Helsinki Center of Economic Research

Discussion Papers

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Discussion Paper No. 23
October 2004

ISSN 1795-0562

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Abstract

This paper develops a two-region, three-sector model of economic geography to suggest that the international non-tradability of environmental amenities may generate incentives to abuse environmental policy. In equilibrium both regions convert a suboptimally large share of environmental amenities into tradable natural resources. The aim of strategic environmental policy is to increase the size of the domestic market, in order to attract manufacturing firms. We also show that these distortions vanish if (i) also the end products of development are non-tradable or (ii) if there are technologies, which allow amenities to enter international exchange.

Keywords: non-traded goods, strategic environmental policy, firm location

JEL Classification: Q28, R3

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* This paper is a part of the research agenda of Research Unit on Economic Structures and Growth (RUESG) in the University of Helsinki, funded jointly by the Academy of Finland, University of Helsinki, Bank of Finland, Nokia Group, and the Yrjö Jahnsson Foundation. I'm grateful to Pertti Haaparanta, Seppo Honkapohja, Erkki Koskela, Mikko Leppämäki, Kaushik Mitra, Soren Bo Nielssen, Markku Ollikainen and Michael Rauscher for useful comments. The usual disclaimer applies.

1 Introduction

A salient property of most environmental amenities is that they cannot be (easily) transported from one location to another. By contrast, the end products of polluting and resource-extracting industries typically enter international exchange. As an example, consider a pristine forest, which can be either preserved or developed. Whereas products such as timber, pulp and paper are traded in international markets, environmental amenities like scenic beauty and clean air, or the capacity of the forest to protect the land against erosion, are in general site-dependent and non-transportable. Thus international exchange is rather difficult, and as a general rule amenities are consumed at the site of "production". In this sense amenities resemble typical home market goods, say, the services provided by a local theater or barbershop.

One of the functions, or side effects, of environmental policy is then to influence the allocation of resources between tradable and non-tradable goods. This paper argues that this function may generate incentives to abuse environmental policy. If decisions are made in a decentralized manner (at a local or national level), there can be too much extraction of resources and too little preservation.

To present the argument, the paper develops a two-region, three-sector model of economic geography. The manufacturing sector produces a large number of differentiated variates, features increasing returns to scale, monopolistic competition and costly transportation, and uses mobile capital as its sole input. In order to economize in transportation costs, both regions would like to have a large share of manufacturing.[1] Natural resources and environmental amenities are both derived from environmental resources by constant returns to scale. While natural resources are internationally tradable, amenities are non-tradable. The task of environmental policy is to allocate environmental resources between the alternative uses. As we assume that environmental problems are local, the standard externality problem can be addressed at the regional level. However,

[1] This cost-of-living effect also motivates strategic environmental policy in Markusen et al. (1995) and Pfluger (2001). More generally, it motivates trade policy, and many other forms of public policies in models of economic geography. See e.g. Baldwin et al .(2003) and references therein.

in order to attract manufacturing firms, regional policy-makers face incentives to convert too big a share of environmental resources into tradable natural resources. This is because development increases the size of the local market, which in turn makes the region more attractive as a manufacturing location. We also show that the incentives to overdevelop vanish, (i) if also the end products of development (natural resources) are non-tradable, or (ii) if there are technologies, such as ecotourism, which allow amenities to enter international exchange.

To understand these findings, the following simple thought experiments may be helpful. Consider a two-sector economy, which is identical to our model, except for the fact that there are no environmental amenities. Then assume that the production of natural resources in one of the regions increases, say there is technological progress, or new reserves are found. As a consequence, the income of that region rises.[2] If both natural resources and manufactured goods are normal, people increase their consumption in both categories. The region exports more natural resources (or imports less), and there is a demand spillover to the manufacturing sector.

Next consider the same situation, but the second sector is environmental amenities (or barbershops), instead of natural resources. Then for some reason the quality of the environment improves (the barbers become more productive), and more amenities become available. While this certainly ameliorates the standard of living, there are no pecuniary externalities to the manufacturing sector. As amenities are internationally non-tradable, it is not possible to raise exports and shift a part of the extra consumption to manufactured goods. The improved availability of amenities simply implies more local consumption of amenities. Likewise it is easy to conclude that while a deterioration in the quality of the environment is bad for utility, it does not lower the demand for manufactured goods.

Combining these two thought experiments, and going back to the original model, gives the entire picture. Now the increase in the production of natural resources is not a result of technological change, but it is achieved at the expense of lower envi-

[2] If the country exports natural resources, we have to assume that the negative terms of trade effect is not too pervasive.

ronmental quality. As the tradable natural resources generate demand spillovers to the manufacturing sector, while non-tradable amenities generate no spillovers, the demand for manufactured products increases, which attracts more manufacturing to the region. However, reallocating resources between two non-tradable or two tradable sectors has no effects on the third industry. Thus if natural resources are non-tradable, or if amenities can enter international exchange, there are no incentives to deviate from socially optimal policies.

To the best of our knowledge, there are no previous studies analyzing what implications the non-tradability of amenities may have on environmental policy[3]. Nevertheless, the paper has connections to several branches of literature. First, we use a variant of the (so called) footloose capital (FC) model of economic geography (see e.g. Baldwin et al. 2003, especially Ch. 3, or Martin and Rogers 1995). The FC model has a number of characteristics, which make it appealing for policy analysis. It has a unique analytically tractable equilibrium, but it still captures the home market effect: the size of the market affects firm location.[4] Recently, the FC approach has been used for analyzing several policy issues including the supply of public infrastructure, capital taxation and tax competition, regional transfers and trade policy (see Baldwin et al. 2003, and references therein). In particular, Pfluger (2001) studies environmental taxation in the FC framework; this paper will be discussed in more detail below.[5]

Second, this paper shares some common ground with the literature on resource-led growth, which emphasizes the role of home market demand, deriving from a "leading" sector such as agriculture or natural resources, in industrialization and economic development. While the argument has often been formalized in a closed economy framework (see e.g. Murphy et al. (1989a)), Sachs and Warner (1999) and Buffie (1992) demonstrate how resource-led growth may arise in a three-sector open economy. These authors also

[3]However, some work has ben done on how to regulate polluting sectors producing tradable and non-tradable goods. Typically, a key question here is whether an individual country has strategic reasons to regulate tradable and non-tradable sectors differently. See e.g. Rauscher (1994, 1997).

[4]Empirically, the home market effect has been documented by e.g. Davis and Weinstein (1998,1999).

[5]There is also an interesting recent paper by Rauscher (2003), who analyzes how environmental policies affect the location of polluting activities

show that the assumptions concerning trading costs in different sectors play a key role in determining whether or not demand spillovers from natural resources or agriculture favor the modern part of the economy.[6] The policies of resource-led growth have been advocated by economists and policy-makers[7], and there is also some empirical evidence in favor of the hypothesis (as well as against it)[8]. In our model both regions follow the policies of resource mobilization, which however backfire in equilibrium, as the regions end up competing for the same manufacturing investments.

