}_{HL}(t_{LL}, 0, 0) &
\end{aligned}
\tag{16}
$$

By Kuhn-Tucker necessary conditions,

$$
\begin{aligned}
t_{HH}: \quad & \partial_t W_{HH} \cdot (1+\theta) \leq 0 \\
c_{HH}: \quad & \partial_c W_{HH} \cdot (1+\theta) \leq 0 \\
t_{HL}: \quad & \partial_t W_{HL} \cdot (1+\theta) \leq 0 \\
c_{HL}: \quad & \partial_c W_{HL} \cdot (1+\theta) \leq 0 \\
t_{LH}: \quad & \partial_t W_{LH} - \theta \cdot \partial_t \hat{W}_{HH} \leq 0 \\
t_{LL}: \quad & \partial_t W_{LL} - \theta \cdot \partial_t \hat{W}_{HL} \leq 0 \\
G: \quad & -\partial_G W_{HL} + \partial_G W_{LH} - \theta \cdot (\partial_G \hat{W}_{HH} + \partial_G W_{HL}) = 0
\end{aligned}
\tag{17}
$$

results similar to Bordignon *et al.* [7] are obtained. The central government's redistributive policy proves to be *less equalizing* than under complete information

Proposition 4.1 *Under adverse selection (and moral hazard), optimal regional grants do not completely off-set interregional inequalities in terms of social marginal utility of public service.*

Proof. Redistribution occurs only in the states of the world in which there is a productivity differential among regions. By condition G in (17)

$$\partial_G W_{LH} > \partial_G W_{HL} \tag{18}$$

given that, by assumption, the incentive-compatibility constraint is binding. ∥

Optimal regional grants under adverse selection does not affect regional policy of rich regions with respect to symmetric information one. Nevertheless, a *tax-rate effort premium* (i.e. an optimal *upward distortion* of the tax rate) affects the regional policy of poor regions. As usual, the optimal distortion allows a relaxation of incentive-compatibility constraint for rich regions. In other terms, the marginal willingness to pay is lower than the marginal cost of public funds for poor regions.

Proposition 4.2 *Under adverse selection (and moral hazard), optimal regional grants (1) do not affect tax policy of rich region and (2) induce* tax-rate effort premium*, with respect to the optimal regional policy under symmetric information.*

Proof. See Appendix B. ‖

Under the specified setting (preferences and technology) and under adverse selection, optimal regional grants involve (1) imperfect equalization grant system (trade off between redistribution and incentives) and, for poor regions, (2) a tax effort premium. The specific assumptions about preferences and technology deliver a more defined result with respect to Bordignon *et al.* [7]. This will prove useful to contrast the normative effect of optimal regional grants in the case of adverse selection and moral hazard.

5 Optimal regional grants in devolved-powers states

In section 4, asymmetric information was introduced as a fundamental difference between central and regional governments in the capacity to verify actual regional income. A better knowledge of social and economic fundamentals was argued to characterize federalism. In the case of devolution, the capacity to verify the status of social and economic fundamentals has to be viewed as basically *symmetric*. This symmetry, nevertheless, is not sufficient to recover *perfect information*. Indeed, regional governments are able to hide their tax collection policies, thus the informational setting is a pure moral hazard one.

In section 5.1, the model is adapted to the incomplete information setting. Section 5.2 updates the benchmark case of optimal grants under symmetric but incomplete information. In section 5.3, incentive compatibility under moral hazard is addressed. Section 5.4 focuses on optimal regional grants under moral hazard.

5.1 The incomplete information setting

Under pure moral hazard, it is crucial to understand the structure of regional and central policies, to correctly write and solve the central government's optimization program. Let us recall the informational structure of the model under incomplete information. Both central and local governments do not observe regional income *realization* when decide their policies, and cannot verify it *ex post*. Central government observes regional tax rates and designs optimal grants. To exploit at best its information and implement interregional redistribution, central government will *condition* interregional transfer on actual realization of m and t. In other terms, redistribution between the two regions can be implemented only on the basis of *ex post* values taken by observable variables (in this case, t and m). Regional governments choose their tax policy (t and c) on the basis of the optimal granting system.

