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Construction of facilities under asymmetric information: do constitutions matter?*

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Abstract

A country consists of two non-overlapping regions, each ruled by a local authority. The federal government plans to construct a facility in one of the regions. If the facility is constructed, it generates a social value in the host region and has spillover effects in the rest of the country. The federal government does not observe the local value (which can be high or low) because it is in fact the local authority's private information. To deal with this informational gap, the federal government designs an incentive-compatible mechanism, specifying if the facility should be constructed and a scheme of interregional transfers. But the federal government is constitutionally constrained to respect a given measure of both regions' welfare. The shape of the optimal mechanism depends on the values of the local and spillover effects and on the type of constitutional constraint that the federal government faces.

Keywords: Fiscal federalism - Constitutional constraints - Facilities - Intergovernmental transfers - Asymmetric information

JEL Codes: D82 - H77

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1 Introduction

Federal governments intervene in regions, states or localities, even in countries where decentralization prevails, like in the USA. For example, federal governments construct facilities like prisons, waste disposals, airports or dams. In order to decide whether or not to construct such facilities and how to finance them, federal governments need to know their impact on the welfare of different regions. But, as it has long been recognized [e.g. Oates, 1972], local authorities know some of their constituency's characteristics better than federal governments. So local authorities may be tempted to use this information opportunistically, in order to induce the federal government to adopt a decision that favors its constituency.[1] This paper deals precisely with incentive problems that emerge in institutional contexts where federal decisions about construction of facilities are taken under asymmetric information.

As Tresch (1981) suggested, such problems can only be rigorously analyzed in second-best asymmetrical information environments. The public economics literature that adopted such approach has studied two different issues. The first issue is related to NIMBY, an acronym that describes the well-known controversy of siting noxious facilities. Whereas such facilities are supposed to benefit the majority of the population, the community designated as the host often views the project's impact to be negative and thus try to oppose its construction. Among others, Goetze (1982), Kleindorfer and Kunreuther (1986), Easterling and Kunreuther (1992, 1996) and Frey et al. (1996) have analyzed different mechanisms (auctions, monetary compensations, insurance) designed to obtain the acceptance of host localities. The second issue concerns the design of intergovernmental transfers to finance a national public good (or a local public good with externalities) under asymmetric information. Cremer et al. (1996) and Lockwood (1999) have studied the impact of incentive problems on the design of interjurisdictional transfers and on the level of public goods.

These papers suffer from an important drawback: they do explicitly consider neither prerogatives that federal governments have nor constitutional constraints they face. On the one hand, papers that analyze mechanisms to obtain the acceptance of noxious facilities assumed that the federal government is obliged to respect the local status quo, i.e. the level of welfare whithout the facility being constructed. But often federal governments have

[1] Concerning noxious facilities, Goetze (1982) points that, in host localities, expressed fears of risk are regarded as exaggerated and perhaps strategically motivated.

the constitutional power to implement policies that do not respect everybody's status quo, if it is in the general interest to do so.[2] On the other hand, papers that deal with intergovernmental transfers under asymmetric information implicitly assume that federal governments, because of their pre-eminence, are not constrained towards local authorities. Bordignon et al. (2001) state that "*Given the coercitive powers of the federal government, it is natural to assume that both regions are forced to play this game and thus we do not impose any participation constraint*". But federal governments seldom are completely free, specially if national projects yield negative values for some regions. In fact, federal governments are constitutionally constrained to respect lower levels of government.[3] The purpose of this paper is precisely to add these two features to the existing literature.[4] Our goal is to characterize, in a fiscal federal setting under asymmetric information, the optimal system of interregional transfers to finance a facility when the federal government is constitutionally constrained to respect local authorities but it does not have to ensure necessarely their status quo.

We present a simple model of a country consisting of two non-overlapping and equally wealthy regions, each ruled by a local authority. Following an

[2] On January 10, 2002, the U.S. Secretary of Energy S. Abraham decided to recommend to President Bush approval of the Yucca Mountain site (Nevada) for the development of a nuclear waste repository. In spite of Nevadans strongly resistance to the project, Abraham justifies his decision because "there are compelling national interests that requires us to complete the sitting process and move forward with the development of a repository" (Headquarter's press release, U.S. Department of Energy).

[3] In some countries, when local authorities consider that federal decisions are arbitrary, they can resist them judicially. In 1985, the U.S. Congress enacted the Low Level Radioactive Waste Policy Amendments Act. Among other things, this law imposes upon States the obligation to provide for the disposal of waste generated within their borders. The act contained three types of incentives to encourage the States to comply with that obligation. New York State and two of its counties filed a suit against the United States, seeking a declaratory judgement that the three incentives were unconstitutional. The U.S. Supreme Court declared that effectively one of the incentive schemes proposed by the Congress were inconsistent with the Tenth Amendment - which states that "The powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States". See New York *v.* United States 505 U.S. 144 (1992).

[4] These aforementioned considerations also apply to the theoretical literature that deals with revelation of preferences for public goods. On the one hand, it is well known that Clarke-Groves mechanisms may not respect participation constraints. On the other hand, both static mechanisms [Green and Laffont (1979)] or dynamic procedures [Malinvaud (1971), Drèze and De la Vallée Poussin (1971)] ensure each agent with the status quo. Makowski and Mezzetti (1994) is closer to our analysis because, in the second part of their paper, they consider the possibility of weakening the ex-post individual rationality constraints. But, as they impose ex-ante budget balancing (whereas we impose ex-post budget balancing), they find results that go in an opposite direction than ours.

utilitarian objective, the federal government plans to construct a facility in one region. If it is undertaken, the facility generates a social value in this region and also has spillover effects in the other region. Both the local value and the spillover effect can be positive or negative. The utilitarian federal government should decide whether to construct the facility and, if so, how to finance it. The federal government is constitutionally constrained to set transfers in order to maintain each region's welfare above a certain value. But the federal government does not observe the facility's local value (which can be high or low) because it is the local authority's private information. To deal with this informational gap, the federal government designs an incentive-compatible mechanism, specifying if the facility should be constructed and a scheme of interregional transfers. Therefore, the shape of the optimal mechanism will depend upon the local value, the spillover level and how the constitutional constraint is stringent.

The most important results are the following. First, in a full-information framework, the traditional Samuelson's rule (equalization of marginal utilities of private consumption) does not always apply when the project is undertaken. Indeed, it may be optimal to undertake a project when one of the constitutional constraints is binding. In that case, the region with the lowest value will be compensated with respect to the Samuelson's rule.

Second, in the asymmetric information framework, the distortions depend upon how stringent are constitutional constraints. In particular, when only Pareto improving projects are undertaken, the federal government faces a unique type of local misbehavior, namely the understatement of the facility's local value. This problem occurs when the project is relatively "bad" for the region for which the government imperfectly observes the local value. The way to deal with this problem is to distort downward inter-regional transfers and also the decision to undertake the project. Projects that yield to relatively low local values are optimally shutdown whereas they should have been constructed under full-information. However, when the constitutional constraints are less stringent, another type of local misbehavior appears, namely the exaggeration of the local value. This problem occurs when the project is relatively "good" in the region for which the government imperfectly observes the local value. Therefore, additional distortions appear.

In the next section we present the model and we analyze the full-information case. Then we study the problem when the federal government faces asymmetric information. In particular, we will give a special attention to extreme values of the constitutional constraints. Finally, we conclude. All proofs are in the Appendix.

2 The model

The nation The country is composed by two separate regions $i = L, R$, each ruled by a local authority. Due to high communication or transaction costs, we rule out the possibility of agreements between the regions. On the top, the federal government has to decide whether to construct, in region L, a national facility of a given size.[5] We formalize this decision as an index variable

$$\delta = \begin{cases} 1 \; if \; the \; facility \; is \; constructed \\ 0 \; otherwise \end{cases}$$

The other region R represents the "rest of the country".

