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Think Locally, Act Locally: Spillovers, Spillbacks, and Efficient Decentralized Policymaking

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We analyze models with interjurisdictional spillovers among heterogeneous jurisdictions, such as CO_2 *emissions that affect the global environment. Each jurisdiction's emissions depend upon the local stock of capital, which is interjurisdictionally mobile and subject to local taxation. In important cases, decentralized policymaking leads to efficient resource allocation, even in the complete absence of corrective interventions by higher-level governments or coordination of policy through Coasian bargaining. In particular, even when the preferences and production technologies differ among the agents, the decentralized system can result in globally efficient allocation.* (*JEL* D62, H23, H73, H87, Q58)

Urbanization, industrialization, and other economic activities produce greenhouse gas emissions that affect the earth's atmosphere and thus may produce important external effects. These and similar externalities create a presumption that decentralized policymaking is likely to produce socially inefficient outcomes, as individual jurisdictions—nations or subnational governments—neglect the spillover benefits created by their policies. Although we do not doubt the validity of such concerns in general, the following analysis shows that there is more to the story. National and subnational governments do not exist in economic isolation from the rest of the world. In particular, as we will show, the linkages that arise from decentralized competition for capital investment or other productive resources alter the incentives facing decentralized policymakers. Even when externalities are truly global in nature, completely decentralized policymaking may lead to socially efficient outcomes.

In stating the key theme and distinguishing feature of our analysis so directly, we do not wish to claim more than is justified. As will become clear, decentralized policymaking in the presence of interjurisdictional spillovers may indeed produce inefficient outcomes in certain circumstances. A number of remedies are available with which to manage positive or negative external effects, whether they stem from pollution or from other causes. These include Pigouvian

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taxes and subsidies (Arthur C. Pigou 1920), Coasian bargaining (Ronald H. Coase 1960; George J. Stigler 1966), the folk theorem of repeated interactions (Drew Fudenberg and Eric Maskin 1986), and other incentive mechanisms, e.g., Edward H. Clarke (1971), Theodore Groves and John Ledyard (1977), and Hal R. Varian (1994), among others. Under appropriate circumstances, each of these offers some hope that externality-based inefficiencies may be mitigated or avoided altogether.

At the same time, however, we realize the limitations of these prescriptions. In the context of global environmental problems, for instance, no global authority has the power to implement corrective taxes or subsidies. Countries are far from symmetric, both spatially and temporally, implying that the folk theorem cannot provide us much hope in reality. Coasian bargaining may not be completely hopeless, since nations can and do enter into treaties with one another, but treaty negotiation and enforcement processes are obviously cumbersome and far from costless. This is especially true when the externalities in question, such as those arising from the emission of greenhouse gases, are truly global in nature. These externalities affect literally every nation, and negotiations with very large numbers of countries are highly complex and costly. The impasse over the ratification and implementation of the Kyoto Protocol, a protocol to the United Nations Framework Convention on Climate Change, illustrates this problem.

Recognizing that there may be no perfect solutions to externality problems, it is all the more important to understand thoroughly the underlying nature of external effects in particular cases and to verify precisely how inefficiencies may arise. The present paper focuses on the problem of multijurisdictional externalities associated with industrialization, urbanization, and economic development. An important theme in the literature of fiscal competition, exemplified by a well-known paper by Wallace E. Oates and Robert M. Schwab (1988), is that both fiscal and regulatory instruments influence the amount and location of such externality-producing activities.[1] In some cases, depending on the range of available instruments and on informational and other constraints, competitive pressures may lead governments to control pollution or other externalities efficiently, with the important proviso that these effects do not spill over jurisdictional boundaries. When there are interjurisdictional spillovers, the literature consistently finds, as intuition would suggest, that decentralized policymaking produces socially inefficient outcomes.