Putting it in probabilistic terms, both regional and central governments now face a probability distribution of m depending on regional tax policy (t, c) which is only partially observable (t), while it is partially *hidden action* (c). The structure of the model insures that tax collection effort is also *ex post* un-observable. Otherwise, the central government could condition its own policy - G - to the *ex post* verification of c. Indeed, if the regional government shrinks, taxable income falls at its lowest level whatever the state of productivity $y \in \{y_L, y_H\}$. But, a low level of taxable income does not provide any *ex post* information about the level of c: this is so because in the low state of regional productivity, taxable income is invariably low. Hence, once the central government observes $m = y_L$ cannot conclude anything about the behavior of the concerned regional government.

Thus, the probability distribution of m can be determined

$$\begin{aligned} Prob\left\{ m \leq y_L \;\middle|\; \frac{t}{2 \cdot c} \geq y_H - y_L \right\} &= 1 \\ Prob\left\{ m \leq y_L \;\middle|\; \frac{t}{2 \cdot c} < y_H - y_L \right\} &= \frac{1}{2} \\ Prob\left\{ m \leq y_H - \frac{t}{2 \cdot c} \;\middle|\; \frac{t}{2 \cdot c} < y_H - y_L \right\} &= 1 \end{aligned} \tag{19}$$

The probability distribution (19) respects *first order stochastic dominance.* Starting form values of t and c such that

$$\frac{t}{2 \cdot c} \geq y_H - y_L$$

then a sufficiently large reduction of t or increase of c may reverse the inequality (20), thus making *more probable* higher levels of m. If the values of t and c are such that the inequality (20) is reversed, then a reduction of t or increase of c raises the value of $m = y_H - \frac{t}{2 \cdot c}$ that is reached in the high state of the regional income.

5.2 Re-defining symmetric information policies

Up to this point, the properties of *optimal policies under symmetric information* have been analyzed through a *complete information* setting. This restriction involves no loss of generality as long as interregional redistribution is taken into account. In other terms, Proposition 3.1 holds also under incomplete (but symmetric) information.

On the contrary, under incomplete information, optimal regional policies change, with respect to complete information. The reason is that while optimal regional grants can be (and are) determined on an *ex post* basis - thus equalizing *ex post* social marginal utility of public funds, regional policies are necessarily chosen *ex ante* with respect to the realization of the fundamental random process (on m), and indeed they influence it as shown in the previous section. Hence, regional governments have to determine their tax policy on the basis of the expectation of m.

The central government's program is, thus, constrained by reduced available information (regional tax policy is now invariable for the four possible states of the regional incomes)

$$\max_{\{t',c',G'\}} W_{HH}(t',c',0) + W_{HL}(t',c',-G') + W_{LH}(t',c',G') + W_{LL}(t',c',0)$$

Optimization conditions are

$$\begin{aligned} t': \quad & \partial_t E[W] = 0 \\ c': \quad & \partial_c E[W] = 0 \\ G': \quad & \partial_G W_{LH} = \partial_G W_{HL} \end{aligned} \tag{20}$$

where

$$\begin{aligned} \partial_t E[W] &= \partial_t W_{HH} + \partial_t W_{HL} + \partial_t W_{LH} + \partial_t W_{LL} \\ \partial_c E[W] &= \partial_c W_{HH} + \partial_c W_{HL} + \partial_c W_{LH} + \partial_c W_{LL} \end{aligned}$$

and (t',c',G') are the optimal central and regional policies under symmetric but incomplete information.

Proposition 3.1 still holds: *optimal regional grants under symmetric (and incomplete) information entails the interregional equalization of social marginal utility of public funds.* In other terms, the effect of optimal grants on redistribution remains unchanged with respect to complete information. It is not so for regional tax policy, since the tax rate and enforcement effort are chosen *ex ante* with respect to the realization of regional incomes.

5.3 Incentive incompatibility of symmetric information grants

If tax enforcement is not verifiable by central government, a region could increase its welfare by *deviating from the optimal symmetric information policy* (i.e. tax enforcement implied by (20)). Symmetrically to the case of adverse selection, we assume that

$$\begin{aligned} & W_{HH}(t',c',0) + W_{HL}(t',c',-G) + W_{LH}(t',c',G) + W_{LL}(t',c',0) < \\ & < \tilde{W}_{HH}(t',0,G) + \tilde{W}_{HL}(t',0,0) + \tilde{W}_{LH}(t',0,G) + \tilde{W}_{LL}(t',0,0) \end{aligned} \tag{21}$$

where $\tilde{W}_{sz}$ (for any $s, z \in \{L, H\}$) is the welfare of regions that lower (to zero) their tax enforcement effort, thus depressing taxable income ($m = y_L$) for any state of regional productivity. The effect of regional tax policy (hidden reduction of tax collection effort) reflects on the other region via the grant system, thus producing an interregional fiscal externality.

