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Capital Mobility, Land Policy and Biodiversity

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Abstract

We analyze the effects of capital mobility on biodiversity and welfare. We discuss a simple general equilibrium model with trade in capital between two countries, North and South. Our model contains three factors of production: land, labor and capital. Land and capital are taxed. Biodiversity is introduced using a species-area curve. This simple framework serves several purposes. First, as in comparable models with trade in goods, liberalization might lead to decreases in global biodiversity if land policy is too lax. Second, strategic interaction between countries adjusting their policies in the face of liberalization depends on biodiversity specifics. Third, it is shown that cooperation in land policy is beneficial for global biodiversity when countries are very similar. The difference between the cooperative and non-cooperative solution becomes less clear when countries differ in terms of endowments or preferences.

Keywords: Biodiversity, Capital Mobility, Interjurisdictional competition, Land policy**.**

1. Introduction: Globalization and Biodiversity Conservation

Since the beginning of the 1990's an increasing number of economists, biologists and other scientists have paid attention to the question of biodiversity conservation and the rate of species extinction. Although being difficult to predict, estimated extinction rates are far higher than historical rates. There is consensus that the root cause of this and other forms of environmental degradation is (economic) activity by humans. This has resulted in habitat loss, over-harvesting and pollution of the environment (Polasky et al.,2004). At the same time, economic growth in some parts of the world has been higher than ever before, and the world has seen a rapid increase in trade flows and international investments. It seems that globalization has taken a new pace at the same time when many ecosystems face growing pressure from human action.

According to Geoffrey Heal globalisation in itself has not lead to a decrease in biodiversity (Heal, 2002). Globalisation, as defined by the increase in mobility of factors of production, the lowering of transport costs and the increase in international trade and investment, cannot be the prime cause since degradation of the environment happens worldwide. Heal states that '*Population growth, habitat loss and biodiversity loss are global problems, in the sense that they are occurring globally and have global consequences. But they are not problems of globalization* (Heal, 2002)'.

The simple observation that habitat conversion and the resulting loss in biodiversity occur everywhere in the world is, according to Heal, proof of this statement. Worldwide the scarcity of land has been greater than ever before not due to globalization, but because of fast growing populations and enormous boosts in income per capita. These developments imply that many species, and nature in general, compete with other (economic) activities for scarce resources. The result is that trade, trade policy and international institutions occupied with conservation can not stop the trend of habitat loss (Schulz, 1996). In fact, when valued at the margin many biological assets offer such a low rate of return that from an economic point of view disinvestment is not irrational at this point in time (Bulte & Van Kooten, 2000).

Nonetheless, Heal's remarks can be criticized on several accounts. In sum, globalization affects patterns of human economic activity with respect to space and time, and provides for many new opportunities that have no precedent in history. Let us elaborate more closely on these aspects of globalization.

First, Heal neglects the fact that globalization may be a force of economic growth by itself. In the field of economic development there is still a lively debate what determinants of economic growth are key, but most authors agree that the concepts of geography, openness and institutions seem to matter the most (Rodrik, 2001). Empirically, there is some evidence that increased openness to trade and factor flows, given the right set of domestic institutions, increases the rate of economic growth. For example, many have argued that export-led growth was one of the main drivers behind the East-Asian miracle. So by providing for new opportunities of economic growth, reductions in tariffs, quota's, capital controls and other restrictions to trade and factor mobility have fuelled indirectly a growth process that endangers global biodiversity.

Second, Heal's statement ignores the fact that reductions in transport costs have altered spatial patterns of economic activity. Both biodiversity and economic activity are not spread uniformly across space. For example, in the European Union there is often a larger discrepancy in income between different regions within a country than between various countries itself. Thus intra-country variety in income per capita is larger than inter-country variety in income per capita. Very much comparable to economics similar patterns of spatial heterogeneity exist in the biological realm. Some ecosystems such as tropical rainforests contain significantly more species than others. On a global scale, more than 80% of the world's biodiversity is contained in 5% of the world's land area. These areas are called ecological hotspots. Thus, spatial heterogeneity is an issue in both economics and ecology (Barbier & Rauscher, 2007; Eppink & Withagen, 2005).