The facility We assume that, if the facility is constructed, it generates a local value v_L (in region L) and a spillover value v_R (in the other region R). But we do not restrict the signs of both values v_L and v_R: we want to study all possible cases of public facilities, which can be the following:

- $v_L > 0$ and $v_R > 0$: the facility is beneficial for the entire national population.
- $v_L > 0$ and $v_R < 0$: the project is beneficial only for region L but generates a negative externality in the other region R (e.g. an upstream dam in L).
- $v_L < 0$ and $v_R > 0$: a typical noxious facility, that is beneficial for the rest of the country but to the detriment of the host region L (e.g. a prison or a waste disposal).
- $v_L < 0$ and $v_R < 0$: the project has a negative value for the entire country's population.

The facility costs c, which is common knowledge. If it is undertaken, the federal government bears this cost.

The regions We formalize the local authority as the representative agent of each region. For the sake of simplicity, we assume that both regions have

[5] Our paper does not analyze the choice of the place where the national facility should be constructed. Although this is a crucial problem for some kind of facilities (e.g. prisons), there are many others for which their construction's place is not an issue (e.g. nuclear waste disposals, dams...). For such facilities, it may be the case that there exists only one locality that has the appropriate hydrological and geological characteristics to become the host.

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the same income, so $y_L = y_R = y$[6]. We also assume that the project is not so costly that a region is not able to undertake it by itself, i.e. $c < y$. With this income y, region i can consume a private good in quantity q_i. Each region derives the same utility from the consumption of this good. We formalize this as a strictly increasing and concave utility function u, with $u(0) = 0$.

In order to ensure the project's financing, the federal government designs a scheme of intergovernmental transfers t_i.[7] When $t_i < 0$, the federal government subsidizes region i; when $t_i \geq 0$, region i is taxed. Taking into account each region's budget constraint $q_i = y - t_i$, the utilities of both regions will be $U_L = u(y - t_L) + \delta v_L$ and $U_R = u(y - t_R) + \delta v_R$. That is, we assume that the utility is separable between the private and the public good. Given the discrete approach adopted in the paper, the utility ends out to be quasilinear in the facility's value.

The federal government Its goal is to maximize an utilitarian national social welfare given by $W(t_L, t_R, \delta) = U_L + U_R$, subject to $t_L + t_R \geq \delta c$, which is the federal budget constraint (BB).

The federal government controls the decision variable δ. On the one hand, it can impose to the region L the project's undertaking, even if the value v_L is negative. On the other hand, it can prohibit the facility's construction, even if v_L is so high that region L wants to undertake it by itself. Although this seems to be a command economy, the country's constitution impose to the federal government another type of constraint on the allocations (δ, t_L, t_R) that it can set. This restriction, denoted by CC_i, has the following form:

$$u(y - t_i) + \delta v_i \geq k \qquad CC_i$$

The federal government is constrained to leave to both regions a minimal level of utility $k \in (-\infty, u(y)]$. The greatest minimal utility $u(y)$ is the status quo level and ensures only Pareto improving construction of facilities. We can think that the constitution prohibits the federal government to exploit a region, at the detriment of the other. The lowest bound corresponds to the case of a non constrained utilitarian government. In this last case, every project that has a high value for the country *as a whole* will be undertaken. As we mentioned in the introduction, one of the objectives of this paper is to

[6]This rules out any redistributional concerns.

[7]For the sake of simplicity, we rule out the possibility of transfers $t_i \neq 0$ when the facility is not constructed. Although our formalization precludes any redistribution, such transfers could help to relax incentive problems. Nevertheless, the main results of the paper would remain unchanged.

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characterize the optimal allocations for different constitutional constraints, or equivalently, for different levels of the minimal utility k. Next we analyze the full-information benchmark.

2.1 Full-information

Assume that the federal government is able to observe the value of v_L and v_R. Hence it has to solve the following program denoted by $\mathfrak{P}$

$$\mathfrak{P}\begin{cases} \underset{\delta,t_L,t_R}{Max} & u(y-t_L)+u(y-t_R)+\delta\left(v_L+v_R\right) \\ & \\ & subject\ to \\ & \\ & u(y-t_L)+\delta v_L \geq k \qquad CC_L \\ & u(y-t_R)+\delta v_R \geq k \qquad CC_R \\ & t_L+t_R \geq \delta c \qquad BB \end{cases}$$

The following lemma completely characterizes the optimal full-information allocations (δ^*, t_L^*, t_R^*).

Lemma 1 *The decision $\delta^*(v_L, v_R) = 1$ if and only if conditions (A), (B) or (C) hold.*

- *Condition (A):* $v_L \geq k - u\left(y-\frac{c}{2}\right)$, $v_R \geq k - u\left(y-\frac{c}{2}\right)$ *and* $v_L \geq 2\left[u(y) - u\left(y-\frac{c}{2}\right)\right] - v_R$

  In this case, transfers are $t_L^* = t_R^* = \frac{c}{2}$.
- *Condition (B)* $v_L \,\square\, k - u\left(y-\frac{c}{2}\right)$ *and* $v_R \geq 2u(y) - k - u(2y - c - u^{-1}(k - v_L))$

  In this case, transfers are $t_L^* = y - u^{-1}(k-v_L) < \frac{c}{2}$ *and* $t_R^* = c - y + u^{-1}(k - v_L) > \frac{c}{2}$.
- *Condition (C)* $v_R \,\square\, k - u\left(y-\frac{c}{2}\right)$ *and* $v_L \geq 2u(y) - k - u(2y - c - u^{-1}(k - v_R))$

  In this case, transfers are $t_R^* = y - u^{-1}(k-v_R) < \frac{c}{2}$ *and* $t_L^* = c - y + u^{-1}(k - v_R) > \frac{c}{2}$.

Condition (A) describes the parametric area where the Samuelson's rule applies (marginal utilities are equalized between the two regions, i.e. $t_L =$

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$t_R = c/2$). The first two inequalities insure that each region's constitutional constraint is satisfied, while the third one means that total welfare must be higher than the one obtained when the facility is not constructed. Conditions (B) and (C) describe parametric areas for which the facility is undertaken when the constitutional constraint of one of the regions is binding. If CC_i is binding, transfer t_i^* is given by the binding constitutional constraint and region i is compensated with respect to the transfers given by the Samuelson's rule. When $k \to -\infty$, the Samuelson's rule always applies so conditions (B) and (C) vanish.

For further use, we will denote $v_L^*(v_R, k)$ the value of v_L (as a function of v_R and k) above which a facility is constructed under full-information. Straightforward use of lemma 1 leads to:

$$v_L^*(v_R,k) = \begin{cases} 2u(y) - k - u(2y - c - u^{-1}(k - v_R)) & if\ v_R \square k - u\left(y - \frac{c}{2}\right) \\ 2\left[u(y) - u\left(y - \frac{c}{2}\right)\right] - v_R & if \begin{cases} k - u\left(y - \frac{c}{2}\right) \square v_R \\ v_R \square 2u(y) - k - u\left(y - \frac{c}{2}\right) \end{cases} \\ k - u\left(2y - c - u^{-1}(2u(y) - k - v_R)\right) & if\ 2u(y) - k - u\left(y - \frac{c}{2}\right) \square v_R \end{cases}$$

Full-information allocations can be seen in the following graphic, where each couple (v_R, v_L) represents a facility.

Insert Figure 1 here

The function $v_L^*(k, v_R)$ is represented by the bold curve. Below this curve, no projects are undertaken. We can easily show that this frontier is decreasing and convex in v_R. In the parametric area denoted by A, the project is financed following the Samuelson's rule. Note that, in this area, the utility of region i, with $v_i \square u(y) - u\left(y - \frac{c}{2}\right)$, verifies $k \square U_i \square u(y)$. In other words, every undertaken project that verifies $v_i \square u(y) - u\left(y - \frac{c}{2}\right)$ is not Pareto improving for region i (except for the extreme case when $k = u(y)$). In area B, the constitutional constraint CC_L binds and, in area C, CC_R binds.