5.4 Optimal regional grants in devolved-powers states

Central government is unable to verify c and, given the assumption introduced in the last section, its optimization program has to incorporate an incentive compatibility constraint. The central government's program under moral hazard is

$$\begin{gathered} \max_{t,c,G} W_{HH}(t,c,0) + W_{HL}(t,c,-G) + W_{LH}(t,c,G) + W_{LL}(t,c,0) \\ s.t.: \\ W_{HH}(t,c,0) + W_{HL}(t,c,-G) + W_{LH}(t,c,G) + W_{LL}(t,c,0) \geq \qquad (\theta) \\ \geq \tilde{W}_{HH}(t,0,G) + \tilde{W}_{HL}(t,0,0) + \tilde{W}_{LH}(t,0,G) + \tilde{W}_{LL}(t,0,0) \end{gathered} \tag{22}$$

By Kuhn-Tucker conditions,

$$\begin{aligned} t: \quad & \partial_t E[W] = -\theta \cdot \left(\partial_t E[W] - \partial_t E[\tilde{W}] \right) \\ c: \quad & \partial_c E[W] = 0 \\ G: \quad & \partial_G W_{LH} - \partial_G W_{HL} = \theta \cdot \left(\partial_G \tilde{W}_{HH} + \partial_G \tilde{W}_{LH} \right) \end{aligned} \tag{23}$$

By conditions (23), we see that incentive compatibility constraints affect optimal regional grants. As regards interregional redistribution, by inspection of last expression in (23) we observe that Proposition 4.1 still holds.

As before, optimal regional grants affect regional tax policy.

Proposition 5.1 *Under moral hazard, optimal regional grants (1) do not distort optimal tax enforcement effort, and (2) if tax rate and tax enforcement are substitutes in terms of expected regional welfare*

$$\triangle_c \partial_t E[W] = \partial_t E[W] - \partial_t E[\tilde{W}] < 0$$

induce tax-rate discouragement*, with respect to symmetric and incomplete information policies.*

Proof. The proof follows by inspection of the first two conditions in (23). ‖

6 Conclusions

In section 4 and 5, propositions (4.1, 4.2, and 5.1) characterizing the working of central and regional policies under respectively federalism (in which local governments have a more accurate knowledge of social and economic fundamentals because of historically consolidated political and bureaucratic capacity) and devolution (characterized by *ex ante* incomplete information that uniformly affects local and central governments) are worked out.

Under a specific and unified set of assumptions, we saw that federalism led to less than perfect redistribution between regions in case of interregional income differentials (as in Bordignon *et al.* [7]) and to a *tax-rate effort premium* (i.e. an incentive to increase the tax rate). This result relies on the specific structure of preferences and technology. Bordignon *et al.* [7] showed that, under a different specification of preferences, optimal regional grants could determine also *tax-rate discouragement*.

Nevertheless, it is interesting that, as showed in this paper, *under the same set of assumptions* about preferences and technology, the *qualitative* prescription that is worked out for optimal regional grants under federalism could be *inconsistent* with optimality of grants under devolution. Under devolution, if tax rate and tax enforcement are substitutes *in terms of expected regional welfare*, the normative prescription is that regional grants should induce regions to *lower* their tax rates (Proposition 5.1).

The intuition of such normative prescription is quite straightforward: if tax rate is a substitute of tax collection effort, by imposing an optimal *ceiling* to the former an incentive to increase the latter is provided. Here, as in the case of adverse selection, different structural conditions - bringing to complementarity of tax rate and tax collection effort in terms of expected regional welfare - determine the opposite result (tax effort premium with respect to symmetric information).

Both normative prescriptions of adverse selection and moral hazard optimal regional grants may be reversed by different structural assumptions. However, this paper shows that the normative prescriptions featuring the optimal regional grants may (and indeed usually do) differ following the considered informational setting. In other words, the worth of correct assessment of the informational setting (either adverse selection or moral hazard) underlying the institutional setting (either federalism or devolution) may be quite relevant. Putting it differently, missing to correctly assess the informational setting may create perverse incentives that could eventually bring the system away from efficiency, rather than approaching it.

