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OPTIMAL GRANTS UNDER ASYMMETRIC INFORMATION: FEDERALISM VERSUS DEVOLUTION

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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 standard model, it is shown that optimal distortion that grants induce on regional fiscal policy significantly differs between federalism (adverse selection and moral hazard) and devolution (pure moral hazard).

Keywords: Intergovernmental grants, Adverse selection, Moral hazard

JEL classification: H77, D82

1 Introduction

Intergovernmental fiscal relations are a traditional topic in economics (Inman and Rubinfeld [20]; Oates [32]). 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 [31]).

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 [37]).

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.* [5]; Bordignon *et al.* [8]; Bucovetsky [10]; Cremer *et al.* [13]; Cremer and Pestieau [14]; Lockwood [26]; for a survey, see also Van Puyenbroeck [37]) involves an adverse selection framework (asymmetric information about *the status of fundamentals*). Moral hazard (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.* [7], [8]) 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 [3] show 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 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)

[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.

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.* [8]. 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 and *tax planning* services for the whole economy. Public sector is made by a local government in each of the two regions and a central government. Local governments provide a public service. The production of public and private goods are constant returns to scale and, for the sake of simplicity, the price of both composite good and public service is assumed to be normalized to unity and equal across the economy. Tax planning services are produced by competitive firms sharing the same technology.

Households are assumed to be identical up to their income, y_j, and *tax residence*, $j \in \{1, 2\}$. They provide the sole production factor of the economy (i.e. work services) inelastically to private and public sector and their preferences are represented by the utility function

$$u(x_j, g_j) = v(x_j + r(g_j)) \tag{1}$$

where: $v(.)$ and $r(.)$ are strictly increasing, twice continuously differentiable, and concave[3]; moreover, x_j is household's private consumption, and g_j is the publicly-provided service[4]). Household's budget constraint is affected by *regional tax policy* (that is given by the pair of tax rate, t_j, and tax collection effort, c_j):

$$y_j - t_j \cdot m_j - a_j - x_j \geq 0 \tag{2}$$

[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.

[4]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 $d(.)$.

Given individual's income, *tax burden* is equal to the sum of the income tax liability, $t_j \cdot m_j$, and household's expenditure in tax planning services, a_j, (the *avoidance expenditure*). *Taxable income*, m_j, differs from the actual one since some costly activities (a_j) can be undertaken on the part of households in order to reduce their tax bill. To simplify the analysis let tax planning expenditure be as follows:

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

The idea underlying the described *tax game* between households and regional government is that a *formally* legal technology exists, in the framework of the economy, that allows to reduce taxable income. As remarked by Mayshar [28], 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.* The *rationale* for such assumption is that the legal system, namely the tax code, is affected by some *incompleteness* (in the sense of *contract theory*; see Bolton and Dewatripont [6], section IV) that hinders regional government to design optimal rules involving perfect *tax compliance.* It can, thus, be assumed that households can exploit taxing *loopholes*, at some cost, and that tax code incompleteness (and loopholes) can be reduced by tax administration (in the 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.

Household's income is a non-negative random variable distributed as follows

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

Moreover, it is assumed that individual incomes are identically distributed and perfectly correlated within the jurisdiction[5] but independent across different regions. All regions have the same population and each household is irrelevant with respect to it[6].

Each local government controls the public service provision of its own region. Regional government j (i.e. the local government ruling on jurisdiction j) maximizes the social welfare of its jurisdiction under local budget constraint[7]

$$G_j + t_j \cdot m_j - g_j - e_j \geq 0 \tag{4}$$

[5]This simplifying assumption does not imply a loss in the generality of the analysis. Indeed, a more general model would be characterized by individual incomes distributed following specific density functions. The average regional income would result from the joint distribution of individual incomes. Hence, the regional government objective function could be written as expected value over the individual incomes.

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

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

for any given $y_j \in \{y_L, y_H\}$; where G_j is the net grant afforded to the local government j by the *intergovernmental grant system*, and e_j is the tax collection public expenditure. The tax collection expenditure increases (and is convex) in the tax enforcement effort c_j, but it is also determined by the state of regional income:

$$e_j = \frac{y_H - y_j}{y_H} + \frac{c^2}{2} \tag{5}$$

for any $y_j \in \{y_L, y_H\}$. The idea underlying the equation (5) is that an higher regional income reduces the *cost of tax enforcement*.

The model is designed as a three-stages game. At the first stage, central government fixes the rules for intergovernmental grants implementation[8]. 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[9].