Third, globalization has affected the speed by which mobile factors of production can relocate to other, more profitable regions. With less or no detachment to their original resource base, mobile factors have fewer incentives to acquire a sustainable relation with their environment. By the time the local environment is degraded, spatial adjustment drives mobile factors of production into unexplored areas. Thus, one should differentiate theories concerning renewable resource management with respect to factor mobility. A careful investigation of this aspect seems to be absent in most of the work on trade and renewable resources (Barbier & Bulte, 2005)

Footloose Capital and Labor Mobility

A crucial difference however between the various mobile factors of production lies in the reason for immigration. Standard economic theory predicts that capital will flow to those regions where marginal returns are highest. In the absence of transport cost or adjustment costs these capital flows result in equalization of the net return to capital across regions. Labour on the other hand has more to consider than just real wages. In many models of environmental policy and labour mobility it is assumed that agents care about the state of the environment as well. If moving to a richer region implies a setback in environmental amenities that can be consumed in that region, then immigration might not be so profitable than was initially thought. In other words, people's immigration decisions depend on more than just profitability and might include, next to environmental considerations, also social, cultural and political motives.

Thus, without further restrictions on capital flows, there are clear differences between the incentives for immigration by mobile factors of production. In the context of biodiversity, one might conjecture that people like to move not only to those regions where real wages are high, but also where one can enjoy environmental amenities such as a diverse set of species. To date the literature has mainly focused on household mobility in the context of environmental pollution (a public bad). Even though pollution is transboundary, household mobility works as a disciplinary mechanism for competing jurisdictions to provide for an optimal amount of public goods. The intuition is that in the presence of zero adjustment costs jurisdictions will avoid hurting other regions, since this will eventually lead to higher pollution at home as well (Haavio, 2005; Hoel, 1997).

Factor Mobility and Environmental Pollution

As opposed to environmental pollution, the problem of providing for an optimal amount of biodiversity is characterized by various differences. First, environmental pollution is a public bad whereas biodiversity is a public good. Both ‘goods’ share the characteristic that they do not directly affect the budget of the government compared to standard public goods such as defence, education, healthcare and infrastructure. Of course, the main reason is that sub optimal outcomes with respect to biodiversity or environmental pollution are both the result of human action that fails to consider all external benefits and costs.

Second, environmental pollution is a direct consequence of certain production processes. A decrease in biodiversity on the other hand is not always a direct consequence of the production process. Biodiversity is assumed to depend directly on the available amount of habitat. If land is an input of production, an increase in economic activity may lead to a decrease in the amount of land available for habitat purposes. As a result, biodiversity might decline. The severity will depend on the land intensity of the sector under consideration and the robustness of the ecosystem, the initial size of the habitat and connectivity to remaining habitat patches.

Third, for many polluting intensive industries various technologies are often there to counter emissions. Government policy in the form of emissions restrictions or taxation might induce firms to implement new technologies and abate where possible. To protect biodiversity on the other hand, fewer instruments are available so far. Species protection is in many cases considered to be expensive and habitat protection emerges as the best alternative. The question then arises how to protect habitat from land conversion for agriculture or other economic activities.

Why Biodiversity and Factor Mobility?

The reasons for studying the relation between factor mobility and biodiversity are many. First, most work in the economic literature has only focused on the connection between trade and biodiversity. From an empirical point of view this is somewhat understandable since international trade and the associated invasion of alien species are among the most important causes of species decline (Polasky et al., 2004). Nevertheless, other threats to the environment and biodiversity exist in the form of urbanization, industrialization and eco-tourism. The latter activity is especially important for developing countries and is closely related to the mobility of capital. In particular, the underdevelopment theory of tourism describes the control of ecotourism resources by multinational enterprises in the developing world. For example, in Zimbabwe of the 1980's more than 90% of eco-tourism revenues were expatriated to the parent countries. Only a small amount was reinvested in the home country causing excessive environmental degradation, among other problems related to sustainable development (Isaacs, 2000; Ziffer, 1989).

Second, from a theoretical perspective globalization is more than just international trade: factor mobility and foreign direct investment are also part of this phenomenon. In a related area of interest that was described above, i.e., the relation between internationalisation and pollution, this definition of globalization is recognized. Environmental pollution has been the topic of much theoretical analysis where theory has focussed on both models of trade and capital movements (Rauscher, 1997; Copeland & Taylor, 2003). Even though trade and factor flows are perfect substitutes in a first-best world, ambiguous results are obtained in settings with market imperfections and externalities. Since we often consider a second-best world in the subdiscipline of environmental economics, it is not surprising that in the intersection with international economics ambiguous results are to be expected when comparing models with factor mobility on the one hand and trade flows on the other hand. We conjecture that in the area of environmental amenities, and biodiversity in particular, theories that are based solely on trade models are no substitutes for models that include factor mobility (For models with trade only see Smulders et al. (2004) and Polasky et al. (2004)).