Appendixes

A

In this Appendix, conditions on objective functions of regional (section A.1) and central (section A.2) government, to characterize the optimal regional and central policies through optimization programming techniques, are considered.

A.1 Concavity of regional objective function and existence arguments

Let the *net social benefit* be defined as a function of regional tax policy. The (gross) social benefit of regional policy is given by the *value* of public service that is provided (i.e. the difference between total regional revenues, $G + t \cdot m$, and regional expenditure to reduce avoidance activities, e, multiplied by a given shadow price, λ). To obtain the *net* social benefit, the total cost imposed on private sector because of regional taxation has to be subtracted by the gross social benefit (i.e. the summation of the regional tax revenues, $t \cdot m$, and the avoidance expenditure of private sector, a). Thus, the formula of the net social benefit of regional policy, $B(y, t, c, G)$, is obtained:

$$B(y,t,c,G) = \lambda \cdot (G + t \cdot m(y,t,c) - \frac{c^2}{2} - \frac{y_H - y}{y_H}) - (t \cdot m(y,t,c) + a(y, m(y,t,c), c)) \tag{24}$$

for any $\lambda \in \Re_+$.

Lemma A.1 *The net social benefit function is never (strictly) concave in regional policy, $(t, c) \in \Re^2_+$, independently of the level of the shadow price.*

Proof. The net social benefit function, $B(y, t, c, G)$, is (strictly) concave in $(t, c) \in \Re^2_+$ if and only if its Hessian matrix is definite negative, hence if and only if

$$\partial^2_{tt} B < 0 \tag{25}$$

$$\partial^2_{tt} B \cdot \partial^2_{cc} B - \partial^2_{tc} B^2 > 0 \tag{26}$$

It is easy to check that condition (25) implies that λ has to lie in a given range, that is a function of the structure of a. $\|$

The concavity of $B(y, t, c, G)$ was proved not to be *generic* in terms of possible preference structures (relationship between λ and a). But, once a concave net social benefit function is afforded, the concavity of regional government indirect objective function is warranted.

Proposition A.2 *The objective function of the regional government, $W(y,t,c,G)$, is (strictly) concave on $\Re^2_+$ provided that the net social benefit, $B(y,t,c,G)$, is (strictly) concave in the regional policy, (t,c) (for any $\lambda \in \Re_+$).*

Proof. The regional government objective function is strictly concave on $\Re^2_+$ if and only if its Hessian matrix is definite negative, hence if and only if

$$\partial^2_{tt}W < 0 \tag{27}$$
$$\partial^2_{tt}W \cdot \partial^2_{cc}W - \partial^2_{tc}W^2 > 0 \tag{28}$$

It is easy to check that the second derivatives of the Hessian matrix can be represented as follows

$$\partial^2_{tt}W = \partial^2_{tt}A + \partial_x u \cdot \partial^2_{tt}B \tag{29}$$
$$\partial^2_{tc}W = \partial^2_{tc}A + \partial_x u \cdot \partial^2_{tc}B \tag{30}$$
$$\partial^2_{cc}W = \partial^2_{cc}A + \partial_x u \cdot \partial^2_{cc}B \tag{31}$$

with $\lambda = MRS$ and

$$\partial^2_{tt}A = \partial^2_{xx}u \cdot m^2 - 2 \cdot \partial^2_{xg}u \cdot m \cdot (m + t \cdot \partial_t m) + \partial^2_{gg}u \cdot (m + t \cdot \partial_t m)^2 \tag{32}$$
$$\begin{aligned}\partial^2_{tc}A = \partial^2_{xx}u \cdot m \cdot \partial_c a - \partial^2_{xg}u \cdot [m \cdot (t \cdot \partial_c m - \partial_c e) + \partial_c a \cdot (m + t \cdot \partial_t m)] + \\ + \partial^2_{gg}u \cdot (m + t \cdot \partial_t m) \cdot (t \cdot \partial_c m - \partial_c e)\end{aligned} \tag{33}$$
$$\partial^2_{cc}A = \partial^2_{xx}u \cdot \partial_c a^2 - 2 \cdot \partial^2_{xg}u \cdot \partial_c a \cdot (t \cdot \partial_c m - \partial_c e) + \partial^2_{gg}u \cdot (t \cdot \partial_c m - \partial_c e)^2 \tag{34}$$