The distribution of relevant information in the economy is as follows. Households know their actual private income (y_j), before choosing taxable income. Regional and central governments know, at least, the probabilistic distribution of actual incomes. 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 the actual level of private income 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 government is *symmetric*. If only regional governments are aware of the actual level of private income (section 4), *adverse selection and moral hazard* characterize intergovernmental relations. Finally, when regional and central governments share the knowledge of private income distribution but are unaware of its actual realization (section 5), *pure moral hazard* arises.

[8]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).

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

2.1 Household's optimization program

Following a consolidated approach, the game can be solved by backward induction[10]. 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).

Knowing its income[11], y, the household chooses its taxable income (given the structure of *regional fiscal policy*, (t, c, g)), $m \in [y_L, y_H]$, that cannot be lower than y_L. By the assumptions about household's preference structure, the optimization program

$$\max_{m \in [y_L, y_H]} u(y - t \cdot m - a(y, m, c), g) \tag{6}$$

determines the same solution set of the minimization of household's tax burden function

$$\min_{m \in [y_L, y_H]} t \cdot m + a(y, m, c) \tag{7}$$

Given the necessary and sufficient[12] condition for the minimum

$$\begin{array}{lll} t + \partial_m a > 0 & \text{and} & m = y_L \\ t + \partial_m a = 0 & \text{and} & m \in [y_L, y_H] \\ t + \partial_m a < 0 & \text{and} & m = y_H \end{array} \tag{8}$$

the taxable income is a function of tax rate, tax enforcement effort, and income, $m(y, t, c)$[13]. The structure of the optimization problem implies that the optimal taxable income chosen by households is independent of the public service level.

It is easy to check that, if a is (strictly) convex in m, tax base shrinks as tax rate increases[14]. The assumed structure of avoidance expenditure implies a specific

[10] Without any intention of comprehensiveness, a fundamental reference as regards backward induction is Kreps and Wilson [21]. On the definition of *subgame perfect equilibrium* see also the seminal paper by Selten [36].

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

[12] By the continuity of the tax burden function and the compactness of the feasible set, $[y_L, y_H]$, a solution exists. Moreover, *Slater's constraint qualification* is satisfied (given that the set $[y_L, y_H]$ is non-empty); by strict convexity of a in m ($\partial^2_{mm} a > 0$), the solution is unique.

[13] 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.

[14] Indeed, by comparative statics of the condition (8) in non-corner solutions, it follows that:

$$\partial_y m = -\frac{\partial^2_{my} a}{\partial^2_{mm} a}$$

tax base function:

$$m(y,t,c)=\begin{cases} y_L & \text{if } \frac{t}{2\cdot c}\geq y-y_L \\ y-\frac{t}{2\cdot c} & \text{if } \frac{t}{2\cdot c}< y-y_L \end{cases} \tag{9}$$

with $y \in \{y_L, y_H\}$.

3 Optimal regional grants under symmetric information

In the considered model, central and regional objectives coincide (maximize the respectively central and regional social welfare), therefore possible divergence between principal (central government) and agents (regional governments) objectives could arise 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 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.

In this section, optimal transfer rules under symmetric information are considered to work out a benchmark for the asymmetric information analysis. The information about private (thus, regional) income is assumed to be complete, namely, central and local authorities know actual private income. 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 are unconstrained, hence *lump sum* grants are implementable. 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

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$$\partial_t m = -\frac{1}{\partial^2_{mm} a}$$

$$\partial_c m = -\frac{\partial^2_{mc} a}{\partial^2_{mm} a}$$

thus, only the sign of the second equation can be determined, by the strict convexity of a in m: *increasing the tax rate makes more profitable, for households, to reduce their taxable income, facing a higher avoidance expenditure.* The determination of the sign of the first and the second conditions needs further assumptions about the structure of a

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.

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 (4) holds always with equality. Thus, the (indirect) objective function of the local government can be written as

$$W(y,t,c,G) = u(y - t \cdot m(y,t,c) - a(y, m(y,t,c), c), G + t \cdot m(y,t,c) - e(y,c)) \quad (10)$$

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

In the Appendix A, sufficient conditions for the concavity of regional government's objective function (10) are considered. In particular, let

$$B(y,t,c,G) = \lambda \cdot (G + t \cdot m(y,t,c) - e(y,c)) - (t \cdot m(y,t,c) + a(y, m(y,t,c), c)) \quad (11)$$

be the *net social benefit* associated to given regional, (t,c), and central, G, policies; where λ is any given shadow price for regional public service that the local government can use to "evaluate" its public provision projects[15]. It is easy to check that the the maximization of (11) is a different way to attain the optimal regional policy, provided that the shadow price, λ, is suitably chosen and coincides with the marginal willingness to pay for the public service[16].