Third, in a survey on trade and renewable resources, Bulte and Barbier (2005) recognize that considerations of factor mobility and interjurisdictional competition are absent. Combined models of factor mobility and trade would allow us to study more thoroughly the sometimes-conflicting incentives and challenges that governments face in the era of globalization. Besides caring about biodiversity and environmental amenities, jurisdictions compete to attract economic activity. In the literature on tax competition it is readily understood that factor mobility matters for policymakers. With parts of the tax base becoming increasingly mobile, interjurisdictional competition in for example environmental regulations might lead to situations of a 'race to the bottom'. In addition, other problems with respect to the provision of public goods exist as well. In all these outcomes, fiscal externalities and environmental externalities prevent individual states choosing policies that are optimal from a collective point of view. A socially sub optimal outcome might prevail if governments fail to internalise these externalities.

Thus, there exist both theoretical and empirical reasons to study more closely the relation between factor mobility on the one hand, and biodiversity (conservation) on the other hand. In the next section we will focus first on the interaction between capital mobility, biodiversity and interjurisdictional competition. The question here is whether non-cooperative behaviour can still lead to situations where global biodiversity is protected, under the pressure of attracting capital that forms an important part of the tax base. After that, this paper will use a set of models from the geographical economics literature to answer similar questions related to biodiversity and factor mobility in a spatial setting. Here, the introduction of economics of imperfect competition and transport costs might give rise to completely other outcomes with respect to policymaking and biodiversity conservation.

2. Interjurisdictional Competition, Capital Mobility and Biodiversity

The problem of providing for an optimal amount of public goods in the presence of capital mobility has received much attention in the literature on capital taxation (Mieszkowski & Zodrow, 1986; Wilson, 1999). Biodiversity, like many environmental amenities, is an important example of such a public good. By its very nature though, it has some problems of its own that are not common to other public goods. First and foremost a social planner dealing with biodiversity has to consider budgetary implications, that is, money spent on for example habitat conservation is money that cannot be used to buy private goods. Second and uncommon to other public goods, the pursuit of other goals set by he government might directly interfere with the aim of preserving biodiversity. Here the challenge of attracting capital and fostering economic activity within the borders of its jurisdiction runs opposite to another need, society's wish to protect biodiversity.

Most of the economics literature on biodiversity has focused on problems of economic policy in the context of goods mobility, i.e., models of trade and biodiversity. Polasky et al. (2004) and Smulders et al. (2004) consider the problem of habitat conversion, land-use and biodiversity in standard trade models. Relying on relatively simple connections between the ecological and the economic realm, such as the so-called species-area curve, they relate a region's flow of goods with a region's natural endowments and global biodiversity. Polasky et al. (2004) show that, under the right conditions, specialization of production across countries can also lead to specialization in terms of species.

So far the issue of factor mobility has been neglected. In the era of globalization and for various reasons mentioned in the first chapter, one would expect the mobility of capital to be equally important to the issue of trade, especially giving the footloose aspect of polluting industries. This paper focuses on the issue of biodiversity in the presence of capital mobility. Let us consider some basic challenges that policy makers face in the context of a simple neoclassical framework where trade frictions are absent and production takes place under conditions of perfect competition and constant returns to scale.

A Simple Neoclassical Framework

-Factor Endowments and Factor Mobility

We consider a model of two symmetric regions, North and South. Variables in the South are denoted by an asterix (*). Variables are denoted by capitals whereas small letters are used for functions. Both regions produce a homogenous good under constant returns to scale and perfect competition. Trade is assumed to occur without frictions and is thus costless. We normalize the price P of the aggregate good, $P = 1$. The good is produced using three factors of production: land T_M, labour L and capital K. Most of the time however, we will focus only on land and capital, and implicitly assume labour away. Our setting is somewhat similar to Rauscher (1997) and Wang (1995), who both consider the relation between capital mobility and environmental pollution.