Hence, conditions (27) and (28) can be written as

$$\partial^2_{tt}A + \partial_x u \cdot \partial^2_{tt}B < 0 \tag{35}$$
$$\begin{aligned}(\partial^2_{tt}A \cdot \partial^2_{cc}A - \partial^2_{tc}A^2) + \\ + \partial_x u \cdot (\partial^2_{tt}A \cdot \partial^2_{cc}B + \partial^2_{cc}A \cdot \partial^2_{tt}B - 2 \cdot \partial^2_{tc}A^2 \cdot \partial^2_{tc}B^2) + \\ + \partial_x u^2 \cdot (\partial^2_{tt}B \cdot \partial^2_{cc}B - \partial^2_{tc}B^2) > 0\end{aligned}$$

The value of $\partial^2_{tt}A$ is always non-positive by concavity of $u(x,g)$, for any value of m and $\partial_t m$. Moreover,

$$\begin{aligned}\partial^2_{tt}A \cdot \partial^2_{cc}A - \partial^2_{tc}A^2 = \\ = (\partial^2_{xx}u \cdot \partial^2_{gg}u - \partial^2_{xg}u^2) \cdot [m \cdot (t \cdot \partial_c m - \partial_c e) - \partial_c a \cdot (m + t \cdot \partial_t m)]^2 \geq 0\end{aligned} \tag{36}$$

by concavity of $u(x,g)$. Finally, (26) and (36) imply

$$\partial^2_{tt}A \cdot \partial^2_{cc}B + \partial^2_{cc}A \cdot \partial^2_{tt}B - 2 \cdot \partial^2_{tc}A^2 \cdot \partial^2_{tc}B^2 \geq 0 \tag{37}$$

Therefore, the Proposition holds. $\|$

By Proposition A.2, the maximization of regional government objective function on $\Re^2_+$ is proven to be a (strictly) concave optimization program, hence Kuhn-Tucker conditions are necessary and sufficient for the global maximum.

The final step of this Appendix is to provide a proof of the existence of the maximum, that is not *a priori* warranted, given that the set $\Re^2_+$ is not compact. In what follows, the proof of existence is characterized under the concavity of the *net revenue function*[18], $NR(y,t,c) = t \cdot m(y,t,c) - \frac{c^2}{2} - \frac{y_H - y}{y_H}$.

Lemma A.3 *If $NR(y,t,c)$ is concave on $\Re^2_+$, it admits a maximum, $(\bar{t},\bar{c}) \in \Re^2_+$.*

Proof. To proof the statement it is sufficient to show that Weierstrass theorem is applicable. Firstly, it has to be remarked that

$$NR(y,0,0) = 0 \cdot m(y,0,0) - \frac{0^2}{2} - \frac{y_H - y}{y_H} = -\frac{y_H - y}{y_H} \tag{38}$$

Hence, the proof follows from the fact that:

$$\lim_{(t,c)\to(+\infty,+\infty)} NR(y,t,c) = -\infty \tag{39}$$

Indeed, $NR(y,t,c) \in [-\frac{c^2}{2} - \frac{y_H-y}{y_H}, y - \frac{c^2}{2} - \frac{y_H-y}{y_H}]$, for any $(t,c) \in \Re^2_+$, and both boundaries $-\frac{c^2}{2} - \frac{y_H-y}{y_H}$ and $y - \frac{c^2}{2} - \frac{y_H-y}{y_H}$ go to minus infinity as c goes to plus infinity. Therefore, a maximum exists. $\|$

The above Lemma can be considered as a *generalization* of the Laffer curve argument to the case of multiple tax policy instruments. It allows to state the following Lemma which is very important to insure the existence of the optimal regional policy.

Lemma A.4 *Let $(\bar{t},\bar{c}) \in \Re^2_+$ be a tax policy that maximizes tax revenues, then any tax policy, $(t',c') \in \Re^2_+$, that maximizes the regional government objective function, $W(y,t,c,G)$, is such that*

$$(t',c') \in [0,\bar{t}] \times [0,\bar{c}] \tag{40}$$

Proof. Given the tax policy that maximizes the net revenues, $(\bar{t},\bar{c})$, let the total differential of $W(y,t^*,c^*,G)$ be considered, for any tax policy profile $(t^*,c^*) \in \Re^2_+$:

$$\begin{aligned} dW(y,t^*,c^*,G) = {} & [-\partial_x u \cdot m + \partial_g u \cdot (m + t \cdot \partial_t m)] \cdot dt + \\ & +[-\partial_x u \cdot \partial_c a + \partial_g u \cdot (t \cdot \partial_c m - \partial_c e)] \cdot dc \end{aligned} \tag{41}$$