By usual economic analysis, (11) has a (unique) maximum if $B(y,t,c,G)$ is (strictly) concave with respect to regional tax policy (for any λ). The following Proposition establishes the relationship between the concavity of the net social benefit (11) and the regional government objective (10).

Proposition 3.1 *The objective function of 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 regional policy, (t,c) (for any $\lambda \in \Re_+$).*

[15] In other words, $B(y,t,c,G)$ is surplus of households associated to the public policy *net* of the tax burden it involves.

[16] Hence, it is equal to the marginal rate of substitution, MRS, between public and private consumption.

Proof. See Appendix A. ‖

Taking into account the specification of avoidance expenditure, the net social benefit function can be written as

$$B(y,t,c,G) =$$

$$= \begin{cases} \lambda \cdot (G + t \cdot y_L - \frac{y_H - y}{y_H} - \frac{c^2}{2}) - [t \cdot y_L + (y - y_L)^2 \cdot c] & \text{if } \frac{t}{2 \cdot c} \geq y - y_L \\ \lambda \cdot [G + t \cdot (y - \frac{t}{2 \cdot c}) - \frac{y_H - y}{y_H} - \frac{c^2}{2}] - t \cdot (y - \frac{t}{4 \cdot c}) & \text{if } \frac{t}{2 \cdot c} < y - y_L \end{cases} \tag{12}$$

with $y \in \{y_L, y_H\}$. It is easy to check that a necessary and sufficient condition for (12) to be strictly concave is that $\lambda > \frac{1}{2}$[17]. Thus, imposing that $MRS = \frac{\partial_g u}{\partial_x u} > \frac{1}{2}$, is a sufficient condition to insure concavity of regional (and central) indirect objective function.

The Kuhn-Tucker conditions for the maximum[18] of (10) - or (11), are

$$\begin{aligned} \partial_t W &= -\partial_x u \cdot m + \partial_g u \cdot (m + t \cdot \partial_t m) \leq 0 \\ \partial_c W &= -\partial_x u \cdot \partial_c a + \partial_g u \cdot (t \cdot \partial_c m - \partial_c e) \leq 0 \end{aligned} \tag{13}$$

the first addend of conditions (13) - 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

$$\begin{aligned} MRS = \frac{\partial_g u}{\partial_x u} &= \frac{1}{1 + \frac{t}{m} \cdot \partial_t m} = MCPF_t \\ MCPF_t = \frac{1}{1 + \frac{t}{m} \cdot \partial_t m} &= \frac{\partial_c a}{t \cdot \partial_c m - \partial_c e} = MCPF_c \end{aligned} \tag{14}$$

The economic intuition underlying the optimal regional policy, conditions (14), is:

[17]Technically, if (and only if) the condition in the text is satisfied, $B(y,t,c,G)$ is strictly concave in t and c for $\frac{t}{2 \cdot c} < y - y_L$, and it is strictly concave in c (and linear in t), for $t \geq 2 \cdot y \cdot c$. Provided that $m = y_L$ when $\frac{t}{2 \cdot c} \geq y - y_L$, $W(t,c,G)$ proves to be concave in t, c, and G.

[18]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 [4]). In the Appendix A, the existence of the solution is discussed.

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*[19] - condition (14);

2. the *marginal cost of public funds* raised through different *policy instruments* (tax rate - $MCPF_t$ - or tax enforcement - $MCPF_c$) is equalized - condition (14).

It has to be remarked that, if $y = y_L$, the $MCPF_t = 1$ and $MCPF_c = 0$; therefore, in the case of low income, 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. More generally, when $y = y_H$, if the optimal tax rate is so high 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.

3.2 Optimal interregional grants

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

Regional income is *ex ante* a random variable performing two possible states: 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 income revelation, 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[20] by choosing

[19] 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 $MCPF_c$).