Finally, there is an important connection to the literature on environmental policy and firm location. Recent empirical studies, typically using panel data, have indicated that environmental regulations do matter, when firms choose where to open new plants.[9] As it is no doubt the case in reality, these papers assume that the main connection from environmental policy to firm location runs through production costs. However, this paper suggests, that there may also be a secondary link on the demand side, via the size of the market.

Theoretical papers have then studied whether firm delocation and capital mobility may generate incentives to abuse decentralized (national or local) environmental policy in an economy, where more direct and efficient strategic tools, such as investment subsidies, or various trade policy instruments, cannot be applied (due to e.g. WTO rules)[10]. In a simple benchmark model with constant returns to scale and perfect competition,

[6] In an open economy a natural resource boom may also lead to a Dutch disease: under certain circumstances, the modern sector shrinks. For a survey of the Dutch disease literature, see e.g. Corden (1984).

[7] For a review of ealier economic literature, see e.g. Murphy et al. (1989a). A leading example presented in this paper is sir Arthur Lewis who in 1953 makes increases in farm productivity and in cash crop exports a cornerstone of his proposed development strategy for the Gold Coast. In a famous quote, cited by Murphy et al.(1989b) a Venezuelan minister states that expanding oil production is like sowing the seeds of development.

[8] For supporting evidence see e.g. Murphy et al. (1989a) and Duranton (1998), and references therein. More skeptikal findings are reported e.g. by Sachs and Warner (1999).

[9] See e.g. Becker and Henderson (2000), Greenstone (2002), Henderson (1996), Keller and Levinson (2002), List and Co (2000), List et al. (2003).

[10] This limited-policy-space assumption is evidently also adopted in this paper. A critical appraisal of the assumption can be found for example in the recent survey by Copeland and Taylor (2004).

environmental policies conducted by small countries are optimal, as long as there is no transboundary pollution (Oates and Schwab (1988)). If countries are large, the manipulation of the rental rate of capital is a possible source of socially non-optimal policies (e.g. van Long and Siebert (1991)). In models of imperfect competition, decentralized environmental policies may be too lax (ecological dumping), but under certain circumstances also excessively stringent ("not in my backyard" or NIMBY) regulations are adopted in equilibrium. Markusen et al. (1995), Rauscher (1995) and Hoel (1997) establish these results in a framework with two countries and a single imperfectly competitive firm. Pfluger (2001) reaches similar conclusions in a model with monopolistic competition.[11] In these models there are several interregional spillover effects, which arise from firms' market power, transportation costs, changes in tax revenue, as well as environmental problems. These spillovers are partly positive and partly negative[12], opening up the possibilities of both ecological dumping and NIMBY.[13]

Of the papers discussed above, the contribution by Pfluger (2001) falls closest to the present paper, since Pfluger (2001) analyzes strategic environmental policy in a FC-type model. However, the model variant adopted by Pfluger differs somewhat from our framework, reflecting the different focus of these studies. In particular, Pfluger uses a model version with quasi-linear utility, which eliminates income effects in individual demand functions.[14] Although the market size still affects firm location in this model variant (if regional population changes), changes in per capita income have no effect. This assumption then cuts down the demand side effect of environmental policy. By contrast, the focus of the present paper is on the demand side linkage, as this allows

[11] Also, Ulph and Valentini (2001) show, in a duopoly model, that the fact that plants are footloose, when environmental policies are set, does not necessarily increase the extent of ecological dumping.

[12] Reducing a home region's emission taxes induces a relocation of capital and firms into the home region. After the policy change, the prices charged by firms located in the home region are lower and local pollution is reduced in the other regions which is beneficial to foreign households; however foreigners also have to import more, which increases transport costs, and foreign tax income is reduced.

[13] As discussed by e.g. Rauscher (1995) and Pfluger (2001), the inefficiency in the choice of emission taxes relies on the absence of additional policy instruments.

[14] A textbook treatment of the quasi-lnear FC model, with some comparison to the "standard" FC framework, can be found in Baldwin et al. (2003, Ch 16.2).

the analysis of (non)tradability issues. To communicate the main message as sharply as possible, we have then adopted a framework where environmental policy has no cost side effects on manufacturing: our model assumes that the manufacturing sector is clean. This assumption also simplifies the logic of strategic environmental policy, in the sense that only the interregional spillovers arising from transportation costs remain.[15] As a result, in equilibrium decentralized environmental policy can be either socially optimal or excessively lax; the NIMBY alternative is ruled out[16].

The remaining of the paper is structured as follows. Model basics are presented in Section 2. Section 3 studies the location of manufacturing firms. Section 4 analyzes environmental policy, and characterizes the social optimum. Section 5 shows that the decentralized equilibrium of the model is inefficient under the basic set of assumptions, with tradable natural resources and non-tradable amenities. Section 6 then demonstrates that decentralized policies are socially efficient if both natural resources and amenities are either non-tradable or tradable. Finally Section 7 concludes.

2 The model

The economy consists of two identical regions, indexed by $i = 1, 2$, and produces two types of goods: manufactured commodities and natural resources. Manufactures are composed of a large number of differentiated goods, each produced out of capital subject to economies of scale, with a monopolistically competitive market structure. The perfectly competitive natural resource sector converts environmental amenities into tradable homogenous goods with a constant returns to scale technology.

There is an equal number of immobile consumers living in both regions. Consumers are all identical and derive utility out of consumption and environmental amenities. They

[15] The remaining three channels, analyzed by e.g. Pfluger (2001), are eliminated as (i) environmental policy does not affect pricing in the imperfectly competitive sector, (ii) mobile firms or factors of production are not taxed (iii) the mobile sector does not pollute.

[16] Given that the model is deliberately designed in such a way that all cost side linkages from environmental policy to firm location are eliminated, this result can hardly be taken as strong evidence against NIMBY. The finding is probably best interpreted as an indication that demand side effects, when acting on their own, can give rise to ecological dumping, but not NIMBY.

all share the Cobb-Douglas utility function

$$U = C_M^{\alpha} C_R^{\beta} E^{\gamma} \tag{1}$$

where C_M is consumption of manufactured goods, C_R consumption of natural resources and E environmental amenities. The parameters α, β and γ are positive and add up to unity.

There is a trade-off between the production of natural resources and the quality of the environment. For each unit of natural resources (S) extracted, one unit of environmental amenities (Q) is lost

$$Q = \omega - S \tag{2}$$

where ω is a parameter describing the pristine environment. As we shall below consider a situation, where amenities can be traded internationally, we make a distinction between regional consumption (E_i) and "production" (Q_i) of amenities.