[18]A different kind of conditions involves the study of the asymptotic behavior of the regional objective function.

by the concavity of the net revenue function, the optimal tax policy reform (i.e. the change in the tax policy that increases the regional welfare) corresponding to the generic tax policy profile, (t^*, c^*), is such that

$$\begin{aligned} dt^* < 0 \quad & \forall (t^*, c^*) \in \{(t, c) \in \Re^2_+ : t^* \geq \bar{t}\} \\ dc^* < 0 \quad & \forall (t^*, c^*) \in \{(t, c) \in \Re^2_+ : c^* \geq \bar{c}\} \end{aligned} \tag{42}$$

moreover, the sign of dt^* and dc^* is undetermined when respectively $t^* \leq \bar{t}$ and $c^* \leq \bar{c}$. Hence, if there is a maximum, it is inside the square $[0, \bar{t}] \times [0, \bar{c}]$. $\|$

Finally, the existence proposition can be stated.

Proposition A.5 *If the net revenue function is strictly concave, then a tax policy,* (t, c) *that maximizes the regional objective function exists and is unique.*

Proof. The proof follows by the concavity of $W(y, t, c, G)$ and the compactness of the set of *relevant* regional policies. $\|$

A.2 Concavity of central government function and existence arguments

The concavity of the central government objective function in regional and central policies (t, c, G) is proven, taking into account Proposition A.2 and the assumptions on the shape of individual preferences.

Proposition A.6 *The objective function of central government,* $W(y, t, c, G)$*, is (strictly) concave on* $\Re^2_+ \times \Re$ *provided that the net social benefit,* $B(t, c)$*, is (strictly) concave in the regional policy,* (t, c) *(for any* $\lambda \in \Re_+$*).*

Proof. By Proposition A.2, the central government objective function, $W(y, t, c, G)$, is (strictly) concave if and only if

$$\begin{aligned} \partial^2_{tt} W \cdot \partial^2_{cc} W \cdot \partial^2_{GG} W + 2 \cdot \partial^2_{tc} W \cdot \partial^2_{cG} W \cdot \partial^2_{tG} W + \\ -\partial^2_{tc} W^2 \cdot \partial^2_{GG} W - \partial^2_{tG} W^2 \cdot \partial^2_{cc} W - \partial^2_{cG} W^2 \cdot \partial^2_{tt} W < 0 \end{aligned} \tag{43}$$

that is true if $B(y, t, c, G)$ is (strictly) concave, given the concavity of individual preferences. Indeed, (43) can be written as

$$\begin{aligned} (\partial^2_{tt} A \cdot \partial^2_{cc} A - \partial^2_{tc} A^2) \cdot \partial^2_{GG} A - (\partial^2_{tG} A^2 \cdot \partial^2_{cc} A + \\ -2 \cdot \partial^2_{tc} A \cdot \partial^2_{tG} A \cdot \partial^2_{cG} A + \partial^2_{cG} A^2 \cdot \partial^2_{tt} A) + \\ +\partial_x u \cdot [(\partial^2_{tt} A \cdot \partial^2_{cc} B + \partial^2_{cc} A \cdot \partial^2_{tt} B - 2 \cdot \partial^2_{tc} A^2 \cdot \partial^2_{tc} B^2) \cdot \partial^2_{GG} A + \\ -(\partial^2_{tG} A^2 \cdot \partial^2_{cc} B - 2 \cdot \partial^2_{tc} B \cdot \partial^2_{tG} A \cdot \partial^2_{cG} A + \partial^2_{cG} A^2 \cdot \partial^2_{tt} B)] + \\ +\partial_x u^2 \cdot (\partial^2_{tt} B \cdot \partial^2_{cc} B - \partial^2_{tc} B^2) \cdot \partial^2_{GG} A \end{aligned} \tag{44}$$

Moreover, some algebra allows to show that

- $$\begin{aligned}(\partial^2_{tt}A \cdot \partial^2_{cc}A - \partial^2_{tc}A^2) \cdot \partial^2_{GG}A + \\ -(\partial^2_{tG}A^2 \cdot \partial^2_{cc}A - 2 \cdot \partial^2_{tc}A \cdot \partial^2_{tG}A \cdot \partial^2_{cG}A + \partial^2_{cG}A^2 \cdot \partial^2_{tt}A) = 0\end{aligned}$$