In the next figure, we can see how full-information allocations vary with k.

Insert Figure 2 here

When $k \to -\infty$, the bold curve becomes a straight line above which Samelson's rule always prevails. When $k = u(y)$, the curve is strictly convex. Obviously, the less stringent are the constitutional constraints, the more projects will be undertaken.

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3 Asymmetric information on v_L

Now we assume that v_L can have two different values $\underline{v}_L < \overline{v}_L$. Moreover we assume that, although the region L knows the value of v_L (it's type), the federal government is unable to observe whether v_L is in fact high ($\overline{v}_L$) or low ($\underline{v}_L$). The facility generates benefits v_R all over the nation that are observable. But, on the top of that, there are local conditions that are unobservable for the federal government.[8] The federal government has some beliefs about this local value v_L. Lets denote these beliefs by $\mu = \Pr[v_L = \overline{v}_L]$ and by $1 - \mu = \Pr[v_L = \underline{v}_L]$. Next we completely characterize the optimal allocations under asymmetric information.

It is convenient to solve this problem adopting a mechanism design approach, as advocated by Crémer et al. (1996). The federal government will ask the region L to announce its type $\widetilde{v}_L$ and will commit to implement the allocation $(\delta(\widetilde{v}_L), t_L(\widetilde{v}_L), t_R(\widetilde{v}_L))$. In this setting, the Revelation Principle applies. So the federal government can set incentive-compatible allocations (δ, t_L, t_R) that are conditional on both possible values of v_L. We denote those allocations by $(\overline{\delta}, \overline{t}_L, \overline{t}_R)$ when they concern a high local value region (i.e. a region L with $\overline{v}_L$) and by $(\underline{\delta}, \underline{t}_L, \underline{t}_R)$ in the other case.

Now, in order to maximize the national social welfare, the federal government solves the new program $\mathfrak{P}'$

[8] For example, the federal government may want to construct an new airport in region L. A federal agency with technical expertise, like the U.S. Federal Aviation Administration, may know the value of improvement in air traffic for both regions L and R. But only L's local authority is able to observe how damaging, in terms of the increase in noise, the installation of the airport is.

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$$
\mathfrak{P}' \left\{
\begin{array}{ll}
\underset{\substack{\underline{\delta}, \underline{t}_L, \underline{t}_R \\ \overline{\delta}, \overline{t}_L, \overline{t}_R}}{Max} & \mu \left[u(y - \overline{t}_L) + u(y - \overline{t}_R) + \overline{\delta} \left(\overline{v}_L + v_R \right) \right] \\
& +(1-\mu) \left[u(y - \underline{t}_L) + u(y - \underline{t}_R) + \underline{\delta} \left(\underline{v}_L + v_R \right) \right] \\
& \\
& subject\ to \\
& \\
& u(y - \underline{t}_L) + \underline{\delta}\, \underline{v}_L \geq k \quad \underline{CC}_L \qquad u(y - \overline{t}_L) + \overline{\delta} \overline{v}_L \geq k \quad \overline{CC}_L \\
& u(y - \underline{t}_R) + \underline{\delta}\, \underline{v}_R \geq k \quad \underline{CC}_R \qquad u(y - \overline{t}_R) + \overline{\delta} \overline{v}_R \geq k \quad \overline{CC}_R \\
& \underline{t}_L + \underline{t}_R \geq \underline{\delta} c \quad \underline{BB} \qquad \overline{t}_L + \overline{t}_R \geq \overline{\delta} c \quad \overline{BB} \\
& u(y - \overline{t}_L) + \overline{\delta} \overline{v}_L \geq u(y - \underline{t}_L) + \underline{\delta} \overline{v}_L \quad \overline{IC} \\
& u(y - \underline{t}_L) + \underline{\delta}\, \underline{v}_L \geq u(y - \overline{t}_L) + \overline{\delta} \underline{v}_L \quad \underline{IC}
\end{array}
\right.
$$

where $\overline{IC}$ and $\underline{IC}$ represent the incentive-compatibility constraints, for region $\overline{v}_L$ and $\underline{v}_L$ respectively. It is straightforward to realize that an incentive-compatible allocation must set $\underline{\delta} \Box \overline{\delta}$. This monotonicity result, fairly common in agency theory, implies that under asymmetric information, there may be at most 3 configurations of facilities. They are the following:

- Configuration I: regardless of the local value v_L, the facility is always undertaken $(\underline{\delta}^I = \overline{\delta}^I = 1)$
- Configuration II : only a facility that has a high local value $\overline{v}_L$ is constructed $(\underline{\delta}^{II} = 0, \overline{\delta}^{II} = 1)$
- Configuration III: no matter its local value v_L, the project is abandoned $(\underline{\delta}^{III} = \overline{\delta}^{III} = 0)$.

3.1 When full-information allocations are not implementable

Under asymmetric information, some full-information allocations are incentive-compatible. This comes from the quasilinearity of the region's utility function. For example, for relatively high values of $v_R, \underline{v}_L$ and $\overline{v}_L$, transfers given by the Samuelson's rule are incentive-compatible because both type of regions have the same level of private consumption. But this is not always the case. The following lemmas describe the parametric areas, in the $(\underline{v}_L, \overline{v}_L, v_R)$

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space, where full-information allocations are not implementable. To clarify the exposition, we will first present the case when the project is relatively detrimental for region R, i.e. when $v_R \square u(y) - u\left(y - \frac{c}{2}\right)$. Then we turn to the case where the project is relatively beneficial for region R, i.e. when $v_R \geq u(y) - u\left(y - \frac{c}{2}\right)$.

Lemma 2 *When $v_R \square u(y) - u\left(y - \frac{c}{2}\right)$, full-information allocations are not implementable if and only if $(\underline{v}_L, \overline{v}_L, v_R)$ belongs to the parametric area defined in (a) or (b):*

$$(a) \quad \begin{cases} v_R \square k - u\left(y - \frac{c}{2}\right) \\ v_L^*(v_R, k) + k - u(y) \square \underline{v}_L \square v_L^*(v_R, k) \square \overline{v}_L \end{cases}$$

$$(b) \quad \begin{cases} k - u\left(y - \frac{c}{2}\right) < v_R \square u(y) - u\left(y - \frac{c}{2}\right) \\ u(y) - u\left(y - \frac{c}{2}\right) \square \underline{v}_L \square v_L^*(v_R, k) \square \overline{v}_L \end{cases}$$

Suppose that the federal government offers the menu $(\underline{\delta}^*, \underline{t}_L^*, \underline{t}_R^*)$ and $(\overline{\delta}^*, \overline{t}_L^*, \overline{t}_R^*)$. Given that in (a) and (b), $\underline{v}_L \square v_L^*(v_R, k)$, the full-information configuration of projects should have been II^* (i.e. $\overline{\delta}^* = 1$ and $\underline{\delta}^* = 0$). Given that the facility is detrimental for region R, the government sets full-information transfers such that $k \square U_R(\overline{t}_R^*(k)) \square u(y)$. In this case, the high local value region benefits from an utility $\overline{U}_L(\overline{t}_L^*(k)) \geq u(y)$ since it is optimal to undertake the project[9]. Thus, if $\underline{v}_L$ is sufficiently large, the low local value region (i.e. the region L with $\underline{v}_L$) finds optimal to mimic the high local value region, by announcing $\widetilde{v}_L = \overline{v}_L$, in order to obtain the construction of the facility and have an utility $\underline{U}_L(\overline{t}_L^*(k))$, with $\underline{U}_L(\underline{t}_L^*(k)) = u(y) \square \underline{U}_L(\overline{t}_L^*(k)) \square 2u(y) - k$.