The key characteristics of the manufacturing sector are monopolistic competition and product differentiation. To incorporate both of these aspects into the model, we adopt the familiar approach of Dixit and Stiglitz (1977), in assuming that the manufactured aggregate is a CES-function of a large number (m) of differentiated commodity varieties

$$C_M = \left[\sum_{i=1}^{m} c_i^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{3}$$

where $\sigma > 1$ is the elasticity of substitution between any two varieties.

There are n_1 manufacturing firms in region 1 and n_2 firms in region 2, each producing a single product variety. A major objective of our analysis will be to see how environmental policy affects this regional distribution of manufacturing. Firms within each location are symmetric and serve both locations, a firm located in region 1 and 2 charging prices p_1 and p_2, respectively. Transporting manufactured goods is costly. Transportation costs take the Samuelson ice-berg form[17] making consumer prices in regions 1 and 2 p_1 and p_2 for domestic varieties, and $p_2\tau$ and $p_1\tau$ for imports, where $\tau > 1$ is a measure of

[17] If x units of a commodity are exported, only x/τ, $\tau > 1$, units reach the destination. The rest 'melts' under way.

transportation costs. Transportation costs also affect the general consumer price level of each region, captured by the $CES-$price indices

$$P_1 = [n_1 p_1^{1-\sigma} + n_2(p_2\tau)^{1-\sigma}]^{\frac{1}{1-\sigma}}$$
$$P_2 = [n_1(p_1\tau)^{1-\sigma} + n_2 {p_2}^{1-\sigma}]^{\frac{1}{1-\sigma}} \tag{4}$$

In addition to indicating how much utility consumers can achieve with a certain income, the price indices, depending on the number and the regional distribution of firms, also serve to measure the intensity of competition in the regional markets.

To assess firms' profitability, we need to know their sales.[18] We denote the total expenditure of consumers living in regions 1 and 2 on manufactured varieties by y_1 and y_2. Consumer maximization implies that a firm's share of the expenditure depends on the price it charges, compared to the general price level in the region:

$$p_1 x_1 = (\tfrac{p_1}{P_1})^{1-\sigma} y_1 + (\tfrac{p_1\tau}{P_2})^{1-\sigma} y_2$$
$$p_2 x_2 = (\tfrac{p_2}{P_2})^{1-\sigma} y_2 + (\tfrac{p_2\tau}{P_1})^{1-\sigma} y_1 \tag{5}$$

The first term on the right hand side of equations (5) refers to domestic sales and the second term to foreign sales; x_1 and x_2 denote the quantity sold by the representative firm located in region 1 and 2. The equations (5) will, in a moment, allow us to determine the equilibrium distribution of firms, given transportation costs and total regional expenditures. Before that, however, we must have a brief look at the production side.

Capital is the only input needed in manufacturing. We fix the size of the aggregate capital stock to unity and assume that all consumers own an equal share of the stock. Capital is mobile between regions; we denote the share of the stock allocated to region 1 by k, where $k \in [0, 1]$.

Increasing returns to scale arise from the presence of fixed costs and constant marginal costs. To produce x units of a manufactured variety

$$K = a + bx \tag{6}$$

[18] The following results arising from consumer and firm optimization are standard, and we report them rather briefly. For a more detailed account, see e.g. Krugman (1991) or Fujita et al. (1999, Ch. 4).

units of capital are needed. Profit maximization by firms implies that the prices charged are equal to marginal costs, plus a constant mark-up: $p_1 = \frac{\sigma}{\sigma-1} b r_1$, $p_2 = \frac{\sigma}{\sigma-1} b r_1$, where r_1 and r_2 are the rental rates of capital, in regions 1 and 2, respectively.

Because of free entry, firms must earn zero profits in equilibrium. There is a unique level of operation $\overline{x} = \frac{a(\sigma-1)}{b}$, at which sales are just big enough to cover the fixed costs; at a larger scale there would be a profit, at a smaller scale a loss. As the equilibrium level of production $\overline{x}$ depends on parameters, only, it is possible to show, with the help of equation (6), that the number of firms is proportional to the amount of capital: with an appropriate choice of units we can simply write $n_1 = \frac{k}{a\sigma}$, $n_2 = \frac{1-k}{a\sigma}$.

Finally, choosing units of measurement appropriately, we can simplify these equations without any loss of generality[19] (see Fujita et al. (1999), p. 54). Setting $b = \frac{\sigma-1}{\sigma}$ and $a = \sigma^{-1}$, the pricing equation becomes $p_i = r_i$ for $i = 1, 2$, the output level at which firms make no profits is $\overline{x} = 1$, and the regional distribution of manufacturing is measured by the index of capital allocation $n_1 = k$ and $n_2 = 1 - k$.

As a summary of model basics, it may be useful to remark that our framework is the footloose capital model (Baldwin et. al 2003, Ch. 3) with the following modifications: (i) On top of manufactured goods and natural resources[20], there are environmental amenities. (ii) Both constant returns to scale sectors (natural resources and amenities) use environmental resources, while only capital is needed in manufacturing;[21] thus the (clean) manufacturing sector is affected by environmental policy only through the home market effect.[22]

[19] It can be shown that the outcome of the environmental policy - firm location game is unaffected by these normalizations.

[20] Following a standard practice in the literature, Baldwin et al.(2003) call the constant returns to scale sector 'agriculture'.

[21] In the standard FC model the agricultural sector employs regionally immobile labor, while both labor and mobile capital are needed in manufacturing.

[22] A brief comparison to typical center-periphery models (e.g. Krugman 1991) can be found at the end of the next section.

3 Firm location

This section studies the equilibrium location of manufacturing firms. In particular, we want to show that, with given environmental policies, this allocation is unique.

To find the equilibrium of the manufacturing location subgame, we solve the equations (5) for the rental rates of capital, r_1 and r_2, in terms of market sizes, y_1 and y_2, and regional price levels P_1 and P_2:

$$\begin{aligned} r_1^\sigma &= P_1^{\sigma-1} y_1 + (P_2 \tau^{-1})^{\sigma-1} y_2 \\ r_2^\sigma &= P_2{}^{\sigma-1} y_2 + (P_1 \tau^{-1})^{\sigma-1} y_1 \end{aligned} \tag{7}$$

These equations tell that a firm located in region i can pay a high yield if it has good access (no transportation costs) to a large market (high y_i) with little competition (high P_i). The equilibrium allocation of manufacturing firms may assume two different forms: (i) In an interior equilibrium, with $k \in (0,1)$, optimization by investors implies that capital must earn the same rental rate in both regions. (ii) In an end point equilibrium all production is in one region. To rule out profitable deviations, the rental rate paid by a hypothetical firm moving to the periphery must be lower than that earned in the center.