In this paper, we analyze a class of models in which there are interjurisdictional spillovers among heterogeneous jurisdictions and in which it nevertheless is the case that decentralized policymaking may lead to efficient resource allocations, even in the complete absence of corrective interventions by higher-level governments *or* coordination of policy through Coasian bargaining. We emphasize that decentralized policymaking can still result in globally efficient allocations, even when preferences and production technologies differ among jurisdictions and governments have information, and care, only about local environmental impacts. Our analysis exploits an admittedly stylized but very standard model of tax competition as its fundamental analytical tool. Transboundary pollution provides a useful illustrative example of the interjurisdictional spillovers that are the focus of our analysis, but the application of our model is not restricted to environmental issues. As we discuss briefly in the conclusion, the results of our analysis can be applied to many kinds of spillover issues, such as positive externalities associated with the development of human capital.

[1] The literature on competition is reviewed, e.g., by John D. Wilson (1999), George R. Zodrow (2003), Wilson and Wildasin (2004); see these papers for additional references. The interaction between decentralized regulation and fiscal policymaking, emphasized by Oates and Schwab, arises in a different context in the literature of "fiscal zoning." See Bruce W. Hamilton (1975) and, for a more comprehensive treatment with many additional references, William A. Fischel (2001). Studies that examine fiscal competition and spillovers include Dietmar Wellisch (1995), Amihai Glazer (1999), Mitch Kunce and Jason F. Shogren (2002), Kjetil Bjorvatn and Guttorm Schelderup (2002), and Helmuth Cremer and Firouz Gahvari (2004). See Wilson (1997) for a review and further references.

I. The Model

We begin by describing the model in its simplest form, deferring discussion of various generalizations until later. The basic model follows the canonical tax competition model with mobile capital and capital-related externalities, pioneered by Oates and Schwab (1988), with which some readers may be familiar.

Preferences.—In this model, there are N jurisdictions, within each of which a single representative agent resides. This agent consumes a composite private good, denoted by x_i for jurisdiction i, and a local public good g_i, both of which are goods, and also suffers from environmental damage e_i, which is a "bad."[2] The utility of the household residing in jurisdiction i is denoted $u_i(x_i, g_i, e_i)$, with $u_{ix} > 0$, $u_{ig} > 0$, and $u_{ie} < 0$, where u_{ix} represents the marginal utility of the private good and u_{ig} and u_{ie} are interpreted similarly. Furthermore, the sign restriction on u_{ie} is inessential; if $u_{ie} > 0$, then commodity e is interpreted as a local environmental "good" rather than a bad. We discuss other possible examples later, but for now continue with the interpretation of e_i as environmental damage, a bad. Note that preferences may differ across jurisdictions; we do not assume that preferences are homogeneous.

Production Technologies.—Perfectly competitive private firms produce the composite private good in each jurisdiction. The production process uses capital, with k_i the amount of capital employed in locality i. There is at least one immobile input to the production process, such as labor, land, or other (privately owned) natural resources (forests, minerals, etc.). The amounts of all of these immobile inputs are treated as fixed (in particular, we abstract from labor/leisure trade-offs and treat the size of the local labor force as exogenously given), so that local production can be written simply as $f_i(k_i)$. We assume a well-behaved neoclassical production function exhibiting constant returns to scale in all inputs, so that there are no pure profits (or, equivalently, pure profits are the return to one or more of the immobile factors of production), with f_i increasing and strictly concave in the amount of capital; letting subscripts denote partial derivatives, this means that $f_{ik} > 0 > f_{ikk}$. Note that production functions may differ across jurisdictions; we do not assume that technologies are identical.

Public Goods and Environmental Spillovers.—The public good g_i in each jurisdiction is produced using the all-purpose private good; each unit of g_i requires one unit of this good. Public goods do not play a crucial role in the analysis and are included for the sake of generality and for comparison with environmental or other externalities.

Externalities do, of course, play a crucial role in the analysis. Environmental damage is linked to the use of the capital input: each unit of capital employed in jurisdiction i results in a units of environmental damage there. In addition, the use of capital in jurisdiction i causes environmental damage in other jurisdictions, that is, there are environmental spillovers. The degree of spillover is captured by a parameter β, with $\beta \in [0, 1]$, so that

$$e_i = ak_i + \beta \sum_{j \neq i} ak_j. \tag{1}$$

When $\beta = 0$, environmental quality in any one jurisdiction depends only on local economic activity. In this case, as in the models of Oates and Schwab (1988) and many other authors, there