In the extreme case where the federal government ensures that a project is undertaken only if the status-quo is respected ($k = u(y)$), a project is abandoned if and only if the utility of a region is strictly lower than $u(y)$. Therefore, in this particular case, the low local value region has no incentives to mimic the high local value region:

Corollary 3 *When $v_R \square u(y) - u\left(y - \frac{c}{2}\right)$, full-information allocations are always implementable if $k = u(y)$.*

We now turn to the study of facilities that generate a relatively high value v_R to the region R.

[9] Recall that, in order to construct the facility, $\overline{U}_L(\overline{t}_L^*(k)) + U_R(\overline{t}_R^*(k)) \geq 2u(y)$ must hold.

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Lemma 4 *When* $v_R \geq u(y) - u\left(y - \frac{c}{2}\right)$*, full-information allocations are not implementable if and only* $(\underline{v}_L, \overline{v}_L, v_R)$ *belongs to the parametric area defined in (c) or (d):*

$$(c) \quad \begin{cases} u(y) - u\left(y - \frac{c}{2}\right) \square v_R \\ \underline{v}_L \square v_L^*(v_R, k) \square \overline{v}_L \square u(y) - u\left(y - \frac{c}{2}\right) \end{cases}$$

$$(d) \quad \begin{cases} 2u(y) - k - u\left(y - \frac{c}{2}\right) \square v_R \\ v_L^*(v_R, k) \square \underline{v}_L \square k - u\left(y - \frac{c}{2}\right) \end{cases}$$

Again suppose that the federal government offers a menu that sets, for each state of nature i, the optimal full-information allocation. In the parametric areas characterized in (c) and (d), the high local value region wants to mimic the low local value region. Indeed, when (c) holds, $\underline{v}_L \square v_L^*(v_R, k) \square \overline{v}_L$, so the full-information configuration of projects should have been II^* (i.e. $\overline{\delta}^* = 1$ and $\underline{\delta}^* = 0$). Given that the project is detrimental for the high local value region L, the government sets full-information transfers such that $k \square \overline{U}_L(\overline{t}_L^*(k)) \square u(y)$. Thus, the high local value region finds optimal to mimic the low local value region in order to obtain the rejection of the project and have a utility $\overline{U}_L(\underline{t}_L^*(k)) = u(y) \geqslant k$. It is straightforward to see that, in the extreme case where the government insures that a project is undertaken if the status-quo is respected ($k = u(y)$), the high local value region has no incentives to mimic the low local value region.

Corollary 5 *In case (c), full-information allocations are implementable if and only if* $k = u(y)$

If (d) holds, the full-information configuration of projects should have been I^* (i.e. $\underline{\delta}^* = \overline{\delta}^* = 1$). Under this circumstance, the full-information transfers $\underline{t}_L^*$ increase with $\underline{v}_L$[10]. So the region L with $\overline{v}_L$ would like to pay less for the project, pretending to be $\underline{v}_L$. In the extreme case where $k = -\infty$ (pure utilitarianism), there is no such problem of mimicking since both high and low regions L pay the same cost $\frac{c}{2}$ in the full-information case.

Corollary 6 *In case (d), full-information allocations are implementable if and only if* $k \longrightarrow -\infty$.

To sum up, when the facility is detrimental for R, we observe (for some parameters) upward mimicking. When the project is beneficial for R, we observe downward mimicking. In the extreme case where $k = u(y)$ (the

[10] Recall that, in this case, $\underline{t}_L^* = u(y) - u^{-1}(-\underline{v}_L)$ so $\frac{d\underline{t}_L^*}{d\underline{v}_L} = (u^{-1})'(-\underline{v}_L) > 0$.

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central government implements only Pareto improving projects), there is no problem of mimicking in areas described by (a), (b) and (c). In the opposite case where $k \longrightarrow -\infty$ (pure utilitarianism), the downward mimicking observed in (d) vanishes.

In all other parametric areas, the full-information allocations are implementable. We now turn to the description of the second best allocation problem in the particular cases presented above.

3.2 Optimal allocations under asymmetric information

Suppose that, for specific values of the parameters $\underline{v}_L$ and $\overline{v}_L$, full-information allocations are not implementable. Let's denote by

$$\overline{t}_i^j \text{ and } \underline{t}_i^j, \{i = L, R; j = I, II, III\}$$

transfers paid by region i in configuration of projects j.

Let's assume that the federal government wants to implement the configuration I. In that case, the binding incentive-compatibility constraint yields to $u(y - \overline{t}_L) = u(y - \underline{t}_L)$. This implies that optimal (second-best) transfers are such that $\overline{t}_L^{I'} = \underline{t}_L^{I'}$.[11] Thus, solving problem $\mathfrak{P}'$ is equivalent to solve problem $\mathfrak{P}$ with three regions $(\underline{v}_L, \overline{v}_L, v_R)$ and an equal transfer for the low and high local value regions.

Now let's assume that the federal government wants to implement the configuration II. The analysis of such configuration depends upon which incentive-compatibility constraint is binding:

- If $\underline{IC}_L$ is binding, then the transfer is such that the low local value region is indifferent between doing the project or not, i.e. $u(y - \overline{t}_L^{II'}) + \underline{v}_L = u(y)$.
- If $\overline{IC}_L$ is binding, then the transfer is such that the high local value region is indifferent between doing the project or not, i.e. $u(y - \overline{t}_L^{II'}) + \overline{v}_L = u(y)$.
- Else, $\overline{t}_L^{II'} = \overline{t}_L^*$.

Finally, if the federal government plans to implement the configuration III, no transfers are made so $\overline{t}_L^{III'} = \underline{t}_L^{III'} = t_R^{III'} = 0$.

[11] We denote by j' a configuration j implemented via distorted transfers, distorted with respect to full-information transfers t^*.

Optimal second-best transfers define, for each configuration of projects, a level of welfare. This permits the characterization of the parametric area where a particular configuration is preferred to the other ones. The computations can be found in the appendix. We just present in the following section the shape of second-best optimal allocations for each configuration and we compare them to the full-information one. Additionally, we give a graphical illustration of the parametric areas defining the optimal configurations.

For easy of exposition, we will present in the following part the optimal design of transfers when $\underline{IC}_L$ is binding (i.e in cases (a) or (b) of Lemma 4) and then turn to the case where $\overline{IC}_L$ is binding (cases (c) and (d) of Lemma 5).

3.2.1 Optimal second-best allocations when the project yields a low local value to region R

Let's assume that $v_R \Box u(y) - u\left(y - \frac{c}{2}\right)$. If the federal government plans to implement configuration I, $\underline{IC}_L$ is binding. Moreover, CC_R is binding in case (a), so second-best transfers should be

$$\underline{t}_L^{I'} = \overline{t}_L^{I'} = \overline{t}_L^{*} = \begin{cases} c - y + u^{-1}(k - v_R) & \text{in case } (a) \\ \frac{c}{2} & \text{in case } (b) \end{cases}$$

In other words, both high and low local value regions pay the transfer $\overline{t}_L^{*}$ that would be optimal in a full-information world, with $v_L = \overline{v}_L$. Since configuration II was adopted under full-information, these second-best transfers, if implemented, yields to an upward distortion of δ.

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If the federal government plans to implement the configuration II, given that $\underline{IC}_L$ binds, second-best transfers are given by

$$\begin{cases} \overline{t}_L^{II'} = y - u^{-1}(u(y) - \underline{v}_L) \\ \underline{t}_L^{II'} = 0 \end{cases}$$

In other words, if these transfers are implemented, there is an upward distortion of the transfer paid by the high local value region.

Graphically, Figure.3 represents an illustration of the second-best configuration of projects in case (a) in the $(\underline{v}_L, \overline{v}_L)$ space.[12]

Insert Figure 3 here

[12] Case (b) implies similar distortions.