We start with the interior equilibrium, and require that $r_1 = r_2 = 1$.[23] Then using equations (7) and (4) shows that nominal yield is equalized between regions if

$$[k + (1-k)\phi]\, y_2 = [(1-k) + k\phi]\, y_1 \tag{8}$$

where $\phi \equiv \tau^{1-\sigma}$ measures the "freeness" of trade; this "freeness" rises from $\phi = 0$, with infinite trading costs, to $\phi = 1$, with zero trading costs. A notable feature in equation (8) is that it is linear in k, and thus has a unique solution. Exploiting the fact that aggregate expenditure on manufactured goods must be equal to capital income, $y_1 + y_2 = 1$ and

[23] That is, we use capital as the *numeraire*.

thus $y_j = 1 - y_i$, the solution to (8) is[24]

$$n_i = \frac{1}{2} + \frac{1+\phi}{1-\phi}\left(y_i - \frac{1}{2}\right) \tag{9}$$

The condition (9) describes the equilibrium allocation of manufacturing firms, as long as it implies an n_i which is economically meaningful, that is $0 \leq n_i \leq 1$. This is the case, if the difference in market sizes is not too big: for an interior equilibrium to exists, we must have $y_i \in \left[\frac{\phi}{1+\phi}, \frac{1}{1+\phi}\right]$. If y_i lies outside these bounds, the equilibrium is of type (ii), and all industry is clustered in the region with the bigger market. Thus

$$n_i = \begin{cases} 0 & \text{if } y_i < \frac{\phi}{1+\phi} \\ \frac{1}{2} + \frac{1+\phi}{1-\phi}\left(y_i - \frac{1}{2}\right) & \text{if } y_i \in [\frac{\phi}{1+\phi}, \frac{1}{1+\phi}] \\ 1 & \text{if } y_i > \frac{1}{1+\phi} \end{cases} \tag{10}$$

The equation (10) sows that the regional allocation of manufacturing depends on the size of the market. The region with the bigger market attracts more firms. As the share of imports decreases, this also lowers the price level: plugging (10) into (4) gives the price indices as a function of market sizes

$$P_i = \begin{cases} \tau & \text{if } y_i < \frac{\phi}{1+\phi} \\ (1+\phi)^{\frac{1}{1-\sigma}} y_i^{\frac{1}{1-\sigma}} & \text{if } y_i \in [\frac{\phi}{1+\phi}, \frac{1}{1+\phi}] \\ 1 & \text{if } y_i > \frac{1}{1+\phi} \end{cases} \tag{11}$$

The size of the market it affected by environmental policy. The exact form of this relation depends on the assumptions concerning the (non)tradability of environmental amenities and natural resources. These linkages are studied in more detail in sections 5 and 6, and now we simply denote them by

$$y_i = y_i(S_i, S_j) \tag{12}$$

To better understand why our FC-type model has a unique, algebraically solvable equilibrium, it may be useful to briefly contrast the present framework to the well-known center-periphery model by Krugman (1991). In the center-periphery model there

[24] Although the notation is somewhat different, the equation (8) is identical to the equation 3.12 in Baldwin et al. (2003), characterizing the long run equilibrium of the FC model.

are two key mechanisms which give rise to circular causation, and create self-reinforcing agglomerations and multiple equilibria. First, there is a linkage from firm location to production costs. As mobile workers care about real wages, firms operating in the center, where the price level tends to be lower, can offer lower nominal wages and still attract labor. Second there is a linkage from industry location to market size, as purchasing power is embodied in mobile manufacturing workers.[25] Both of these mechanisms are eliminated in our framework, where the reward of footloose capital is repatriated to immobile consumer-investors, who base their decisions on nominal yields.[26]

4 Environmental policy

We can now proceed to the analysis of environmental policy. Our primary aim is to demonstrate that decentralized decision-making may result in a race to the bottom, with excessive development and a too low quality of the environment. This is done, of course, by comparing the decentralized solution to the (second best[27]) social optimum

The aim of the social planner is to divide environmental resources between preservation and development so as to maximize social welfare. When deciding how much natural resources to extract the planner must take into account the trade-off between resource extraction and environmental amenities (1), the regional price levels (4), the way in which the regional distribution of manufacturing is determined (10) and the linkage between environmental policy and consumers' purchasing power (12). Denoting the indirect utility function of a representative consumer residing in region $i = 1, 2$ by $V_i(S_i, S_j)$, where $j \neq i$, the maximization problem is of the form:

[25] Another mechanism linking firm location to market size is analyzed by Krugman and Venables (1995): manufactured varieties are not demanded by consumers only but also by manufacturing firms, which use them as intermediate goods.

[26] For more discussion, see Baldwin et al. (2003).

[27] The social planner only sets environmental policies in the two regions. The distortions in the manufacturing sector are not addressed. Notice also that unlike in Pfluger (2001), environmental regulations have no effect on the pricing of the monopolistically competitive manufacturing firms. This is because environmental resources are not used as an input in the manufacturing sector.

$$\max_{S_1,S_2} V_1(S_1,S_2) + V_2(S_2,S_1)$$
$$\text{subject to } (1),(4),(10),(12),$$

(Indirect utility functions are derived in the appendix.) Given the symmetry of the model, it turns out to be optimal to develop the same amount of resources in both regions. Thus the regions do not differ in terms of purchasing power, and an equal number of manufacturing plants are opened in both locations, $k = \frac{1}{2}$. Then the characterization of the optimum boils down to the familiar requirement that at the margin, developed and preserved environmental resources should make the same contribution to consumers' welfare. This condition of equal marginal utility can be expressed in the form

$$\frac{\partial U}{\partial E_i} = \frac{\partial U}{\partial C_{Ri}} \tag{13}$$

or equivalently

$$\frac{S_i}{Q_i} = \frac{\beta}{\gamma} \tag{14}$$

When environmental policy is determined in a decentralized manner, the regions only care for the well-being of their own citizens, and the optimization problem facing environmental authorities in region i is of the form

$$\max_{S_i} V_i(S_i,S_j)$$
$$\text{subject to } (1),(4),(12),(10)$$

The appendix shows that the symmetric equilibrium of the game is characterized by the first order conditions[28]

[28] The appendix also analyzes the conditions for the existence of a symmetric equilibrium in pure strategies. Under the basic set of assumptions, with tradable natural resources and non-tradable amenities, such an equilibrium is guaranteed to exist if $\mu \equiv \frac{\alpha}{\alpha+\beta} > 2\frac{\phi}{1+\phi}$. If this requirement is met there is always some manufacturing in both regions, independently of environmental policies; the equilibrium of the location subgame is of type (i), as defined in the previous section. If both amenities and natural resources are either tradable or non-tradable, the (socially optimal) symmetric equilibrium always exists. The appendix also shows that there cannot be any asymmetric equilibria in pure strategies. Thus the symmetric equilibrium, if it exists, is unique (at least in pure strategies).

$$\frac{\partial U}{\partial E_i} = \frac{\partial U}{\partial C_{Ri}} + \frac{\partial U}{\partial C_{Mi}} \frac{\partial C_{Mi}}{\partial P_i} \frac{\partial P_i}{\partial n_i} \frac{\partial n_i}{\partial y_i} \frac{\partial y_i}{\partial S_i} \quad \text{for } i = 1, 2 \tag{15}$$

While the left-hand side of (15) is the marginal utility of environmental amenities and the first term on the right-hand side reflects marginal utility from natural resources, the second term on the right-hand side captures the potential incentives to abuse environmental policy. Decentralized policies can be socially optimal if and only if this strategic term vanishes when the planner's solution, characterized by (13) or (14), is implemented.