[2] The variable g_i may be interpreted as a vector, so that the model allows for an arbitrary number of local public goods.

are no interjurisdictional environmental spillovers. If β is positive, local economic activity (as represented by the level of capital, k_i) causes damage not only to the local environment but in other jurisdictions as well; a low value of β means that these environmental spillovers are small. The upper limit of $\beta = 1$ corresponds to complete or perfect spillovers, where a unit of capital employed in jurisdiction i does just as much damage elsewhere as it does locally. By allowing for interjurisdictional spillovers, our model generalizes that of Oates and Schwab (1988) and others who have used similar models. Note that we do assume that the degree of environmental spillover is the same for all jurisdictions; the implications of relaxing this assumption are discussed later. Phenomena such as greenhouse gas emissions correspond to the case $\beta = 1$: a ton of CO_2 emissions circulates and mixes uniformly throughout the atmosphere, no matter what its source. Let us note, however, that the model assumes that the amount of emissions per unit of capital is constant and fixed at a. The discussion at the end of the next section briefly discusses the use of policies, such as pollution permits, that could affect the amount of emissions per unit of capital, but for the most part our analysis focuses just on the interjurisdictional distribution of polluting activities rather than on abatement policies. Such policies are undoubtedly important in the context of greenhouse gas emissions and in many other instances as well; for our purposes, the greenhouse gas case is of interest mainly as an important illustration of the polar case where the spillover parameter of the model is equal to one.

Endowments.—Let $\bar{k}_i$ denote the stock of capital with which jurisdiction i is endowed. We assume that capital is freely mobile among jurisdictions and fixed in supply to the aggregate of all jurisdictions, so that

$$\sum_i \bar{k}_i = \sum_i k_i. \tag{2}$$

This means that any one jurisdiction may import ($k_i > \bar{k}_i$) or export ($\bar{k}_i > k_i$) capital. Note that endowments may differ across jurisdictions; we do not assume that endowments are identical.

Note for future reference that (1) and (2) imply that

$$e_i = ak_i + a\beta(\bar{k} - k_i), \tag{3}$$

where $\bar{k} \equiv \sum_i \bar{k}_i$ is the aggregate capital stock.

A. *Institutions*

The government in each jurisdiction controls public policy instruments—taxes and expenditures. Other resource allocation decisions are made by private-sector agents operating in competitive markets.

The composite private good that is produced and consumed in each jurisdiction is assumed to be tradable and is chosen as numeraire. Thus, the total value of production in locality i is $f_i(k_i)$. The gross return per unit of capital is thus $f_{ik}(k_i)$, and the total return to the immobile factors of production, owned by the local resident, is $f_i(k_i) - k_i f_{ik}(k_i)$. In addition, households receive income from their endowments of capital and also pay a lump-sum tax T_i to the local government. Denoting the net return to capital by ρ, the private good consumption of the household in jurisdiction i is thus

$$x_i = f_i(k_i) - f_{ik} k_i + \rho\bar{k}_i - T_i. \tag{4}$$

In addition to a local lump-sum tax, the government in each jurisdiction has at its disposal a (source) tax on mobile capital. As a matter of notational convenience, the tax on capital t_i is interpreted as a per-unit tax, although it could equivalently be modeled as an ad valorem tax on the value of capital such as a property tax, or as a source-based tax on capital income such as a corporation income tax.[3] The government budget constraint requires that tax revenues are equal to government expenditures on the local public good,

$$g_i = T_i + t_i k_i. \tag{5}$$

Capital mobility means that the net rate of return must be the same in every jurisdiction in equilibrium, i.e.,

$$f_{ik} - t_i = \rho \qquad \forall i. \tag{6}$$

This system of equations, together with the capital-market clearing condition (2), determines the equilibrium allocation of capital and the equilibrium net rate of return ρ as functions of the vector of capital tax rates $\mathbf{t} \equiv (t_1, \dots, t_n)$.

II. Decentralized Policy: Equilibrium and Efficiency

This section first examines the equilibrium policies chosen by decentralized policymakers. It then describes socially efficient policies. Subsequent subsections compare the equilibrium and efficient policies and discuss extensions, limitations, and further interpretations of the analysis.