Now, for a given value of v_R, a couple $(\underline{v}_L, \overline{v}_L)$ represents a facility, from the federal government's point of view. Remember that in (a), the full-information configuration should have been II^*, with $\overline{t}_L^* = c - y - u^{-1}(k - v_R)$. Under asymmetric information, we observe two kinds of distortions with respect to the full-information allocations: the government implements either another configuration of projects or sets another transfer $\overline{t}_L^{II'}$, paid by the high local value region L.

In the parametric area II', the federal government implements the same configuration than under full-information but there is an upward distortion of the transfer paid by the high local value region L, that is $\overline{t}_L^{II'} > \overline{t}_L^*$. As $\underline{v}_L$ increases, this distortion increases. Thus, above a threshold value of $\underline{v}_L$, the federal government prefers to implement configuration I' with non distorted transfers. This is an upward distortion of δ. Finally, for a low level of $\overline{v}_L$, implementation costs dominate the high social value of the project. Therefore, in the parametric area denoted by III', the project is optimally shutdown. This is a downward distortion of δ.

3.2.2 Optimal allocations when the project yields a high local value in region R

Now let's assume that $v_R \geqslant u(y) - u\left(y - \frac{c}{2}\right)$. If, in cases (c) and (d), the federal government plans to implement the configuration I, $\overline{IC}_L$ is binding. Moreover, for $k - u\left(y - \frac{c}{2}\right) \geq \underline{v}_L$, $\underline{CC}_L$ also binds so

$$\underline{t}_L^{I'} = \overline{t}_L^{I'} = \begin{cases} \frac{c}{2} & if\ \underline{v}_L \geq k - u\left(y - \frac{c}{2}\right) \\ y - u^{-1}(k - \underline{v}_L) & if\ k - u\left(y - \frac{c}{2}\right) \geq \underline{v}_L \end{cases}$$

If implemented, configuration I' represents a downward distortion of the transfer $\overline{t}_L$ in case (d), while in case (c), configuration I' represents an upward distortion of δ.

If the federal government plans to implement configuration II, $\overline{IC}_L$ is only binding when $\overline{v}_L < u(y) - u\left(y - \frac{c}{2}\right)$, so that second-best transfers are given by:

$$\overline{t}_L^{II'} = \begin{cases} y - u^{-1}(u(y) - \overline{v}_L) & \overline{v}_L < u(y) - u\left(y - \frac{c}{2}\right) \\ \frac{c}{2} & if\ \overline{v}_L \geq u(y) - u\left(y - \frac{c}{2}\right) \end{cases}$$
$$\underline{t}_L^{II'} = 0$$

If implemented, configuration II' represents a downward distortion of the transfer $\overline{t}_L$ in case (c), while in case (d), configuration II' represents a downward distortion of δ combined with a downward distortion of $\overline{t}_L$ when $\overline{v}_L < u(y) - u\left(y - \frac{c}{2}\right)$. In other words, implementing II' requires a double distortion when $\overline{v}_L < u(y) - u\left(y - \frac{c}{2}\right)$, because the government wants to prevent the fact that the high region mimicks the low region in order to shutdown the project.

Figure 4 gives an illustration of the second-best configuration of projects in case (c) and (d) :

Insert Figure 4 here

To understand these distortions, note that, under full-information, configuration I^* was adopted when $\underline{v}_L \geq v_L^*(v_R, k)$ (case (d)); else configuration II^* was adopted (case (c)). Hence, when $\underline{v}_L \geq v_L^*(v_R, k)$, the area I' represents the space where there is a downward distortion of the transfer paid by the high local value region. This distortion increases as $\underline{v}_L$ decreases. In the area II', there is a downward distortion of δ with a downward distorted transfer $\overline{t}_L^{II'}$ when $\overline{v}_L < u(y) - u\left(y - \frac{c}{2}\right)$. This distortion on the transfer is higher the lower is $\overline{v}_L$.Therefore, when $\overline{v}_L \geq u(y) - u\left(y - \frac{c}{2}\right)$, configuration II' is prefered below a threshold value $\underline{v}_L$. When $\overline{v}_L < u(y) - u\left(y - \frac{c}{2}\right)$, configuration II' is prefered for low $\underline{v}_L$ and for high $\overline{v}_L$.

When $\underline{v}_L < v_L^*(v_R, k)$, the full-information configuration was II^*. The area II' is the space where there is a downward distortion of $\overline{t}_L$. This distortion is higher the lower is $\overline{v}_L$. Area I' represents the space where there is an upward distortion of δ wich implies higher implementation costs the lower is $\underline{v}_L$. Thus, for high $\overline{v}_L$ and low $\underline{v}_L$, configuration II' is prefered to I'. Moreover, below a threshold value for $\overline{v}_L$, configuration III' is prefered, that is it is optimal to distort downward δ.

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4 Conclusions and future research

First we summarize the model and the main results. We have formalized a country consisting of two non-overlapping regions, each ruled by a local authority. The federal government has planned to construct a public facility in one of the regions. If it is undertaken, this project generates a social value in this region and spillovers in the rest of the country. Both the local value and the external effect can be positive or negative.

The federal government should decide whether to undertake the work and how to finance it. But it does not observe the local value (which can be high or low) because it is in fact the local authority's private information. To deal with this informational gap, the federal government designs an incentive-compatible mechanism, specifying if the project should be undertaken and a scheme of interregional transfers. In its choice, the federal government is constitutionally constrained to respect the regions' welfare.

In this very simple model, we have completely characterized the optimal allocations under asymmetric information. We have also shown the impact of different constitutional constraints on these allocations, specially the distortions that appear in the decision about which projects undertake. The most important result is the emergence of different patterns of misbehavior according to different constitutional rules.

This model enables us to pursue this research in different directions. First of all, we can extend the informational asymmetries, to consider the case where all social values are unknown to the federal government. A second direction could be to endogenize the constitutional setting. We could obtain some insights concerning constitutional design for rising federations, which could serve in political discussion, for example at the European level.

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5 Appendix

5.1 Proof of Lemma 1

For $\delta = 1$, substituting the budget constraint (B), the Lagrangian of the problem can be written as:

$$\begin{aligned} L(t_R, t_L, \alpha_1, \alpha_2, \beta_1, \beta_2) &= u(y - t_L) + u(y - c + t_L) + v_R + v_L + \\ &+\beta_1 \left[u(y - t_L) + v_L - k\right] \\ &+\beta_2 \left[u(y - c + t_L) + v_R - k\right] \end{aligned}$$

where β_i are the Lagrange multipliers associated with the CC_i constraints. First order conditions with respect to t_L, β_1, β_2 are respectively:

$$\begin{cases} -u'(y - t_L) + u'(y - c + t_L) - \alpha_1 + \\ -u'(y - t_L) + u'(y - c + t_L) - \alpha_1 + \\ -\beta_1 u'(y - t_L) + \beta_2 u'(y - c + t_L) = 0 & (1) \\ \beta_1 \left[u(y - t_L) + v_L - k\right] = 0 & (2) \\ \beta_2 \left[u(y - c + t_L) + v_R - k\right] = 0 & (3) \\ \beta_1, \beta_2 \geq 0 & (4) \end{cases}$$

Note that the project will be undertaken if (1) to (5) are fulfilled, together with $W(t_L, t_R, 1) \geq W(0,0,0) = 2u(y)$. We prove point (i) to point (iii) of the lemma successively:

(i) Suppose that $\beta_1 = \beta_2 = 0$, then $t_L = t_R = \frac{c}{2}$. In this case, $\beta_1 = \beta_2 = 0$ if and only if $v_L \geq k - u\left(y - \frac{c}{2}\right)$ and $v_R \geq k - u\left(y - \frac{c}{2}\right)$ by (CC_L) and (CC_R). Moreover, the project will be done if and only if $W\left(\frac{c}{2}, \frac{c}{2}, 1\right) \geq W(0,0,0) \Leftrightarrow 2u\left(y - \frac{c}{2}\right) + v_L + v_R \geq 2u(y) \Leftrightarrow v_L \geq 2\left[u(y) - u\left(y - \frac{c}{2}\right)\right] - v_R$.