Next, by analyzing the expression $\frac{\partial U_i}{\partial C_{Mi}} \frac{\partial C_{Mi}}{\partial P_i} \frac{\partial P_i}{\partial n_i} \frac{\partial n_i}{\partial y_i} \frac{\partial y_i}{\partial S_i}$ into its constituent elements, the logic of strategic environmental policy can be reiterated. As the term $\frac{\partial U_i}{\partial C_{Mi}} \frac{\partial C_{Mi}}{\partial P_i} = -\alpha \frac{U_i}{P_i}$ indicates, the strategic twists in environmental regulation are motivated by the attempt to lower the regional price level and thereby increase the utility consumers derive from the consumption of manufactured varieties. The term $\frac{\partial P_i}{\partial n_i} = -\frac{1-\phi}{\sigma-1} P_i^{\sigma}$ then tells that the price level can be lowered by attracting new manufacturing firms and thus reducing the share of imports. At the same time the cost of living rises in the other region, which loses manufacturing firms, but this negative spillover is not taken into account. Next, the term $\frac{\partial n_i}{\partial y_i} = \frac{1+\phi}{1-\phi}$ states that the way to attract firms is to increase the size of the market. Finally the term $\frac{\partial y_i}{\partial S_i}$ says that environmental policy is a tool by which market size can be manipulated. Now, upon simplification, the first order conditions (15) take the form[29]

$$\frac{S_i}{Q_i} = \frac{\beta + \frac{\alpha}{\sigma-1} \frac{\partial y_i}{\partial S_i} S_i}{\gamma} \tag{16}$$

indicating that in our model decentralized policy may not be socially efficient. Whether or not this is the case, depends, however, on the exact form of the linkage between environmental policy and market size.

[29] Notice that the freeness of trade parameter ϕ does not appear in this formula. This may seem somewhat surprising, since the aim of environmental policy is to economize in transportation costs. This feature of the model arises from the combination of two countervailing effects: The higher the transportation costs, (i) the more the allocation of manufacturing affects utility, but (ii) the less the size of the market matters for firm location. Given the Dixit-Stiglitz-Krugman approach, with CES-utility and iceberg transportation costs, these effects exactly cancel out each other. See also the appendix: the parameter ϕ only enters the indirect utility function as a multiplier.

5 Inefficient equilibrium

This section studies the equilibrium of the model under the basic set assumptions, with tradable natural resources and non-tradable amenities. In equilibrium, local consumption of amenities must be matched by local supply

$$E_i = Q_i \tag{17}$$

Notice that equation (17) is valid both (i) when the environment is strictly a non-market good and (ii) when there are regional markets for (certain aspects of) amenities; say local consumers can buy recreational services. On the other hand, the balance of payments condition

$$y_i + P_R C_{Ri} = \frac{1}{2} + P_R S_i \tag{18}$$

must hold for traded goods, where P_R is the price of natural resources.

A casual inspection of the trade balance (18) already indicates that development increases the size of the market. An expansion in the production of natural resources strengthens the income side of the balance. As manufactured goods are normal, the expenditure on them (y_i) goes up. In particular, in the symmetric equilibrium we have

$$\frac{\partial y_i}{\partial S_i} = P_R - P_R \frac{dC_{Ri}}{dS_i} > 0 \tag{19}$$

The expression (19) simply tells that after development the region increases its net exports of natural resources, which allows extra consumption of manufactured varieties.

It is also easy to derive an explicit expression for y_i. Given the Cobb-Douglas utility function (1) the expenditure and income shares of manufactured goods and natural resources are $\mu \equiv \frac{\alpha}{\alpha+\beta}$ and $1-\mu$, respectively. As all consumers are assumed to own an equal share of the capital stock, both regions get half of the capital income, coming from the manufacturing sector. Income from natural resources is, on the other hand, divided according to the regional production shares. Noting that aggregate capital income is equal to unity, we can now see that the expressions for regional aggregate incomes take the form

$$Y_i = \frac{1}{2} + s_i \frac{1-\mu}{\mu}$$

where

$$s_i \equiv \frac{S_i}{S_1 + S_2} \tag{20}$$

is the share of region i in the supply of natural resources. As consumers spend the share μ of their income on manufactured varieties, the indices of the size of the market can be expressed as follows

$$y_i = \frac{1}{2}\mu + s_i(1-\mu) \tag{21}$$

Now, it is easy to see that converting non-tradable amenities into tradable natural resources increases market size:

$$\frac{\partial y_i}{\partial S_i} = (1-\mu)\frac{1-s_i}{S_1+S_2} > 0 \tag{22}$$

Next, plugging (21) into (10) shows that the region producing more natural resources, and enjoying a lower quality of the environment, succeeds in attracting a larger share of manufacturing firms

$$n_i = \begin{cases} 0 & \text{if } s_i < \frac{1}{2} - \frac{1}{2}\frac{1-\phi}{1+\phi}\frac{1}{1-\mu} \\ \frac{1}{2} + \frac{1+\phi}{1-\phi}(s_i - \frac{1}{2})(1-\mu) & \text{if } s_i \in [\frac{1}{2} - \frac{1}{2}\frac{1-\phi}{1+\phi}\frac{1}{1-\mu}, \frac{1}{2} + \frac{1}{2}\frac{1-\phi}{1+\phi}\frac{1}{1-\mu}] \\ 1 & \text{if } s_i > \frac{1}{2} + \frac{1}{2}\frac{1-\phi}{1+\phi}\frac{1}{1-\mu} \end{cases} \tag{23}$$

Thus although the manufacturing sector is clean, environmental policy affects firm location. Finally, substituting the expressions (22) into the first order conditions characterizing decentralized environmental policy gives

$$\frac{S_i}{Q_i} = \frac{\beta}{\gamma}\left(1 + \frac{1}{2}\frac{\mu}{\sigma - 1}\right) \qquad \text{for } i = 1, 2 \tag{24}$$

As the expression (24) indicates, decentralized decision-making results in an inefficient equilibrium, with too much development and too little preservation. The drive towards the race to the bottom is the stronger, the larger the expenditure share of manufactured varieties μ. On the other hand, the harder it is for consumers to substitute one manufactured variety for another, the more important it is to decrease the share of imports;

thus a small elasticity of substitution σ reinforces the incentives to abuse environmental policy.