A. *Decentralized Policy Equilibrium*

We assume that governments choose their policies to maximize the *equilibrium level of utility* of their residents. Each government is assumed to be small in the sense that it treats the economy-wide net return to capital ρ and the policy choices of other governments as exogenously given. This means that the government in jurisdiction i expects that its choice of the capital tax rate t_i will affect the local capital stock k_i because the local gross rate of return on capital f_{ik} must be sufficiently high to insure that $f_{ik} - t_i = \rho$. This equation can be solved implicitly for $k_i(t_i)$, with $dk_i/dt_i = 1/f_{ikk} < 0$.

Although the individual jurisdictions are assumed to act atomistically in choosing their policies, this does not mean that they ignore the effects of their policy choices on externality spillovers. When jurisdiction i increases its tax rate on capital, it knows that there will be less environmental damage from local economic activity because k_i will fall. However, the capital that leaves one locality does not disappear altogether from the economy, it merely relocates to other jurisdictions. Indeed, substituting $k_i(t_i)$ into (3), one obtains

$$\frac{de_i}{dt_i} = (1 - \beta) a \frac{dk_i}{dt_i}. \tag{7}$$

[3] Although the precise specification of the form of taxation is sometimes important in the analysis of strategic tax competition, this is not the case in the present context since we assume that each jurisdiction is small relative to the capital market, and we may thus specify a per-unit tax without loss of generality.

In other words, each jurisdiction, though acting atomistically and without knowledge of the precise general equilibrium reallocation of capital that results from its own tax policy, nevertheless recognizes that inflows (or outflows) of capital reduce (or increase) the external effects generated in other jurisdictions.

Using the government budget constraint (5) to solve for T_i and substituting into (4), we get

$$x_i = f_i(k_i) - k_i f_{ik}(k_i) + \rho\bar{k}_i - g_i + t_i k_i. \tag{8}$$

Having thus eliminated T_i from the system, the problem facing the government in jurisdiction i is to choose two policy instruments, g_i and t_i, to maximize $u_i(x_i, e_i, g_i)$, taking ρ as given and taking into account the effect of the local capital tax on the equilibrium value of the local capital stock and thus on local environmental quality (via (3)) and on local private good consumption (via (8)).

The two first-order conditions that describe the solution to this local optimization problem are

$$\frac{u_{ig}}{u_{ix}} = 1 \tag{9}$$

and

$$t_i = -a(1-\beta)\frac{u_{ie}}{u_{ix}}. \tag{10}$$

The first of these conditions is the Samuelson condition for efficient local public expenditures; since local governments can raise as much revenue as desired through lump-sum taxation, the Samuelson condition is naturally expected to be satisfied. The second condition shows how governments tax mobile capital. This tax is imposed at a positive rate if local residents value environmental quality, since then $u_{ie} < 0$ (strictly). However, governments also take into account the fact that some proportion β of the local environmental damage that is avoided by driving capital out of their own jurisdictions will "spill back" when capital relocates elsewhere.[4]

B. *Efficient Resource Allocation*

In order to evaluate the efficiency properties of the decentralized policy-setting equilibrium just described, it is necessary to characterize a Pareto-efficient allocation of resources, that is, a solution to the problem

$$\max_{\{(x_i, g_i, k_i)\}} u_1(x_1, g_1, e_1)$$

subject to

$$u_i(x_i, g_i, e_i) - \bar{u}_i = 0 \quad \forall i > 1, \tag{11}$$

[4] To assume that governments take "spillback" effects into account does not require that they monitor the sources of these effects, which are irrelevant. Furthermore, taking these effects into account is not a departure from the assumption of atomistic competition among governments. Spillovers, and thus spillbacks, arise from the fundamental technology of pollution, as specified in (3).

$$\Sigma_i f_i(k_i) - \Sigma_i(x_i + g_i) = 0, \tag{12}$$

(1), and (2).