(ii) Suppose that $\beta_1 = 0$ and $\beta_2 > 0$ then $u(y - c + t_L) + v_R = k$. With point (i), we know that $\beta_2 > 0$ if $v_R < k - u\left(y - \frac{c}{2}\right)$. moreover, for the project to be undertaken, we need further $W(t_L, t_R, 1) \geq W(0,0,0) \Leftrightarrow u(y - t_L) + v_L + k \geq 2u(y) \Leftrightarrow v_L \geq 2u(y) - k - u\left(2y - c - u^{-1}(k - v_R)\right)$.

(iii) Symmetric argument ■

5.2 Proof of Lemma 4

1. Consider that condition (a) or (b) is fulfilled. Then

- in case (a):

$$\begin{aligned} \underline{u}_L\left(\underline{t}_L^*, \underline{\delta}^*\right) &= u(y) \\ \underline{u}_L(\overline{t}_L^*, \overline{\delta}^*) &= u\left(2y - c - u^{-1}(k - v_R)\right) + \underline{v}_L \end{aligned}$$

  where $\underline{u}_L\left(\underline{t}_L^*, \underline{\delta}^*\right)$ represents the utility of a low value region that behaves like that and $\underline{u}_L(\overline{t}_L^*, \overline{\delta}^*)$, the utility of a low value region that misbehaves. One thus have $\underline{u}_L(\overline{t}_L^*, \overline{\delta}^*) - \underline{u}_L\left(\underline{t}_L^*, \underline{\delta}^*\right) = \underline{v}_L + u\left(2y - c - u^{-1}(k - v_R)\right) - u(y) = \underline{v}_L + u(y) - k - v_L^*(k, v_R) \geq 0$ given that $\underline{v}_L \geq v_L^*(v_R) + k - u(y)$.

- in case (b):

$$\begin{aligned} \underline{u}_L\left(\underline{t}_L^*, \underline{\delta}^*\right) &= u(y) \\ \underline{u}_L(\overline{t}_L^*, \overline{\delta}^*) &= u\left(y - \tfrac{c}{2}\right) + \underline{v}_L \end{aligned}$$

  One thus have $\underline{u}_L(\overline{t}_L^*, \overline{\delta}^*) - \underline{u}_L\left(\underline{t}_L^*, \underline{\delta}^*\right) = \underline{v}_L + u\left(y - \frac{c}{2}\right) - u(y) \geq 0$ given that $\underline{v}_L \geq u(y) - u\left(y - \frac{c}{2}\right)$. It follows that the low local region wants to mimic the high local value region in case (a) and (b).

2. Consider that condition (c) or (d) is fulfilled. Then

- in case (c):

$$\begin{aligned} \overline{u}_L(\overline{t}_L^*, \overline{\delta}^*) &= \begin{cases} u\left(y - \frac{c}{2}\right) + \overline{v}_L & \text{if } \overline{v}_L \geq k - u\left(y - \frac{c}{2}\right) \\ k & \text{otherwise} \end{cases} \\ \overline{u}_L\left(\underline{t}_L^*, \underline{\delta}^*\right) &= u(y) \end{aligned}$$

  where $\overline{u}_L(\overline{t}_L^*, \overline{\delta}^*)$ represents the utility of a high value region that behaves like that and $\overline{u}_L\left(\underline{t}_L^*, \underline{\delta}^*\right)$, the utility of a low value region that misbehaves. One thus have $\overline{u}_L\left(\underline{t}_L^*, \underline{\delta}^*\right) - \overline{u}_L(\overline{t}_L^*, \overline{\delta}^*) = \begin{matrix} u(y) - u\left(y - \frac{c}{2}\right) - \overline{v}_L & \text{if } \overline{v}_L \geq k - u\left(y - \frac{c}{2}\right) \\ u(y) - k & \text{otherwise} \end{matrix} \geq 0$. Thus, $\overline{u}_L\left(\underline{t}_L^*, \underline{\delta}^*\right) - \overline{u}_L(\overline{t}_L^*, \overline{\delta}^*) \geq 0$ given that $\overline{v}_L$ □ $u(y) - u\left(y - \frac{c}{2}\right)$ and k □ $u(y)$.

- in case (d):

$$\begin{aligned} \overline{u}_L(\overline{t}_L^*, \overline{\delta}^*) &= \begin{cases} u\left(y - \frac{c}{2}\right) + \overline{v}_L & \text{if } \overline{v}_L \geq k - u\left(y - \frac{c}{2}\right) \\ k & \text{otherwise} \end{cases} \\ \overline{u}_L\left(\underline{t}_L^*, \underline{\delta}^*\right) &= k + \overline{v}_L - \underline{v}_L \end{aligned}$$

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One thus have $= \begin{matrix} -\underline{v}_L - u\left(y - \frac{c}{2}\right) & \text{if } \overline{v}_L \geq k - u\left(y - \frac{c}{2}\right) \\ \overline{v}_L - \underline{v}_L & \text{otherwise} \end{matrix}$. Thus, $\overline{u}_L\left(\underline{t}_L^*, \underline{\delta}^*\right) - \overline{u}_L(\overline{t}_L^*, \overline{\delta}^*) \geq 0$ given that $\underline{v}_L$ □ $-u\left(y - \frac{c}{2}\right)$ and $\underline{v}_L$ □ $\overline{v}_L$. It follows that the high local region wants to mimic the low local value region in case (c) and (d) ■

5.3 Second Best implementation in cases (a) and (b)

Let's denote by

$$F_{k,m}(\overline{v}_L, \underline{v}_L, v_R) = W_k(\overline{v}_L, \underline{v}_L, v_R) - W_m(\overline{v}_L, \underline{v}_L, v_R)$$

the difference between the expected welfare values in configuration k and m. Clearly if $F_{k,m}(\overline{v}_L, \underline{v}_L, v_R) > 0$, the federal government strictly prefers configuration k to configuration m. Equalizing $F_{k,m}(\overline{v}_L, \underline{v}_L, v_R)$ to 0 gives the frontier for which the government is indifferent between configuration k and m as an implicit function of $\overline{v}_L$ and $\underline{v}_L$.

Given the optimal transfers given in section (), one has:

$$\begin{aligned} W_{I'}\left(\overline{v}_L, \underline{v}_L, v_R\right) &= 2u(y) - v_L^*(v_R, k) + \mu\overline{v}_L + (1-\mu)\underline{v}_L \\ W_{II'}\left(\overline{v}_L, \underline{v}_L, v_R\right) &= (2-\mu)\, u(y) + \mu\overline{v}_L - \mu\underline{v}_L \\ &\quad + \mu u(2y - c - u^{-1}(u(y) - \underline{v}_L)) + \mu v_R \end{aligned}$$

It follows that

$$\begin{aligned} F_{I',III'}(\underline{v}_L, \overline{v}_L) &= \mu\overline{v}_L + (1-\mu)\underline{v}_L - v_L^*(v_R, k) \\ F_{I',II'}(\underline{v}_L, \overline{v}_L) &= \underline{v}_L - v_L^*(v_R, k) + \mu[u(y) - v_R - u(2y - c - u^{-1}(u(y) - \underline{v}_L))] \\ F_{II',III'}(\underline{v}_L, \overline{v}_L) &= \mu\left[\overline{v}_L - \underline{v}_L + v_R + u(2y - c - u^{-1}(u(y) - \underline{v}_L)) - u(y)\right] \end{aligned}$$

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5.4 Second Best implementation when (ii) is fulfilled