The main result of this section can be stated as follows:

Proposition 1 *When amenities are non-tradable and natural resources tradable, decentralized environmental policies are socially non-optimal. In equilibrium there is too little preservation and too much development.*

6 Efficient equilibrium

To highlight the role of international (non)tradability in the generation of distortions, this section analyzes situations where both natural resources and environmental amenities are either non-tradable or tradable. We start with the former case.

If natural resources (or more generally the end products of development) cannot be traded internationally, in equilibrium regional consumption of both amenities and natural resources must be equal to regional production:

$$E_i = Q_i, \quad C_{Ri} = S_i, \quad i = 1, 2$$

Since only manufactured goods enter international exchange, the balance of payments becomes

$$y_i = \frac{1}{2}, \quad i = 1, 2 \tag{25}$$

From (25) it is easy to see that environmental policy has no effect on the size of the market y_i. Development simply increases local consumption of natural resources, while lowering the quality of the environment. As there are no demand spillovers to the manufacturing sector, there is no reason to abuse environmental policy. Plugging

$$\frac{\partial y_i}{\partial S_i} = 0$$

into the first order conditions (16) tells that the regions follow socially optimal policies.

Next we move to the case, where both natural resources and environmental amenities are tradable. Although the services provided by the clean environment cannot typically be transported from one country to another, there may be some indirect ways to make them internationally exchangeable. Interregional (eco)tourism offers one possible means to circumvent non-transportability. On the other hand a pristine ecosystem, with high biodiversity, can provide genetic material, which may prove valuable in the development of pharmaceutical products and other tradable goods. A third possible way to combine tradability and preservation is then presented by some primary industries, such as hunting or reindeer husbandry.

When all sectors produce internationally tradable goods, the balance of payments takes the form

$$y_i + P_R C_{Ri} + P_E E_i = \frac{1}{2} + P_R S_i + P_E Q_i \quad i = 1, 2$$

where P_E is the price of amenities. Now environmental policy may affect market size y_i through two main channels. First, with given prices P_R and P_E, a reallocation of environmental resources may increase of decrease regional income. Second, there is a terms of trade effect, as prices P_R and P_E change. For our analysis of (non)tradability issues, the first effect is more relevant. With a suitable choice of assumptions, the terms of trade effect can be ignored. First this can be done if the regions are 'small' players in natural resource and amenity markets. Thus we can think that our two-region model is only a small part of a larger economy. Second, even when the regions are large, the terms of trade effect vanishes[30] in the symmetric equilibrium where the identical regions adopt identical environmental policies; this is because in equilibrium there is no (net) trade outside the manufacturing sector and

$$\frac{\partial P_R}{\partial S_i}(S_i - C_{Ri}) = \frac{\partial P_E}{\partial S_i}(Q_i - E_i) = 0 \quad i = 1, 2$$

Now the effect of environmental policy on market size is given by

$$\frac{\partial y_i}{\partial S_i} = P_R - P_E - P_R \frac{dC_{Ri}}{dS_i} - P_E \frac{dE_i}{dS_i} \tag{26}$$

[30] The manipulation of terms of trade is a well understood motivation for strategic environmental policy (see e.g. Rauscher 1997). To focus on the non-tradability of amenities, we have chosen a symmetric model formulation, where this effect does not arise.

where the expression (26) holds, (i) under the 'small region' assumption or (ii) under symmetric environmental policies. The first part $P_R - P_E$ tells how development affects national income, with given prices. This effect is positive (negative) if and only if the relative price P_R/P_E of natural resources in terms of amenities is greater (smaller) than one. In general, both alternatives are possible. However, in the social optimum

$$MRS = \frac{P_R}{P_E} = MRT = 1$$

where the last equality follows from the linear trade-off (2) between natural resources and amenities. Thus if environmental policies are set optimally, gains in natural resource revenues are exactly cancelled out by the losses on the amenity side.

The second part of (26) $-P_R \frac{dC_{Ri}}{dS_i} - P_E \frac{dE_i}{dS_i}$ then indicates how much the expenditure on natural resources and environmental amenities changes. In the social optimum also this part goes to zero. This is evident if the regions are small: as neither regional income nor market prices change, also demand remains unaltered. In the case of large regions, notice that a small deviation from the social optimum preserves the symmetry between the regions, as (i) regional incomes do not change and (ii) both regions face the same market prices. Then we can conclude that development increases the consumption of natural resources and cuts down the consumption of amenities in both regions:

$$\frac{dE_i}{dS_i} = -\frac{dC_{Ri}}{dS_i}, \quad i = 1, 2$$

Then as under optimal policies $P_R = P_E$, the term $-P_R \frac{dC_{Ri}}{dS_i} - P_E \frac{dE_i}{dS_i}$ vanishes. As a conclusion we can then state that under socially optimal policies

$$\frac{\partial y_i}{\partial S_i} = 0 \quad i = 1, 2 \tag{27}$$

Then, as there are no demand spillovers to the manufacturing sector, the regions do not face incentives to abuse environmental policy.

Given the Cobb-Douglas utility function, we can also derive an explicit formula for market size. Following the same steps as in the previous section yields

$$y_i = \frac{1}{2} + \beta \left(s_i - \frac{1}{2} \right) + \gamma \left(q_i - \frac{1}{2} \right) \quad i = 1, 2 \tag{28}$$

where s_i is given by (20) and

$$q_i = \frac{Q_i}{Q_1 + Q_2}$$

is the share of region i in the supply of amenities. Then under symmetric environmental policies we have

$$\frac{\partial y_i}{\partial S_i} = \frac{1}{4}\left(\frac{\beta}{S_i} - \frac{\gamma}{Q_i}\right) \quad i = 1,2 \tag{29}$$

The expression (29) repeats the argument we already presented above: Development raises natural resource sales, but at the same time amenity revenues go down. While in general either effect may dominate, in the social optimum, characterized by (14), the two sides cancel out each other and $\frac{\partial y_i}{\partial S_i} = 0$.