The first-order conditions characterizing the solution to this problem yield (after some slight manipulation)

$$\frac{u_{ig}}{u_{ix}} = 1, \tag{13}$$

$$f_{ik} + a\,\frac{u_{ie}}{u_{ix}} + \beta\sum_{\ell \neq i} a\,\frac{u_{\ell e}}{u_{\ell x}} = f_{jk} + a\,\frac{u_{je}}{u_{jx}} + \beta\sum_{\ell \neq j} a\,\frac{u_{\ell e}}{u_{\ell x}} \quad \forall i,j. \tag{14}$$

The first of these is again the Samuelson condition for efficient local public expenditure. The second condition characterizes the efficient allocation of capital, taking into account both the productivity of capital and the impact of the capital allocation on local environmental damage and on spillovers. At the margin, a unit of capital must be equally productive in all locations, net of the environmental damage that it causes in its own location and, through spillover effects, in other locations.

C. *The Efficiency of Decentralized Policymaking*

It is immediately apparent that the equilibrium conditions (6), (9), and (10) correspond to the efficiency conditions (13) and (14) when there are no spillovers, i.e., when $\beta = 0$. In this case, each government's local capital tax provides an instrument with which to control the extent of local environmental damage, while the lump-sum tax provides an efficient source of local finance for public expenditures. Thus, our analysis confirms the findings of Oates and Schwab (1988) for the case where our model, like theirs, has no interjurisdictional spillover effects.

Remarkably, the same result holds even when there are spillover effects:

PROPOSITION 1: *The equilibrium allocation of resources in a system with decentralized policymaking is first-best Pareto efficient.*

PROOF:

Adding and subtracting $\beta u_{ie}/u_{ix}$ to the left-hand side of the efficiency condition (14), and similarly adding and subtracting $\beta u_{je}/u_{jx}$ on the right-hand side, it is clear that (14) is satisfied if and only if (note that the summations below are over *all* jurisdictions, including i and j)

$$\left(f_{ik} + a(1-\beta)\,\frac{u_{ie}}{u_{ix}} + \beta\sum_{\ell} a\,\frac{u_{\ell e}}{u_{\ell x}}\right) - \left(f_{jk} + a(1-\beta)\,\frac{u_{je}}{u_{jx}} + \beta\sum_{\ell} a\,\frac{u_{\ell e}}{u_{\ell x}}\right)$$

$$= \left(f_{ik} + a(1-\beta)\,\frac{u_{ie}}{u_{ix}}\right) - \left(f_{jk} + a(1-\beta)\,\frac{u_{je}}{u_{jx}}\right) = 0 \quad \forall i,j.$$

But (6) and (10) imply that this condition is indeed satisfied in equilibrium; furthermore, the Samuelson condition (13) for efficient public good provision is also satisfied in equilibrium, as shown in (9).[5, 6]

Thus, even though each local government (i) chooses policies that represent the interests only of their local resident(s); (ii) is unaware of the amount of damage that local economic activity causes in other jurisdictions (recall that there are *no* symmetry assumptions regarding preferences, technologies, or endowments, and thus no local government i knows the valuation u_{je}/u_{jx} placed on environmental damage in any other jurisdiction $j \neq i$); and (iii) does not communicate, bargain, or coordinate policies with other local governments, the process of decentralized policymaking produces Pareto-efficient outcomes for the entire system of jurisdictions. To achieve efficient resource allocation in this economy with environmental spillovers, it is neither necessary to have a benevolent Pigouvian "visible" hand, for example in the form of a higher-level government that imposes corrective taxes on spillovers, nor to have a somewhat "less visible" hand, for example in the form of a system of treaties or contractually fixed compensatory payments resulting from a Coasian negotiation, which internalize damages resulting from spillovers. This is true whether the spillover effects, as measured by the parameter β, are small or large, and possibly even "global," corresponding to the case where $\beta = 1$.

Indeed, since the analysis places no restrictions even on the *sign* of the local valuation of environmental damage u_{ie}/u_{ix}, it is possible that there are "asymmetric" externalities in the sense that residents in some jurisdictions may be indifferent to environmental quality $(u_{ie}/u_{ix} = 0)$, others regard environmental damage as very harmful $(u_{ie}/u_{ix} \ll 0)$, and still others view it (for some odd reason) as positively desirable $(u_{ie}/u_{ix} \gg 0)$. (Indeed, Nicholas Stern (2007, sect. 3.3) notes that modest global warming may produce some benefits in northern regions, even as it harms other regions.)