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

an optimal (horizontal) system of lump sum grants (G)[21]

$$\max_{\{G^*\}} W_{HH}(t^*_{HH}, c^*_{HH}, 0) + W_{HL}(t^*_{HL}, c^*_{HL}, -G^*) + \\ W_{LH}(t^*_{LH}, 0, G^*) + W_{LL}(t^*_{LL}, 0, 0) \tag{15}$$

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 order conditions[22] are

$$G: \qquad -\partial_G W_{HL} + \partial_G W_{LH} = 0 \tag{16}$$

Given that $\partial_G W_{sz} = \partial_g u_{sz}$, conditions (16) imply

$$\partial_g u_{HL} = \partial_g u_{LH} \tag{17}$$

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

Proposition 3.2 *Under symmetric information*[23] *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 (14) and (17) 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

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

[22]Conditions (16) are necessary and sufficient for the maximum given the concavity of the objective functions of the local governments.

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

decentralized framework is crucially linked to the absence of any *uniformity constraint* (as the one assumed by Oates [31]) to central policy.

This is a special case of the *decentralization principle* investigated by asymmetric information literature[24]. 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 set and the structure of *decentralizable policies* is, generally speaking, affected by the peculiar informational distribution that shapes intergovernmental relations.

Proposition 3.3 *When no specific institutional constraint affects central policy, any central policy can be* decentralized *through an optimal system of regional grants provided that*[25]*:*

a) regional governments cannot collude;

b) communication between central and regional governments is costless.

Proof. See Myerson [30]. ‖

4 Optimal regional grants in federal states

Asymmetric information is introduced in the above setting by assuming that households' *actual* income, 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).

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 actual private income in their jurisdiction, 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 verify *ex ante* the state of regional private income, 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

[24] See for all Myerson [30], Poitevin [33].

[25] As argued by Poitevin [33], a further assumption is needed: central government can commit to implement its interregional policy. As already pointed out (footnote 8), this assumption underlies the structure of the game.

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-income 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 actual regional income. 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.* [27], p. 502) is recalled. As shown in section 2.1, the tax game between households and regional government determines a regional tax base function: $m(y, t, c)$. Under the assumption that the sign of $\partial^2_{ym} a$ does not change for relevant values of parameters, for any given regional tax policy (t and c), actual regional income, 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 (25). 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 (14) 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-income regions cannot deviate. Indeed, by the structure of the taxable income function - expression (9) - when the true regional income 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 income 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

$$W_{HH}(t^*_{HH}, c^*_{HH}, 0) + W_{HL}(t^*_{HL}, c^*_{HL}, -G^*) < \\ < \hat{W}_{HH}(t^*_{LH}, 0, G^*) + \hat{W}_{HL}(t^*_{LL}, 0, 0) \tag{18}$$

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 (18) highlights the timing of the incentive problem: the region uncovers its own income, y, while it does not know the actual income of the other region. Condition (18) 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 incomes. Indeed, the centralization of information, underlying the application of the revelation principle, bridges the consistency gap between incomplete information suffered by each region (*vis à vis* the other region) and regional tax policies taking into account all (truthfully revealed) information.

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.* [8]). Now, the central government is unable to verify actual regional income (that is *privately* known by each regional government), hence its optimization program has to incorporate an incentive compatibility constraint:

$$W_{HH}(t_{HH}, c_{HH}, 0) + W_{HL}(t_{HL}, c_{HL}, -G) \geq \\ \geq \hat{W}_{HH}(t_{LH}, 0, G) + \hat{W}_{HL}(t_{LL}, 0, 0) \tag{19}$$

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.

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

$$
\begin{aligned}
\max_{\{t_s,c_s\}_{s\in\{HH,HL,LH,LL\}},G} & W_{HH}(t_{HH},c_{HH},0)+W_{HL}(t_{HL},c_{HL},-G)+ \\
& W_{LH}(t_{LH},0,G)+W_{LL}(t_{LL},0,0) \\
& \qquad s.t.: \\
W_{HH}(t_{HH},c_{HH},0)+W_{HL}(t_{HL},c_{HL},-G) & \geq \qquad (\theta) \\
& \geq \hat{W}_{HH}(t_{LH},0,G)+\hat{W}_{HL}(t_{LL},0,0)
\end{aligned}
\tag{20}
$$

By Kuhn-Tucker necessary conditions,

$$
\begin{aligned}
t_{HH}: & \quad \partial_t W_{HH}\cdot(1+\theta)\leq 0 \\
c_{HH}: & \quad \partial_c W_{HH}\cdot(1+\theta)\leq 0 \\
t_{HL}: & \quad \partial_t W_{HL}\cdot(1+\theta)\leq 0 \\
c_{HL}: & \quad \partial_c W_{HL}\cdot(1+\theta)\leq 0 \\
t_{LH}: & \quad \partial_t W_{LH}-\theta\cdot\partial_t\hat{W}_{HH}\leq 0 \\
t_{LL}: & \quad \partial_t W_{LL}-\theta\cdot\partial_t\hat{W}_{HL}\leq 0 \\
G: & \quad -\partial_G W_{HL}+\partial_G W_{LH}-\theta\cdot(\partial_G\hat{W}_{HH}+\partial_G W_{HL})=0
\end{aligned}
\tag{21}
$$

results similar to Bordignon *et al.* [8] are obtained. 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 an income differential among regions. By condition G in (21)

$$\partial_G W_{LH} > \partial_G W_{HL} \tag{22}$$

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.* [8]. 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, in a simplified setting.