The results of this section can be summarized as follows:

Proposition 2 *If both amenities and natural resources are either tradable or non-tradable, the decentralized equilibrium is socially optimal.*

7 Concluding remarks

This paper suggested that, in an economy characterized by increasing returns to scale and costly transportation, the fact that environmental amenities are internationally non-tradable may distort decentralized environmental policy. Individual countries or local jurisdictions may have incentives to use too big a share of environmental resources as inputs in the production of tradable goods. The aim of the strategic environmental policy is to increase the size of the domestic market in order to attract new firms and industries. We also showed that these distortions vanish, if (i) also the end products of development are non-tradable, or (ii) if there are technologies allowing environmental amenities to enter international trade.

Appendix

In this appendix we first characterize regional environmental policies in the symmetric equilibrium, and then analyze the existence and the uniqueness of the equilibrium.

The derivation of equation (15)

This section derives the first order conditions (15) characterizing regional environmental policies in the symmetric equilibrium.

Let $V_i(S_i, S_j)$, $i, j \in \{1, 2\}$ and $i \neq j$, be the indirect utility function of a representative consumer residing in region i. $V_i(S_i, S_j)$ is defined by

$$\begin{aligned} V_i(S_i, S_j) &= \max_{y_i, C_{Ai}, E_i} U\left(\frac{y_i}{P_i}, C_{Ri}, \delta E_i + (1-\delta) Q_i\right) \\ &\quad +\lambda_i \left[\frac{1}{2} + P_R S_i + P_E Q_i - y_i - P_R C_{Ri} - P_E E_i\right] \end{aligned} \tag{30}$$

where P_R is the price of natural resources, P_E is the price of (tradable) amenities, δ is an indicator function, which takes the values

$$\delta = \begin{cases} 1 & \text{if amenities are tradable} \\ 0 & \text{otherwise} \end{cases}$$

and λ_i is the Lagrangian multiplier of the budget constraint. The first order conditions of consumer maximization are

$$\frac{\partial U}{\partial C_{Mi}} = \lambda_i P_i, \ \frac{\partial U}{\partial C_{Ri}} = \lambda_i P_R, \ \ \delta \frac{\partial U}{\partial E_i} = \lambda_i P_E \tag{31}$$

Region i sets its environmental policies S_i so as to maximize the welfare of its citizens, while taking the policies followed by the other region as given.

$$\begin{aligned} &\max_{S_i} V_i(S_i, S_j) \\ &\text{subject to } (1), (4), (10), (12) \end{aligned}$$

The first order condition is of the form

$$\begin{aligned} \frac{\partial V_i}{\partial S_i} &= \lambda_i \left[P_R - P_E + \frac{\partial P_R}{\partial S_i}(S_i - C_{R_i}) + \frac{\partial P_E}{\partial S_i}(Q_i - E_i)\right] \\ &\quad - (1-\delta) \frac{\partial U}{\partial E_i} + \frac{\partial U}{\partial C_{M_i}} \frac{\partial C_{M_i}}{\partial P_i} \frac{\partial P_i}{\partial n_i} \frac{\partial n_i}{\partial y_i} \frac{\partial y}{\partial S_i} \\ &= 0 \end{aligned} \tag{32}$$

Next, plug in the first order conditions of consumer maximization (31), and notice that, as the regions are identical, the terms of trade effects $\frac{\partial P_R}{\partial S_i}(S_i - C_{R_i})$ and $\frac{\partial P_E}{\partial S_i}(Q_i - E_i)$

vanish in the symmetric equilibrium. Then the first order condition (32) takes the form (15) appearing in the main text:

$$\frac{\partial U}{\partial E_i} = \frac{\partial U}{\partial C_{Ri}} + \frac{\partial U}{\partial C_{Mi}} \frac{\partial C_{M_i}}{\partial P_i} \frac{\partial P_i}{\partial n_i} \frac{\partial n_i}{\partial y_i} \frac{\partial y_i}{\partial S_i}$$

The existence and uniqueness of the symmetric equilibrium

This appendix establishes that the environmental policy game has a symmetric, socially efficient equilibrium in pure strategies, if both amenities and natural resources are tradable.[31] We also state a simple *sufficient* condition for the existence of a symmetric pure strategy equilibrium under the basic set of assumptions, with tradable natural resources and non-tradable amenities. Finally we show that if a symmetric equilibrium exists, it is also the only equilibrium of the model in pure strategies.

We begin by writing down the indirect utility functions in an explicit form:

$$V_i(S_i, S_j) = P_i^{-\alpha} v_i(S_i, S_j) \tag{33}$$

where the price index P_i is given by (11),

$$v_i(S_i, S_j) = \begin{cases} v_i^N(S_i, S_j) \equiv A y_i^{\alpha+\beta} (S_1 + S_2)^\beta Q_i^\gamma & \text{if amenities are non-tradable} \\ v_i^T(S_i, S_j) \equiv B y_i (S_1 + S_2)^\beta (Q_1 + Q_2)^\gamma & \text{if amenities are tradable} \end{cases}$$

and A and B are (unimportant) constants, which depend on the parameters α, β and γ. It is worth noting that (up to a constant multiplier) $v_i(S_i, S_j)$ is the indirect utility function of region i in a hypothetical economy, where capital is immobile.

Next, let $S_1 = S_2 = \widehat{S}$ be the putative symmetric equilibrium of the environmental policy game. If amenities are tradable, $\widehat{S} = S^*$ is the solution to (14), while with non-tradable amenities $\widehat{S} = S^{**}$ is given by (24). Also let S_L and S_H be implicitly defined by $y_i\left(S_L, \widehat{S}\right) = \frac{\phi}{1+\phi}$ and $y_i\left(S_H, \widehat{S}\right) = \frac{1}{1+\phi}$. If region j follows the putative equilibrium strategy, $S_j = \widehat{S}$, and region i sets $S_i \leq S_L$ ($S_i \geq S_H$), there will be

[31] A symmetric efficient equilibrium also exists, when both amenities and natural resources are non-tradable. Showing this is straightforward, since under these assumptions environmental policy never affects the location choices of manufacturing firms.

no manufacturing in region i (region j); the firm location subgame has an end point equilibrium. If $S_i \in (S_L, S_H)$ the subgame has an interior equilibrium. Notice that $S_L < \widehat{S} < S_H$.

Now assume that country j adopts the strategy $S_j = \widehat{S}$. Then the objective function of country i takes the form

$$V_i\left(S_i, \widehat{S}\right) = \begin{cases} \phi^{\frac{\alpha}{\sigma-1}} v_i\left(S_i, \widehat{S}\right) & \text{when } S_i \in [0, S_L] \\ (1+\phi)^{\frac{\alpha}{\sigma-1}} y_i^{\frac{\alpha}{\sigma-1}} v_i\left(S_i, \widehat{S}\right) & \text{when } S_i \in (S_L, S_H) \\ v_i\left(S_i, \widehat{S}\right) & \text{when } S_i \in [S_H, \omega] \end{cases}$$

(Remember that $\tau = \phi^{\frac{1}{1-\sigma}}$). It is easy to show that the constituent functions $\phi^{\frac{\alpha}{\sigma-1}} v_i\left(S_i, \widehat{S}\right)$, $(1+\phi)^{\frac{\alpha}{\sigma-1}} y_i^{\frac{\alpha}{\sigma-1}} v_i\left(S_i, \widehat{S}\right)$ and $v_i\left(S_i, \widehat{S}\right)$ are single-peaked on $S_i \in [0, \omega]$[32]. Next we study under what conditions also $V_i\left(S_i, \widehat{S}\right)$ is single-peaked, with the maximum at $S_i = \widehat{S}$.