Qualifications.—Proposition 1 is derived within the context of a model that is very general in some respects, but of course it does depend on other assumptions that are less general. For example, one could imagine that the amount of environmental damage produced per unit of investment might vary among jurisdictions: instead of some fixed amount of damage a that is the same for all jurisdictions, there might be climatic, topographical, or regulatory variations among jurisdictions such that the amount of damage caused by each unit of capital in jurisdiction i is an amount a_i, not necessarily the same in all places. Furthermore, the amount of "physical" spillover from one jurisdiction to another might not be the same proportion β for all jurisdictions; instead, there could be a parameter β_{ij} that describes the amount of pollution transmitted (by air, water, etc.) from jurisdiction i to jurisdiction j which could vary across all i and j. In these cases, the proof of Proposition 1 is no longer valid.

[5] To be precise, the correspondence of first-order conditions does not establish that decentralized equilibria are efficient; this is necessary but not sufficient. In this simple model, however, standard assumptions on preferences and technologies guarantee that the necessary conditions are also sufficient.

[6] A referee has suggested the following interpretation of the derivation above, which some readers may find helpful: The optimal policy for each locality is to choose a tax that equalizes the marginal product of capital, net of spillback effects, to the net rate of return on capital (as seen by substituting from (10) into (6)). Efficient capital allocation requires that the social benefit of capital be equalized across jurisdictions (14). The externality part of this social benefit is the own-jurisdiction impact (the second terms on each side of (14) plus the spillover part (the third terms)). The spillover terms can be rewritten, however, to include an augmented spillover effect, summed across *all* jurisdictions as in the first line of the equation in the proof above, minus an "own spillback" term (such as $a(1-\beta)u_{ie}/u_{ix}$ for jurisdiction i). The augmented spillover effect is the same across jurisdictions, so that efficiency requires equalization of the marginal product of capital plus the own-jurisdiction externality net of the spillback, as shown in the second line of the equation in the proof. This condition, as noted, is guaranteed by equilibrium behavior as described in (6) and (10).

Furthermore, the externalities that we have analyzed are not the only conceivable form of externalities. For example, jurisdictions might derive spillover externalities from public expenditures undertaken by others. As a simple polar case, for instance, one might assume that the utility in jurisdiction i depends not on g_i alone but on the total amount of public spending in all jurisdictions $\sum_j g_j$, in effect producing a "voluntary contributions" model of local public good provision (see, e.g., Robin Boadway, Pierre Pestieau, and Wildasin 1989).

Nevertheless, Proposition 1 is still a striking result, and it should be apparent that the magnitude of the efficiency losses from decentralized policymaking is modest if the assumptions of the model are approximately correct. For example, suppose that we generalize the model to let β_{ij} represent the amount of environmental damage suffered in j per unit of damage originating in i. The Samuelson condition for efficient public expenditure continues to be satisfied in the decentralized equilibrium while the equilibrium allocation of capital will no longer be efficient: k_i will be inefficiently high in some jurisdictions and inefficiently low in others. The equilibrium allocation of capital in the model would be continuous in the parameters β_{ij}, however, converging to the efficient allocation as the spillover parameters approach a common value ($\beta_{ij} \to \beta$). The key point is that spillovers themselves do *not* imply any necessary departure from efficiency in decentralized policymaking, even when there are potentially very substantial asymmetries among the preferences, technologies, and endowments of different jurisdictions. The efficiency rationale for intervention in local decision making by a higher-level authority, or for explicit coordination and bargaining among local governments, must rest not on the "first-order" *existence* of spillovers but on the "second-order" *differences* in the amounts of spillover damage from one jurisdiction to another (i.e., not on the fact that $\beta_{ij} > 0$ but on the fact that $\beta_{ij} \neq \beta_{kl}$ for some i, j, k, l).

D. *Extensions, Applications, and Interpretations*

Although the analysis does depend on certain simplifying assumptions, it is at the same time quite general in several important respects. It can accommodate the cases where an activity produces positive as well as negative externalities and where activities that are harmful to some are irrelevant for others, and positively desirable for still others. At no point does the analysis depend on any assumptions of symmetry among jurisdictions, some of which may thus be "rich" while others are "poor," whether because of technological differences or because of differences in endowments. This generality means that the model is amenable to many varied interpretations and applications.