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 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. In other terms, redistribution between the two regions can be implemented only on the basis of *ex post* values assumed 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* (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 true income $y \in \{y_L, y_H\}$. 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 true regional income, taxable income is invariably low. Hence, once the central government observes $m = y_L$, it cannot conclude anything about the behavior of the concerned regional government.

Hence, the probability distribution of m can be determined as follows

$$\begin{aligned} Prob\left\{ m \leq y_L \;\middle|\; \frac{t}{2 \cdot c} \geq y_H - y_L \right\} &= 1 \\ Prob\left\{ m \leq y_L \;\middle|\; \frac{t}{2 \cdot c} < y_H - y_L \right\} &= \frac{1}{2} \\ Prob\left\{ m \leq y_H - \frac{t}{2 \cdot c} \;\middle|\; \frac{t}{2 \cdot c} < y_H - y_L \right\} &= 1 \end{aligned} \tag{23}$$

The probability distribution (23) respects *first order stochastic dominance.* Starting form values of t and c such that

$$\frac{t}{2 \cdot c} \geq y_H - y_L \tag{24}$$

a sufficiently large reduction of t (and/or increase of c) may reverse the inequality (24), thus making *more probable* higher levels of m. If the values of t and c are already such that the inequality (24) is reversed, then a reduction of t (and/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 3.2 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 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 with respect to 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

$$\begin{aligned} t': \quad & \partial_t E[W] = 0 \\ c': \quad & \partial_c E[W] = 0 \\ G': \quad & \partial_G W_{LH} = \partial_G W_{HL} \end{aligned} \tag{25}$$

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 3.2 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. 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 (25)). Symmetrically to the case of adverse selection, we assume the incentive-incompatibility of the symmetric information policies:

$$\begin{aligned} W_{HH}(t',c',0) + W_{HL}(t',c',-G) + W_{LH}(t',c',G) + W_{LL}(t',c',0) < \\ < \tilde{W}_{HH}(t',0,G) + \tilde{W}_{HL}(t',0,0) + \tilde{W}_{LH}(t',0,G) + \tilde{W}_{LL}(t',0,0) \end{aligned} \tag{26}$$

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 income. It is worth noting that the effect of regional fiscal 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. Thus, central government's program under moral hazard is

$$\begin{aligned} &\max_{t,c,G} W_{HH}(t,c,0) + W_{HL}(t,c,-G) + W_{LH}(t,c,G) + W_{LL}(t,c,0) \\ &\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad s.t.: \\ &W_{HH}(t,c,0) + W_{HL}(t,c,-G) + W_{LH}(t,c,G) + W_{LL}(t,c,0) \geq \qquad (\theta) \\ &\quad \geq \tilde{W}_{HH}(t,0,G) + \tilde{W}_{HL}(t,0,0) + \tilde{W}_{LH}(t,0,G) + \tilde{W}_{LL}(t,0,0) \end{aligned} \tag{27}$$

By Kuhn-Tucker conditions,

$$\begin{aligned} t: \quad &\partial_t E[W] = -\theta \cdot \left(\partial_t E[W] - \partial_t E[\tilde{W}]\right) \\ c: \quad &\partial_c E[W] = 0 \\ G: \quad &\partial_G W_{LH} - \partial_G W_{HL} = \theta \cdot \left(\partial_G \tilde{W}_{HH} + \partial_G \tilde{W}_{LH}\right) \end{aligned} \tag{28}$$

By conditions (28), we see that incentive compatibility constraints affect optimal regional grants. As regards interregional redistribution, by inspection of last expression in (28) 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 the optimal regional policy under symmetric (but incomplete) information.*

Proof. The proof follows by inspection of the first two conditions in (28). ‖

6 Conclusions

In sections 4 and 5, four 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 determined.