Similarly, one obtains easily:

$$W_{I'}(\overline{v}_L,\underline{v}_L,v_R,k) = \begin{cases} 2u(y)-v_L^*(v_R,k) \\ +\mu\overline{v}_L+(1-\mu)\underline{v}_L & \text{if } \underline{v}_L \geq k-u\left(y-\frac{c}{2}\right) \\ \mu\left(\overline{v}_L-\underline{v}_L\right)+v_R+k \\ +u\left(2y-c-u^{-1}(k-\underline{v}_L)\right) & \text{if } k-u\left(y-\frac{c}{2}\right) > \underline{v}_L \end{cases}$$

$$W_{II'}(\overline{v}_L,\underline{v}_L,v_R,k) = \begin{cases} 2\left(1-\mu\right)u(y)+ \\ 2\mu u\left(y-\frac{c}{2}\right)+\mu\left(v_R+\overline{v}_L\right) & \text{if } \overline{v}_L \geq u(y)-u\left(y-\frac{c}{2}\right) \\ \left(2-\mu\right)u(y)+\mu v_R+ \\ \mu u(2y-c-u^{-1}(u(y)-\overline{v}_L)) & \overline{v}_L < u(y)-u\left(y-\frac{c}{2}\right) \end{cases}$$

It follows that

$$F_{I',III'}(\underline{v}_L,\overline{v}_L,k) = \begin{cases} -v_L^*(v_R,k)+\mu\overline{v}_L+(1-\mu)\underline{v}_L & \text{if } \underline{v}_L \geq k-u\left(y-\frac{c}{2}\right) \\ \mu\left(\overline{v}_L-\underline{v}_L\right)+v_R-2u(y) \\ +u\left(2y-c-u^{-1}(k-\underline{v}_L)\right)+k & \text{if } k-u\left(y-\frac{c}{2}\right) \geq \underline{v}_L \end{cases}$$

$$F_{I',II'}(\underline{v}_L,\overline{v}_L,k) = \begin{cases} \mu\overline{v}_L+(1-\mu)\underline{v}_L+\mu u(y)-v_L^*(v_R,k) \\ -\mu u(2y-c-u^{-1}(u(y)-\overline{v}_L))-\mu v_R & \text{if } \underline{v}_L \geq k-u\left(y-\frac{c}{2}\right) \text{ and } \overline{v}_L < u(y)-u\left(y-\frac{c}{2}\right) \\ (1-\mu)v_R+\mu\left(\overline{v}_L-\underline{v}_L\right)-\left(2-\mu\right)u(y) \\ +\mu u(2y-c-u^{-1}(k-\underline{v}_L))+k \\ -\mu u(2y-c-u^{-1}(u(y)-\overline{v}_L)) & \text{if } k-u\left(y-\frac{c}{2}\right) > \underline{v}_L \text{ and } \overline{v}_L < u(y)-u\left(y-\frac{c}{2}\right) \\ -\mu\underline{v}_L+(1-\mu)v_R+k \\ +u\left(2y-c-u^{-1}(k-\underline{v}_L)\right) \\ -2(1-\mu)u(y)-2\mu u\left(y-\frac{c}{2}\right) & \text{if } k-u\left(y-\frac{c}{2}\right) > \underline{v}_L \text{ and } \overline{v}_L \geq u(y)-u\left(y-\frac{c}{2}\right) \end{cases}$$

$$F_{II',III'}(\underline{v}_L,\overline{v}_L,k) = \begin{cases} \mu[u(2y-c-u^{-1}(u(y)-\overline{v}_L)) \\ +v_R-u(y)] & \text{if } \overline{v}_L < u(y)-u\left(y-\frac{c}{2}\right) \\ \mu[2u\left(y-\frac{c}{2}\right) \\ -2u(y)+v_R+\overline{v}_L] & \text{if } \overline{v}_L \geq u(y)-u\left(y-\frac{c}{2}\right) \end{cases}$$

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Figure 1: Full-information allocations

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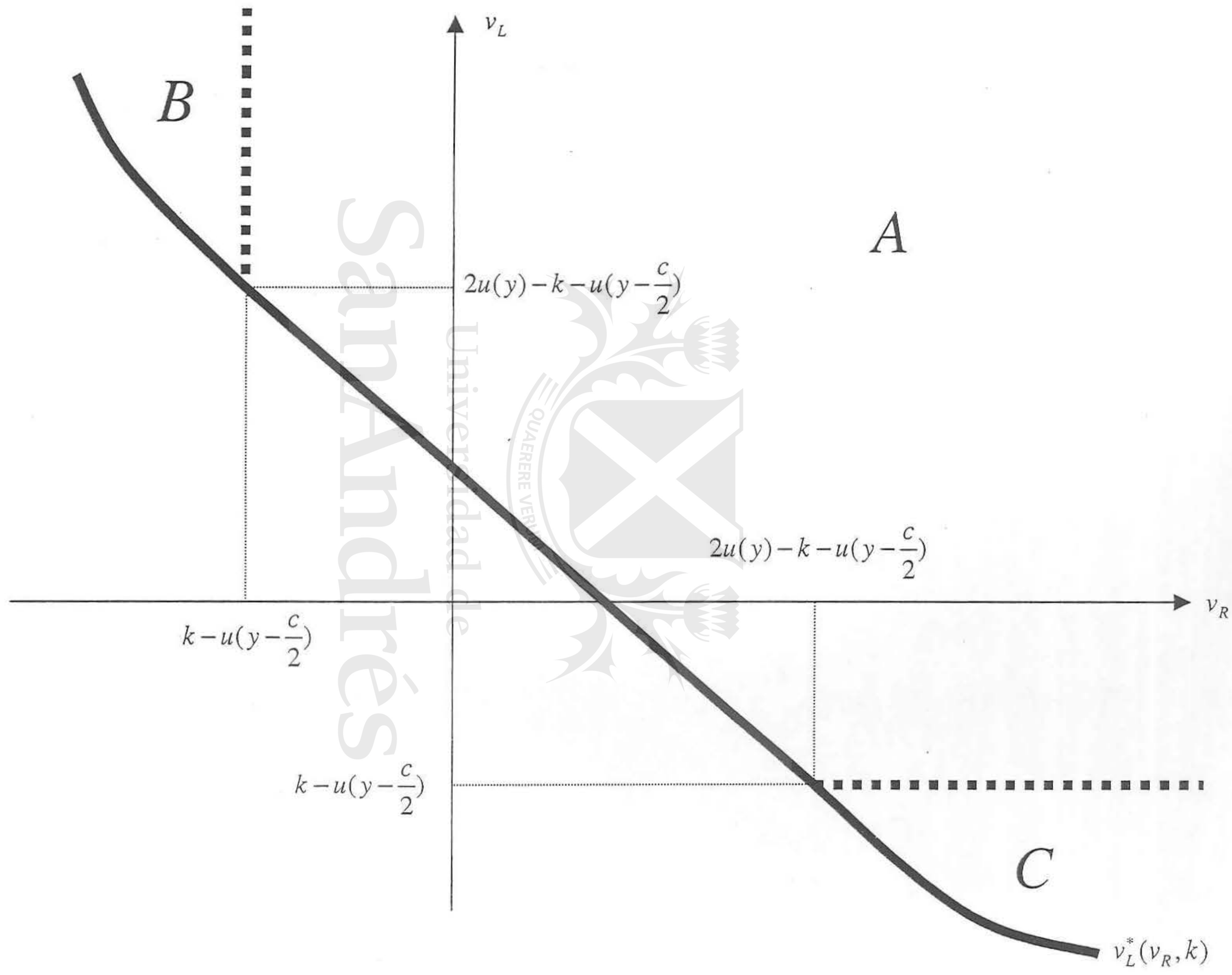

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Figure 2: How full-information allocations vary with k.