The following paragraphs explain how the model and results can be extended to cases where there are many mobile resources, such as both capital and labor, and many types of external effects, including not only negative spillovers like pollution but positive productivity spillovers that may be associated with the utilization of human and nonhuman capital. We also show how the analysis can be applied to the problem of allocation of pollution permits among jurisdictions. These extensions generalize the formal model and expand the scope of application for the key result presented in Proposition 1.[7]

(i) Multiple Mobile Resources.—The model in Section II assumes that "capital" is the only resource that is mobile among jurisdictions. The restriction to a single mobile resource is unnecessary, however, and the model is easily extended to allow for M distinct types of mobile resources.

7 An earlier version of this paper, to which interested readers are referred, discusses these and other extensions in greater detail.

We change the model only by interpreting variables like $\mathbf{k}_i$, $\overline{\mathbf{k}}_i$, $\mathbf{t}_i$, etc., as vectors; thus, for instance, $\mathbf{k}_i = (k_i^1, \dots, k_i^m, \dots, k_i^M)$. Each type of mobile resource may give rise to a different type of externality, with e_i^m the externality associated with the mobile resource of type m in jurisdiction i; the parameters a^m and β^m are specific to each type of mobile resource, which means that some of them may not give rise to any spillover effects at all $(\beta^m = 0)$, while others do $(\beta^m > 0)$. Thus, (1) is now interpreted to mean that the m-th component of the vector $\mathbf{e}_i$ is given by $e_i^m = a^m k_i^m + \beta^m \sum_{j \neq i} k_j^m$. The vector $\mathbf{e}_i$ enters the utility function $u_i(x_i, g_i, \mathbf{e}_i)$ in a general way; in particular, some "externalities" may be zero ($u_{ie}^m = 0$, where the superscript identifies the m-th mobile resource), while others may be positive or negative, and the sign and magnitudes of these effects may differ among jurisdictions. In the special case where different types of mobile resources produce the same kinds of external effects, the external effects enter the utility function as perfect substitutes (thus, for example, different types of resources may result in noise pollution, and the decibels of noise associated with each type are simply added up to determine the total amount of noise that affects consumer welfare).

As in the preceding discussion, the total stock of each mobile resource in the economy as a whole is taken as exogenously fixed. These resources are allocated among jurisdictions in competitive markets so that net rates of return are equalized everywhere. The impact of local taxes on the allocation of mobile resources is now somewhat more complex than before because the entire vector of mobile resources enters the local production functions $f_i(\mathbf{k}_i)$ with no restrictions as to substitutability/complementarity among these inputs. Thus, a change in jurisdiction i's tax rate on mobile resource m, t_i^m, will, in general, affect the entire vector $\mathbf{k}_i$. Still, the characterization of the efficient allocation of resources is essentially no different in the case where there are many mobile resources rather than just one. Once again, the Samuelson condition for efficient local public expenditures must hold, and a version of the condition for efficient capital allocation (14) must hold for each of the mobile resources,

Using exactly the same method of proof, Proposition 1 can be extended to this significantly more general model to show that a decentralized equilibrium is first-best efficient.

(ii) Productivity Spillovers,—It is sometimes argued that FDI promotes productivity growth through positive production externalities, for instance, because multinational enterprises may possess superior production technology and management techniques (Magnus Blomstrom and Ari Kokko 1998). On the other hand, production externalities may arise, possibly in attenuated form, from knowledge or other spillovers that do not depend on the co-location of production activities.

To capture such externalities, assume that the production function in region i is now given by $f_i(K_i)$, where $K_i \equiv k_i + \alpha \sum_{j \neq i} k_j$, thus incorporating an interjurisdictional production externality parameterized by α. (*Intra*jurisdictional spillovers are subsumed within the local production function.) As $\alpha \to 0$, the spillover effect becomes weaker and ultimately vanishes. In the presence of such spillover effects, inefficiencies might arise because individual governments would not take into account the fact that their policies influence productivity in other locations.