We saw that federalism led to less than perfect redistribution between regions in case of income differentials (as in Bordignon *et al.* [8]) and to a *tax-rate effort premium*. This result is based on the specific structure of preferences and technology. Bordignon *et al.* [8] showed that, under an alternative specification of preferences, optimal regional grants could determine also *tax-rate discouragement*.

Nevertheless, this paper points out that, *under the same set of assumptions* about preferences and technology, the normative prescription that is worked out for optimal regional grants under federalism could be *inconsistent* with optimality of grants under devolution. Indeed, 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 discouragement 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 prescription featuring the optimal regional grants may (and indeed usually do) differ following the considered informational setting. In other words, the worth of the 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 push 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; this cost is called tax burden (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:

$$B(y,t,c,G) = \lambda \cdot (G + t \cdot m(y,t,c) - e(y,c)) - (t \cdot m(y,t,c) + a(y, m(y,t,c), c)) \quad (29)$$

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

$$\partial^2_{tt} B < 0 \quad (30)$$

$$\partial^2_{tt} B \cdot \partial^2_{cc} B - \partial^2_{tc} B^2 > 0 \quad (31)$$

It is easy to check that condition (30) 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

$$\partial^2_{tt}W < 0 \tag{32}$$

$$\partial^2_{tt}W \cdot \partial^2_{cc}W - \partial^2_{tc}W^2 > 0 \tag{33}$$

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

$$\partial^2_{tt}W = \partial^2_{tt}A + \partial_x u \cdot \partial^2_{tt}B \tag{34}$$

$$\partial^2_{tc}W = \partial^2_{tc}A + \partial_x u \cdot \partial^2_{tc}B \tag{35}$$

$$\partial^2_{cc}W = \partial^2_{cc}A + \partial_x u \cdot \partial^2_{cc}B \tag{36}$$

with $\lambda = MRS$ and

$$\partial^2_{tt}A = \partial^2_{xx}u \cdot m^2 - 2 \cdot \partial^2_{xg}u \cdot m \cdot (m + t \cdot \partial_t m) + \partial^2_{gg}u \cdot (m + t \cdot \partial_t m)^2 \tag{37}$$

$$\begin{aligned} \partial^2_{tc}A = \partial^2_{xx}u \cdot m \cdot \partial_c a - \partial^2_{xg}u \cdot [m \cdot (t \cdot \partial_c m - \partial_c e) + \partial_c a \cdot (m + t \cdot \partial_t m)] + \\ + \partial^2_{gg}u \cdot (m + t \cdot \partial_t m) \cdot (t \cdot \partial_c m - \partial_c e) \end{aligned} \tag{38}$$

$$\partial^2_{cc}A = \partial^2_{xx}u \cdot \partial_c a^2 - 2 \cdot \partial^2_{xg}u \cdot \partial_c a \cdot (t \cdot \partial_c m - \partial_c e) + \partial^2_{gg}u \cdot (t \cdot \partial_c m - \partial_c e)^2 \tag{39}$$

Hence, conditions (32) and (33) can be written as

$$\begin{aligned} \partial^2_{tt}A + \partial_x u \cdot \partial^2_{tt}B < 0 \\ (\partial^2_{tt}A \cdot \partial^2_{cc}A - \partial^2_{tc}A^2) + \\ + \partial_x u \cdot (\partial^2_{tt}A \cdot \partial^2_{cc}B + \partial^2_{cc}A \cdot \partial^2_{tt}B - 2 \cdot \partial^2_{tc}A^2 \cdot \partial^2_{tc}B^2) + \\ + \partial_x u^2 \cdot (\partial^2_{tt}B \cdot \partial^2_{cc}B - \partial^2_{tc}B^2) > 0 \end{aligned} \tag{40}$$

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,

$$\begin{aligned} \partial^2_{tt}A \cdot \partial^2_{cc}A - \partial^2_{tc}A^2 = \\ = (\partial^2_{xx}u \cdot \partial^2_{gg}u - \partial^2_{xg}u^2) \cdot [m \cdot (t \cdot \partial_c m - \partial_c e) - \partial_c a \cdot (m + t \cdot \partial_t m)]^2 \geq 0 \end{aligned} \tag{41}$$

by concavity of $u(x,g)$. Finally, (31) and (41) imply

$$\partial^2_{tt}A \cdot \partial^2_{cc}B + \partial^2_{cc}A \cdot \partial^2_{tt}B - 2 \cdot \partial^2_{tc}A^2 \cdot \partial^2_{tc}B^2 \geq 0 \tag{42}$$

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 strict concavity of the *net revenue function*[26], $NR(y,t,c) = t \cdot m(y,t,c) - e(y,c)$.