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Figure 3: Second-best configuration of projects in case (a)

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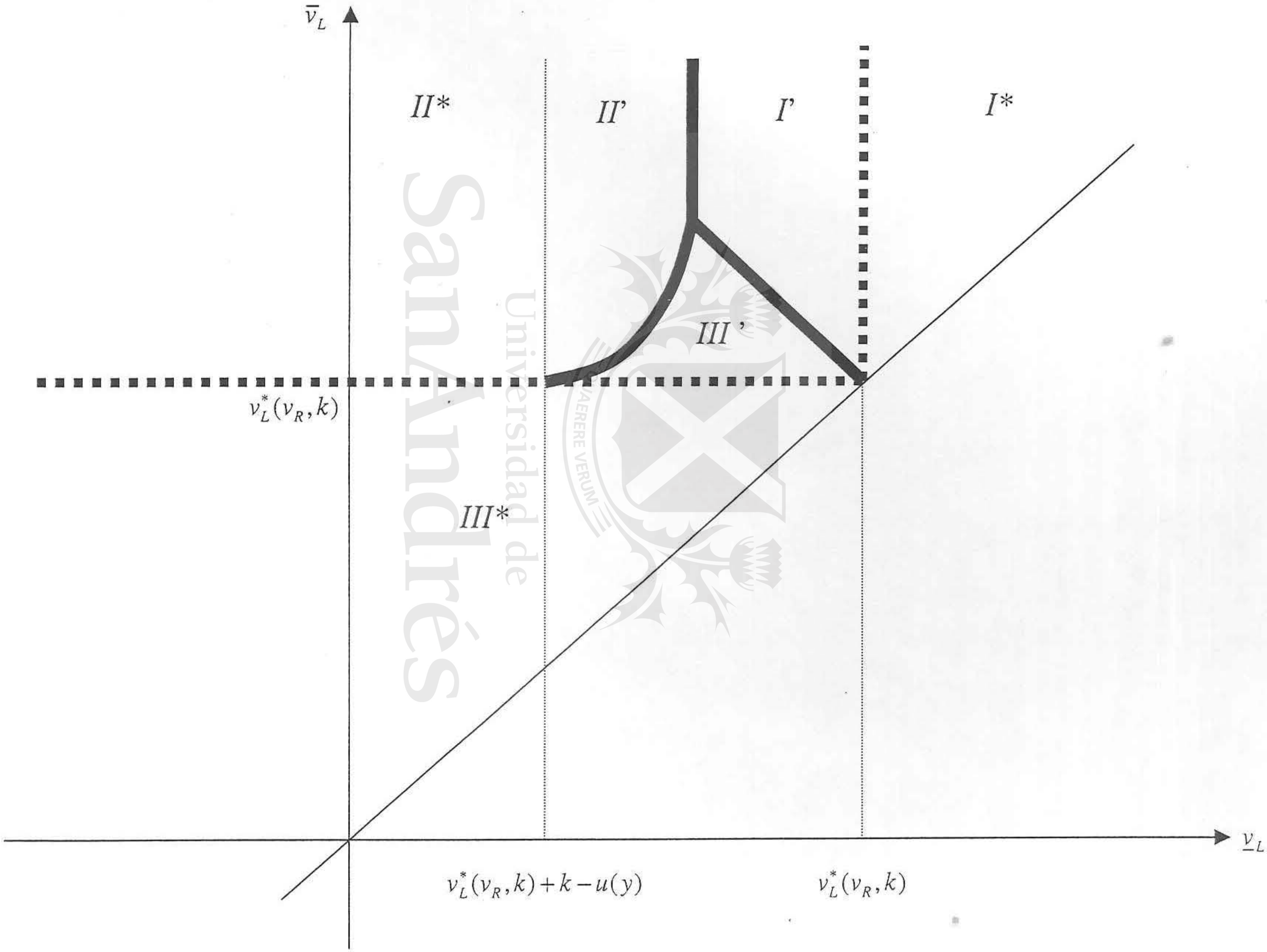

$\bar{v}_L$
II^*
II'
I'
I^*
III'
III^*
$v_L^*(v_R,k)$
$v_L^*(v_R,k)+k-u(y)$
$v_L^*(v_R,k)$
$\underline{v}_L$

Figure 4: Second-best configuration of projects in cases (c) and (d)

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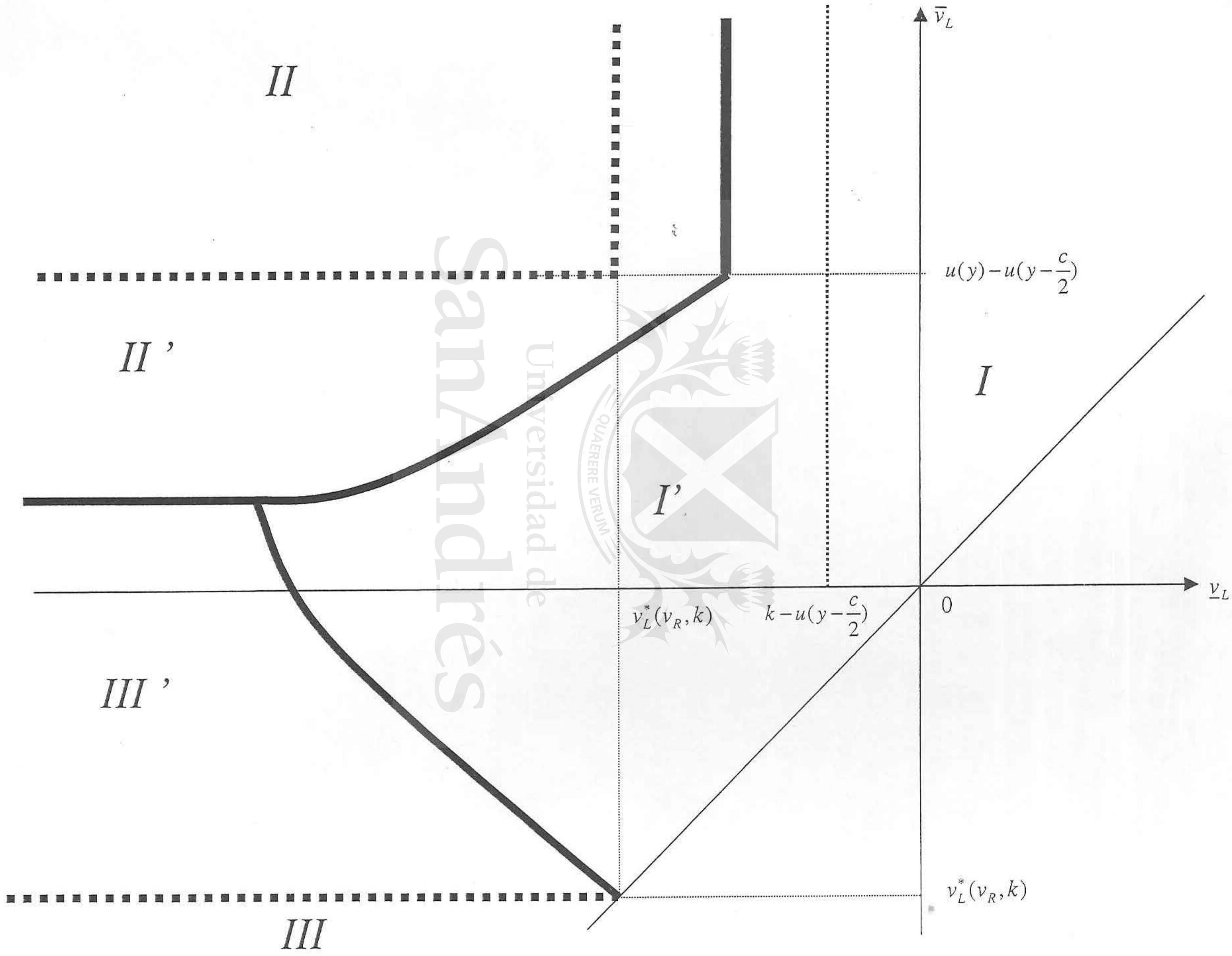

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