The analysis of this model can be developed just as in the base case presented earlier. Analogously to Proposition 1, the decentralized equilibrium allocation of resources is again first-best efficient.

(iii) Tradable Pollution Permits,—The preceding analysis can be interpreted to include the case where polluting activities are regulated by a centralized authority that determines an aggregate amount of tradable pollution permits and in which market forces, coupled with decentralized tax/subsidy policies, determine the spatial distribution of these permits and the associated pollution. Specifically, let $\overline{k}$ now denote the aggregate amount of pollution to be permitted by the

central authority, and let k_i denote the amount of pollution permits acquired by firms in jurisdiction i. The amount of output in locality i is naturally assumed to be an increasing and concave function $f_i(k_i)$ of the amount of permits (and pollution) there; tradable permits in effect transform pollution into another marketed input in the production process. (The variables $\bar{k}$, k_i, etc., may be interpreted as vectors, thus covering the case where there are many types of pollutants and pollution permits.)

Provided that individual jurisdictions are free to tax or subsidize the local use of pollution permits, corresponding to k_i in our model, Proposition 1 (or its generalization to the many-mobile-resource case) implies that the equilibrium distribution of pollution among jurisdictions will be Pareto efficient. In other words, in order to achieve an efficient allocation of resources, the national government need only determine the proper *aggregate* amount of pollution $\bar{k}$, leaving it to local jurisdictions to attract or repel polluting activities to whatever degree best serves local interests. Local governments, in this case, use local information to promote local interests, and in doing so they insure that the aggregate amount of pollution, determined at the national level, is distributed efficiently among localities. This is true even when environmental effects spill over from one jurisdiction to another. This interpretation is noteworthy in that it shows how the analysis can be applied to economies where the total amount of pollution (or other externality-producing activity) can be abated through public policies.

III. Conclusion

The problem of spillover externalities is one that arises in many contexts. Environmental pollution is one important example. It is natural to expect that spillovers, whether positive or negative, could result in inefficient resource allocation unless they are effectively internalized through Coasian contracting or by corrective policies by a higher-level government. Indeed, this possibility has long been known in the specific context of local public economics, at least since Alan Williams (1966), which is just an application of a standard consumption-externality framework to the issue of interjurisdictional spillovers, and it is emphasized throughout the literature on "environmental federalism" (see, e.g., Oates 2002 for discussion and references). The literature on global climate change, as exemplified by the recent Stern (2007) report, highlights the importance of global environmental externalities and the need for explicit international cooperation to internalize them.

The preceding analysis has shown, however, that there are important cases in which decentralized policymaking can result in efficient allocations of resources for an economic system. We analyze a class of models in which there are interjurisdictional spillovers among heterogeneous jurisdictions and in which it nevertheless is the case that decentralized policymaking leads to efficient resource allocations—even in the complete absence of corrective interventions by higher-level governments *or* coordination of policy through Coasian bargaining. A critical feature of these models is that jurisdictions interact not only through pollution or other spillovers, but through an integrated and competitive market for capital (in our baseline model) or of some other resource linked to the production of spillover effects, and that governments are free to tax (or subsidize) this competitively traded resource. Decentralized taxation of freely mobile capital or other resources is often seen as a source of interjurisdictional fiscal externalities that give rise to allocative inefficiency (for discussion and references, see, e.g., Wilson 1999; Wilson and Wildasin 2004). By contrast, in the present analysis, competition for mobile resources plays a crucial role in providing efficiency-enhancing interjurisdictional linkages. Decentralized taxation is essential here; if governments were to rely solely on other revenue sources, the competition allocation of capital would result in equalization of capital productivity in all locations, an allocation that is generally *inefficient* when economic activity generates environmental or other externalities in a system of heterogeneous jurisdictions.

We do not wish to claim, and our analysis does not show, that decentralized policymaking invariably leads to efficient resource allocation. In particular, although our model is very general in important respects, it must be noted that the efficiency results derived here do rely on several simplifying assumptions. The findings are not knife-edge results that disappear with small departures from the underlying assumptions, but it is nonetheless true that they are unlikely to be of use in situations in which the key assumptions are only poorly approximated.

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