Labour L and land T are immobile factors of production, whereas capital K is mobile across regions. Both regions are endowed with a fixed amount of labour (and land), a stock T (and L) in the North and a stock T^* (and *L*)* in the South. Capital owned (K_0) by Northern residents differs from capital employed (K) in the North. The stock of capital owned by the North and the South is defined as respectively $K_0 = K_M + K_X$ and $K_0^* = K_M^* + K_X^*$, with $K_M \geq 0, K_X \geq 0$ and similar restrictions for Southern variables. Capital owned by the North is either employed at home (K_M) or abroad (K_X).

Capital owners are not mobile but capital itself is, and capital earnings are repatriated to the country of origin. The capital identity for the North and the South are respectively defined as $K = K_M + K_X^*$ and $K^* = K_M^* + K_X$. However, in a two-country model the number of different capital allocations is rather limited. Either North or South is a net capital investor. Thus, defining net investment I as $I = K_X - K_X^*$, we can classify capital employed as the difference between capital owned and net investments:

$$K = K_0 - I \tag{1a}$$

$$K^* = K_0^* + I \tag{1b}$$

In what follows we continue by making use of these definitions for capital.

-Ecology and Biodiversity

The ecological part of the model consists of a concave relation between the amount of land available for habitat purposes T_H and the number of local species *s,* known as the species-area curve:

$$s(T_H),\ s^*(T_H^*),\quad s_T > 0, s_{TT} < 0\ ,\quad s_T^* > 0, s_{TT}^* < 0 \tag{2}$$

At times, we may use a special functional form for the species-area curve which includes a parameter κ for carrying capacity:

$$s = \kappa T_H^{\varphi}\quad ,\quad s^* = \kappa^* T_H^{*\varphi}\ ,\quad 0 \le \varphi < 1 \tag{3}$$

The total endowment of land is fixed and is available for either production or habitat area: $T = T_M + T_H$. Of course, in reality species do not only survive within protected areas and there does not need to be a strict separation between economic activity and species preservation (See Polasky et al. (2005)). We assume that the government owns the property rights of the whole land-area. The government can protect biodiversity in its region by setting a high, (uniform) tax on land, thus avoiding the conversion of habitat area in land that is used in production. As a direct result of this property rights regime, the demand for land T_M^d by firms is a function of the tax rate t_M and the capital stock *K* in a particular country. The collected revenues from land taxation and capital taxation (see next section) are spent on a homogenous public good, $G = t_k K + t_m T_M$.

-Production

Production in each country takes place under conditions of constant returns to scale and perfect competition, $Y = f(K_M - I, L, T_M)$. The first and second-order derivatives take the usual signs with diminishing returns to one input and positive cross-order derivatives:

$$f_i > 0\ ,\ f_{ii} < 0\ ,\ f_{ij} > 0\qquad \forall i, j = K, L, T$$

Producers take factor-prices as given. Government policy consists of either setting the tax-rate t_M on land or determining the quota $q = T_M$. In the first case the stock of land used in production is endogenous T_M. (Since we assume that both countries country are small on world markets, the interest rate r is taken as given). In addition, governments may also set a tax rate on capital, t_K. The profit function of a representative Northern (Southern) producer is given by

$$\pi = Y - (r + t_K)(K_M - I) - wL - t_M T_M \tag{4a),(4b}$$

$$\pi^* = Y^* - (r + t_K{}^*)(K_M{}^* + I) - w^* L^* - t_M{}^* T_M{}^*$$

Produces have to pay a tax for using capital inputs so capital is taxed in the country where it is employed. Under conditions of perfect competition (and no factor market distortions), all factors of production earn their marginal product. Profit maximization by producers thus leads to the following set of first-order conditions:

$$f_K = r + t_K, \quad f_L = w, \qquad f_T = t_M$$

$$f_K{}^* = r + t_K{}^*, \quad f_L{}^* = w^*, \qquad f_T{}^* = t_M{}^*$$

Using these factor-market conditions from the North and the South, we have a system of 6 equations with 4 exogenous variables ($L, L^*, t_M, t_M{}^*, t_K, t_K{}^*$), which can be used to solve for the set of 6 endogenous variables ($r, K, w, w^*, T_M, T_M{}^*$). Note here that the reward to capital is equalized by the assumption of perfect capital mobility $(r = r^*)$, and that the total stock of world capital is fixed ($\overline{K} = K + K^*$) such that we only have to solve for K.