- $$\begin{aligned}(\partial^2_{tt}A \cdot \partial^2_{cc}B + \partial^2_{cc}A \cdot \partial^2_{tt}B - 2 \cdot \partial^2_{tc}A^2 \cdot \partial^2_{tc}B^2) \cdot \partial^2_{GG}A + \\ -(\partial^2_{tG}A^2 \cdot \partial^2_{cc}B - 2 \cdot \partial^2_{tc}B \cdot \partial^2_{tG}A \cdot \partial^2_{cG}A + \partial^2_{cG}A^2 \cdot \partial^2_{tt}B) = \\ = (\partial^2_{xx}u \cdot \partial^2_{gg}u - \partial^2_{xg}u^2) \cdot \\ \cdot (m^2 \cdot \partial_{cc}B - 2 \cdot m \cdot \partial_c a \cdot \partial_{tc}B + \partial_c a^2 \cdot \partial_{tt}B) \leq 0\end{aligned}$$

  for any value of m and $\partial_c a$.

Therefore, (43) is satisfied and the Proposition holds. $\|$

Moreover, the argument for existence of central optimal policy in the full information case follows from the remark that the choice of G is shown to lie in a compact set and by the strict concavity of net revenue function. By the assumption of horizontal regional transfers (i.e.: $\sum_{j=1}^{J} G_j \leq 0$, where J is the number of regions in the country), it is possible to define an *inferior* value for the grant to the generic region

$$\underline{G}_j = \inf\{G_j\} = -[\bar{t}_j \cdot m(\bar{t}_j, \bar{c}_j) - \frac{\bar{c}_j^2}{2} - \frac{y_H - y_j}{y_H}] \tag{45}$$

that is given by the maximum of resources that can be extracted by the region (maximizing the net regional tax revenue); and a *superior* value

$$\bar{G}_j = \sup\{G_j\} = \sum_{i \in J_{-j}} [\bar{t}_i \cdot m(\bar{t}_i, \bar{c}_i) - \frac{\bar{c}_i^2}{2} - \frac{y_H - y_i}{y_H}] \tag{46}$$

(where J_{-j} is the set of all regions excluded j) that is given by the sum of the maximum of resources that can be extracted by all other regions.

In both cases, if the boundary behavior of the regional objective functions allow to reach such values for finite values of the objective functions themselves, the transfer of each region lies in the compact set $[\underline{G}_j, \bar{G}_j]$. Hence, a maximum exists and it is unique by the same argument of Proposition A.5 and by the (strict) concavity of the central government objective function (Proposition A.6).

If, on the contrary, the behavior of the regional objective function hinder to reach a complete exploitation (maximum extraction of resources by a given region), then a maximum exists and it is unique as well, by complementing the (strict) concavity of the central objective function with the asymptotic behavior as the lower bound of the set of possible transfer to any region approximates.

B

In this Appendix the proof of Proposition 4.2 is provided.

Lemma B.1 *By Kuhn-Tucker conditions of program (16) or equivalently of the following program*

$$\begin{aligned}
\max_{\{t_s,c_s,G_s\}_{s\in\{HH,HL,LH,LL\}}} \quad & W_{HH}(t_{HH},c_{HH},G_{HH})+W_{HL}(t_{HL},c_{HL},G_{HL})+ \\
& W_{LH}(t_{LH},0,G_{LH})+W_{LL}(t_{LL},0,G_{LL}) \\
& s.t.: \\
W_{HH}(t_{HH},c_{HH},G_{HH})+W_{HL}(t_{HL},c_{HL},G_{HL}) \geq & \qquad (\theta) \\
\geq \hat{W}_{HH}(t_{LH},0,G_{LH})+\hat{W}_{HL}(t_{LL},0,G_{LL}) & \\
G_{HH} \leq 0 & \qquad (\mu_{HH}) \\
G_{HL}+G_{LH} \leq 0 & \qquad (\mu_{HL}) \\
G_{LL} \leq 0 & \qquad (\mu_{LL})
\end{aligned} \tag{47}$$

it follows that

$$1-\theta\cdot\frac{\partial_G \hat{W}_{HH}}{\partial_G W_{LH}}>0 \tag{48}$$

$$1-\theta\cdot\frac{\partial_G \hat{W}_{HL}}{\partial_G W_{LL}}>0 \tag{49}$$

Proof. Kuhn-Tucker conditions with respect to G_{HH}, G_{HL}, G_{LH}, and G_{LL} are