Lemma A.3 *If $NR(y,t,c)$ is strictly concave on $\Re^2_+$, it admits an unique 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

$$NR(y,0,0) = 0 \cdot m(y,0,0) - c(y,0) = -\frac{y_H - y}{y_H} \tag{43}$$

Hence, the proof follows from the fact that:

$$\lim_{(t,c)\to(+\infty,+\infty)} NR(y,t,c) = -\infty \tag{44}$$

Indeed, $NR(y,t,c) \in [-c, y-c]$, for any $(t,c) \in \Re^2_+$, and both boundaries $-c$ and $y-c$ go to minus infinity as c goes to plus infinity. Therefore, a maximum exists and, by strict concavity of $NR(y,t,c)$, it is unique. $\|$

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 the unique 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*

$$(t',c') \in [0,\bar{t}) \times [0,\bar{c}) \tag{45}$$

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

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 $(t^*, c^*) \in \Re^2_+$:

$$dW(y, t^*, c^*, G) = [-\partial_x u \cdot m + \partial_g u \cdot (m + t \cdot \partial_t m)] \cdot dt + \\ +[-\partial_x u \cdot \partial_c a + \partial_g u \cdot (t \cdot \partial_c m - \partial_c e)] \cdot dc \tag{46}$$

By the strict 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

$$\begin{aligned} dt^* < 0 \quad \forall (t^*, c^*) \in \{(t, c) \in \Re^2_+ : t^* \geq \bar{t}\} \\ dc^* < 0 \quad \forall (t^*, c^*) \in \{(t, c) \in \Re^2_+ : c^* \geq \bar{c}\} \end{aligned} \tag{47}$$

moreover, the sign of dt^* and dc^* is undetermined when respectively $t^* < \bar{t}$ and $c^* < \bar{c}$. 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

$$\partial^2_{tt} W \cdot \partial^2_{cc} W \cdot \partial^2_{GG} W + 2 \cdot \partial^2_{tc} W \cdot \partial^2_{cG} W \cdot \partial^2_{tG} W + \\ -\partial^2_{tc} W^2 \cdot \partial^2_{GG} W - \partial^2_{tG} W^2 \cdot \partial^2_{cc} W - \partial^2_{cG} W^2 \cdot \partial^2_{tt} W < 0 \tag{48}$$

that is true if $B(y,t,c,G)$ is (strictly) concave, given the concavity of individual preferences. Indeed, (48) can be written as

$$\begin{aligned}(\partial^2_{tt}A\cdot\partial^2_{cc}A-\partial^2_{tc}A^2)\cdot\partial^2_{GG}A-(\partial^2_{tG}A^2\cdot\partial^2_{cc}A+\\ -2\cdot\partial^2_{tc}A\cdot\partial^2_{tG}A\cdot\partial^2_{cG}A+\partial^2_{cG}A^2\cdot\partial^2_{tt}A)+\\ +\partial_x u\cdot[(\partial^2_{tt}A\cdot\partial^2_{cc}B+\partial^2_{cc}A\cdot\partial^2_{tt}B-2\cdot\partial^2_{tc}A^2\cdot\partial^2_{tc}B^2)\cdot\partial^2_{GG}A+\\ -(\partial^2_{tG}A^2\cdot\partial^2_{cc}B-2\cdot\partial^2_{tc}B\cdot\partial^2_{tG}A\cdot\partial^2_{cG}A+\partial^2_{cG}A^2\cdot\partial^2_{tt}B)]+\\ +\partial_x u^2\cdot(\partial^2_{tt}B\cdot\partial^2_{cc}B-\partial^2_{tc}B^2)\cdot\partial^2_{GG}A\end{aligned}\tag{49}$$

Moreover, some algebra allows to show that

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

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

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

Therefore, (48) 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.: $\sum_{j=1}^{J}G_j\le 0$, 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

$$\underline{G}_j=\inf\{G_j\}=-[\bar{t}_j\cdot m(\bar{t}_j,\bar{c}_j)-\frac{y_H-y_j}{y_H}-\frac{\bar{c}_j^2}{2}]\tag{50}$$

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

$$\bar{G}_j=\sup\{G_j\}=\sum_{i\in J_{-j}}[\bar{t}_i\cdot m(\bar{t}_i,\bar{c}_i)-\frac{y_H-y_i}{y_H}-\frac{\bar{c}_i^2}{2}]\tag{51}$$