We begin with the case where amenities are tradable. The analysis of the main text shows that $(1+\phi)^{\frac{\alpha}{\sigma-1}} y_i^{\frac{\alpha}{\sigma-1}} v_i\left(S_i, S^*\right)$ reaches its peak at $S_i = S^*$ (as $S_1 = S_2 = S^*$ is the putative efficient equilibrium of the model). But also $v_i\left(S_i, S^*\right)$ (and $\phi^{\frac{\alpha}{\sigma-1}} v_i\left(S_i, S^*\right)$) has its maximum at $S_i = S^*$. This is easy to understand, when we recall that $v_i\left(S_i, S_j\right)$ is the objective function of region i in an economy with no capital mobility. In such an economy there are no strategic incentives to abuse environmental policy, in order to attract manufacturing firms. Thus if region j makes the socially efficient choice $S_j = S^*$, also region i finds it optimal to set $S_i = S^*$. Now, $V_i\left(S_i, S^*\right)$ is constructed by compiling three single-peaked functions, which all have their maximum at $S_i = S^*$. As a consequence also $V_i\left(S_i, S^*\right)$ is single-peaked, with the maximum at S^*. But then $S_i = S^*$ is the best response to $S_j = S^*$, and the policy choices $S_1 = S_2 = S^*$ form an equilibrium.

Next we turn to the situation where amenities are non-tradable. The analysis of the main text indicates that $(1+\phi)^{\frac{\alpha}{\sigma-1}} y_i^{\frac{\alpha}{\sigma-1}} v_i\left(S_i, S^{**}\right)$ has its peak at $S_i = S^{**}$ (as $S_1 = S_2 = S^{**}$ is the putative inefficient equilibrium of the model). However $v_i\left(S_i, S^{**}\right)$ (and $\phi^{\frac{\alpha}{\sigma-1}} v_i\left(S_i, S^{**}\right)$) reaches its maximum at some $S_i = \widetilde{S} < S^{**}$. This is because

[32] The second derivative is always negative at an interior extreme point. As the functions are continuous, there can be at most one interior extreme point (a maximum).

the "no-capital-mobility" objective function does not embody any strategic incentives to overdevelop, in order to attract manufacturing firms. Now, if $\widetilde{S} < S_L$, the function $V_i(S_i, S^{**})$ is dual-peaked, with two local maxima at $S_i = \widetilde{S}$ and $S_i = S^{**}$. Depending on circumstances, either $\widetilde{S}$ or S^{**} can be the global maximum of $V_i(S_i, S^{**})$, and $S_i = S^{**}$ is not necessarily the best response to $S_j = S^{**}$.

A simple way to guarantee that there is a symmetric equilibrium in pure strategies is to focus on situations, where the firm location subgame always has an interior equilibrium, independently of environmental policies. Then $V_i(S_i, S^{**}) = (1+\phi)^{\frac{\alpha}{\sigma-1}} y_i^{\frac{\alpha}{\sigma-1}} v_i(S_i, S^{**})$ for $S_i \in [0, \omega]$, and the objective function of region i is evidently single-peaked and reaches its maximum at $S_i = S^{**}$. Thus what we want is that $y_i(S_i, S_j) \in \left(\frac{\phi}{1+\phi}, \frac{1}{1+\phi}\right)$ for all $S_i, S_j \in [0, \omega]$. As $y_i(S_i, S_j) = \frac{1}{2}\mu + (1-\mu)s_i$, when amenities are non-tradable, it is easy to show that the requirement is met if and only if

$$\frac{1}{2}\mu \geq \frac{\phi}{1+\phi}.$$

Thus a symmetric equilibrium is more likely to exist, when the income share of manufacturing (μ) is large and trading costs are not too small (i.e. the "freeness of trade" parameter ϕ is not too close to unity).

Even when the condition $\frac{1}{2}\mu \geq \frac{\phi}{1+\phi}$ is not satisfied, a symmetric equilibrium in pure strategies still exists, if $V_i(S^{**}, S^{**}) \geq V_i\left(\widetilde{S}, S^{**}\right)$, or equivalently

$$(1+\phi)^{\frac{\alpha}{\sigma-1}} \left(\frac{1}{2}\right)^{\frac{\alpha}{\sigma-1}} v_i^N(S^{**}, S^{**}) \geq \phi^{\frac{\alpha}{\sigma-1}} v_i^N\left(\widetilde{S}, S^{**}\right).$$

It is easy to see that this inequality is more likely to hold, when ϕ is small and trade is not too free. (Notice that the local maxima S^{**} and $\widetilde{S}$ are unaffected by changes in the parameter ϕ, which only enters the objective functions as a multiplier.)

The finding that a symmetric inefficient equilibrium in pure strategies is more likely to exist, when trade is costly is rather intuitive. First, with high transportation costs, it is not likely that all manufacturing firms cluster in the region with the bigger market: it is difficult to serve the smaller market from the center, and firms relocating to the periphery tend to earn higher profits. Thus the interior equilibrium in the firm location game, and the strategic incentives to abuse environmental policy. Second, a putative deviation from $S_i = S^{**}$ to $S_i = \widetilde{S}$ involves giving up the manufacturing sector, in order to achieve a better allocation between amenities and natural resources. It is evident that this strategy is less likely to pay off, if trade in manufacturing products is costly.

If the model does have a symmetric equilibrium, this is also the unique equilibrium in pure strategies. The model does not have any *asymmetric* pure strategy equilibria. The proof is simple. Assume that $S_i = \overline{S}$, $S_j = \underline{S}$, where $\overline{S} > \underline{S}$, is an equilibrium. Then, given the value functions (33), it is easy to show that if the first order condition holds for region i, $\partial V_i \left(\overline{S}, \underline{S}\right) / \partial S_i = 0$, it fails to hold for region j, $\partial V_j \left(\overline{S}, \underline{S}\right) / \partial S_j > 0$. Likewise $\partial V_j \left(\overline{S}, \underline{S}\right) / \partial S_j = 0$ implies $V_i \left(\overline{S}, \underline{S}\right) / \partial S_i < 0$. If a symmetric equilibrium in pure strategies does not exist, there can be only mixed strategy equilibria.

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