$$\begin{aligned}
G_{HH}: \qquad & \partial_G W_{HH}+\theta\cdot\partial_G W_{HH}-\mu_{HH}=0 \\
G_{HL}: \qquad & \partial_G W_{HL}+\theta\cdot\partial_G W_{HL}-\mu_{HL}=0 \\
G_{LH}: \qquad & \partial_G W_{LH}-\theta\cdot\partial_G \hat{W}_{HH}-\mu_{HL}=0 \\
G_{LL}: \qquad & \partial_G W_{LL}-\theta\cdot\partial_G \hat{W}_{HL}-\mu_{LL}=0 \\
& \mu_{HH}\cdot G_{HH}=0 \\
& \mu_{HL}\cdot(G_{HL}+G_{LH})=0 \\
& \mu_{LL}\cdot G_{LL}=0
\end{aligned} \tag{50}$$

Substituting μ_{HL} by the expression G_{HL} in the G_{LH} of (50), dividing by $\partial_G W_{LH}$, and rearranging it follows

$$1-\theta\cdot\frac{\partial_G \hat{W}_{HH}}{\partial_G W_{LH}}=(1+\theta)\cdot\frac{\partial_G W_{HL}}{\partial_G W_{LH}}>0 \tag{51}$$

Dividing the expression G_{LL} of (50) by $\partial_G W_{LL}$ and rearranging it follows

$$1 - \theta \cdot \frac{\partial_G \hat{W}_{HL}}{\partial_G W_{LL}} = \frac{\mu_{LL}}{\partial_G W_{LL}} \geq 0 \tag{52}$$

moreover, the inequality in (51) is strict when $G_{LL} = 0$. ‖

Proof of Proposition 4.2 As first, statement (1) is considered. The first four conditions in (17) imply that, in all states of the world, rich region's tax policy is never distorted (as usual, *no distortion at the top*). As for statement (2), by conditions fifth and sixth in (17), a distortion is likely to affect the tax rate of poor regions. After some algebra, conditions fifth and sixth in (17) become

$$\frac{\partial_t W_{LH}}{\partial_G W_{LH}} \cdot \left(1 - \theta \cdot \frac{\partial_G \hat{W}_{HH}}{\partial_G W_{LH}}\right) \leq \theta \cdot \frac{\partial_G \hat{W}_{HH}}{\partial_G W_{LH}} \cdot \left[\frac{\partial_t \hat{W}_{HH}}{\partial_G \hat{W}_{HH}} - \frac{\partial_t W_{LH}}{\partial_G W_{LH}}\right] \tag{53}$$

$$\frac{\partial_t W_{LL}}{\partial_G W_{LL}} \cdot \left(1 - \theta \cdot \frac{\partial_G \hat{W}_{HL}}{\partial_G W_{LL}}\right) \leq \theta \cdot \frac{\partial_G \hat{W}_{HL}}{\partial_G W_{LL}} \cdot \left[\frac{\partial_t \hat{W}_{HL}}{\partial_G \hat{W}_{HL}} - \frac{\partial_t W_{LL}}{\partial_G W_{LL}}\right] \tag{54}$$

By Lemma B.1 and given that the incentive constraint of program (16) is binding,

$$\theta \cdot \frac{\partial_G \hat{W}_{HH}}{\partial_G W_{LH}} \in (0,1)$$

$$\theta \cdot \frac{\partial_G \hat{W}_{HL}}{\partial_G W_{LL}} \in (0,1)$$

Moreover, it is easy to check that the right hand of (53) and (54) are negative.

$$\frac{\partial_t \hat{W}_{HH}}{\partial_G \hat{W}_{HH}} - \frac{\partial_t W_{LH}}{\partial_G W_{LH}} = y_L \cdot \left(\frac{1}{\partial_g r_{LH}} - \frac{1}{\partial_g \hat{r}_{HH}}\right) < 0$$

$$\frac{\partial_t \hat{W}_{HL}}{\partial_G \hat{W}_{HL}} - \frac{\partial_t W_{LL}}{\partial_G W_{LL}} = y_L \cdot \left(\frac{1}{\partial_g r_{LL}} - \frac{1}{\partial_g \hat{r}_{HL}}\right) < 0$$

Hence, the statement in the Proposition holds. ‖

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