(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 (20) or equivalently of the following program*

$$\begin{aligned}
\max_{\{t_s,c_s,G_s\}_{s\in\{HH,HL,LH,LL\}}} \quad & W_{HH}(t_{HH},c_{HH},G_{HH}) + W_{HL}(t_{HL},c_{HL},G_{HL}) + \\
& W_{LH}(t_{LH},0,G_{LH}) + W_{LL}(t_{LL},0,G_{LL}) \\
& s.t.: \qquad (52) \\
W_{HH}(t_{HH},c_{HH},G_{HH}) + W_{HL}(t_{HL},c_{HL},G_{HL}) \geq & \qquad (\theta) \\
\geq \hat{W}_{HH}(t_{LH},0,G_{LH}) + \hat{W}_{HL}(t_{LL},0,G_{LL}) & \\
G_{HH} \leq 0 & \qquad (\mu_{HH}) \\
G_{HL} + G_{LH} \leq 0 & \qquad (\mu_{HL}) \\
G_{LL} \leq 0 & \qquad (\mu_{LL})
\end{aligned}$$

it follows that

$$1 - \theta \cdot \frac{\partial_G \hat{W}_{HH}}{\partial_G W_{LH}} > 0 \tag{53}$$

$$1 - \theta \cdot \frac{\partial_G \hat{W}_{HL}}{\partial_G W_{LL}} > 0 \tag{54}$$

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

$$\begin{aligned}
G_{HH}: \qquad & \partial_G W_{HH} + \theta \cdot \partial_G W_{HH} - \mu_{HH} = 0 \qquad (55)\\
G_{HL}: \qquad & \partial_G W_{HL} + \theta \cdot \partial_G W_{HL} - \mu_{HL} = 0 \\
G_{LH}: \qquad & \partial_G W_{LH} - \theta \cdot \partial_G \hat{W}_{HH} - \mu_{HL} = 0 \\
G_{LL}: \qquad & \partial_G W_{LL} - \theta \cdot \partial_G \hat{W}_{HL} - \mu_{LL} = 0 \\
& \mu_{HH} \cdot G_{HH} = 0 \\
& \mu_{HL} \cdot (G_{HL} + G_{LH}) = 0 \\
& \mu_{LL} \cdot G_{LL} = 0
\end{aligned}$$

Substituting μ_{HL} by the expression G_{HL} in the G_{LH} of (55), dividing by $\partial_G W_{LH}$, and rearranging it follows

$$1 - \theta \cdot \frac{\partial_G \hat{W}_{HH}}{\partial_G W_{LH}} = (1+\theta) \cdot \frac{\partial_G W_{HL}}{\partial_G W_{LH}} > 0 \tag{56}$$

Dividing the expression G_{LL} of (55) by $\partial_G W_{LL}$ and rearranging it follows

$$1-\theta\cdot\frac{\partial_G\hat{W}_{HL}}{\partial_G W_{LL}}=\frac{\mu_{LL}}{\partial_G W_{LL}}\geq 0 \tag{57}$$

moreover, the inequality in (56) is strict when $G_{LL}=0$. $\|$

Proof of Proposition 4.2 As first, statement (1) is considered. The first four conditions in (21) 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 (21), a distortion is likely to affect the tax rate of poor regions. After some algebra, conditions fifth and sixth in (21) become

$$\frac{\partial_t W_{LH}}{\partial_G W_{LH}}\cdot\left(1-\theta\cdot\frac{\partial_G\hat{W}_{HH}}{\partial_G W_{LH}}\right)\leq\theta\cdot\frac{\partial_G\hat{W}_{HH}}{\partial_G W_{LH}}\cdot\left[\frac{\partial_t\hat{W}_{HH}}{\partial_G\hat{W}_{HH}}-\frac{\partial_t W_{LH}}{\partial_G W_{LH}}\right] \tag{58}$$

$$\frac{\partial_t W_{LL}}{\partial_G W_{LL}}\cdot\left(1-\theta\cdot\frac{\partial_G\hat{W}_{HL}}{\partial_G W_{LL}}\right)\leq\theta\cdot\frac{\partial_G\hat{W}_{HL}}{\partial_G W_{LL}}\cdot\left[\frac{\partial_t\hat{W}_{HL}}{\partial_G\hat{W}_{HL}}-\frac{\partial_t W_{LL}}{\partial_G W_{LL}}\right] \tag{59}$$

By Lemma and given that the incentive constraint of program (20) 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 (58) and (59) 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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