-Consumption

Utility of the representative consumer is linear additive in (capital) goods and the natural 'good', i.e., biodiversity. This quasi-linear function is assumed to be quite general and we restrain from specifying it any further, leaving open the possibility of private and public goods being complementary goods:

$$V(C, G, B) = u(C, G) + \eta B \tag{5}$$

where in the absence of savings we have that consumption equals national income

$$C = wL + rK_0$$
$$= f(K_0 - I, L, T_M) + rI - t_M T_M - t_K(K_0 - I) \quad (6a)$$

and similarly for the South

$$C^* = f(K_0^* + I, L^*, T_M^*) - rI - t_M^* T_M^* - t_K^*(K_0^* + I) \quad (6b)$$

Income of the representative agent consists of net labour income and net capital rents that are earned from capital employed in production at home and abroad. Consumption of public goods equals tax revenues from land and capital employed in production: $G = t_M T_M + t_K(K_0 - I)$. Habitat loss ($dT_M = -dT_H$) negatively affects species numbers at home and abroad and the biodiversity index is increasing in local and foreign species numbers:

$$b(s,s^*) = b(s(T_H), as^*(T_H^*)) \;, \qquad T = T_M + T_H \quad (7a)$$
$$b^*(s,s^*) = b(As(T_H), s^*(T_H^*)) \,, \qquad a, A > 0 \quad (7b)$$
$$b_T = -b_S s_T < 0 \,,\; b_{T*} = -b_{S*} s_{T*} < 0$$

Thus, a decrease in land available for habitat purposes means a decrease in local species numbers, thereby lowering the global biodiversity index. Furthermore, these definitions of biodiversity include the possibility of different valuation of foreign species and local species ($a, A > 0$).

-Balance of Payments (BoP)

Production at home can be used either for private consumption or turned costlessly into a public good provided by the government. One of the countries is an importer of physical capital, whereas the other is an exporter of financial capital. In ergo, the flows of physical and financial capital are two sides of the same coin:

$$Y = C + G + X \quad (8a),(8b)$$
$$Y^* = C^* + G^* - X$$

where North is assumed to be a net exporter of capital X and a net importer of financial capital ($-rI$):

$$X = -rI$$

Trade in capital is a necessary condition in this model without savings to ensure that total demand worldwide equals total supply. This might be relevant in cases where one of the two countries is larger in terms of its capital endowment ($K > K^*$). Assuming otherwise symmetric countries, the capital rich country has a higher national income (due to larger capital rents). The capital-rich North is a net investor in the capital-poor South.

-Welfare

Let us now first consider issues of land policy, biodiversity and welfare in the absence of additional public goods ($G = 0$). Tax revenues on land and capital are redistributed to consumers in a lump-sum fashion such that $C = wL + rK_0 + t_M T_M + t_K (K_0 - I) = Y - X$. Then, welfare in North is determined by utility derived from the country's output minus the factor rewards of net foreign investment plus the benefits from global biodiversity

$$V = u[f(K_0 - I, L, T_M) + rI] + \eta b(s(T - T_M), as^*(T^* - T_M{}^*))$$

Environmental policy or land-policy is determined by the land-tax t_M or a restriction on the use of land that is available for production, $T_M = q \leq T$. A higher tax-rate represents, ceteris pauribus, a smaller conversion of habitat into productive land usage. In this way, a higher tax-rate protects local biodiversity.

The Determinants of Trade in Capital between North and South

In the model specified above we have assumed that trade in capital will equalize its return r in all countries. This assumption implies that barriers to trade are completely absent and that capital markets are fully integrated. Before working out questions with respect to optimal environmental policy in such a context, let us consider what happens when countries initially open up to trade in capital. In autarky, barriers to trade prevent equalization of returns to capital. Assuming (1) an exogenous world-price r for capital and (2) capital scarcity (abundance) in the South (North), $K > K^*$, we have the following condition:

$$f_K(K, L, T_M) - t_K < r < f_K{}^*(K^*, L^*, T_M{}^*) - t_K{}^* \qquad (9)$$

If countries are identical in terms of technology ($f = f^*$) and labour endowments ($L = L^*$), differentials in gross autarky prices of capital are driven by different (1) capital endowments ($K \neq K^*$), (2) different tax rates on capital ($t_K \neq t_K{}^*$) or (3) different land/environmental quotas ($T_M = T_M{}^*$)[1]. In autarky, changes in the marginal product of capital are driven by changes in environmental policy: $df_K = f_{KT} dT_M$ and $df_K{}^* = f_{KT}{}^* dT_M{}^*$. Thus more land raises the productivity of capital, a standard result in this model with cooperative factors of production.

Proposition 1. *A country attracts foreign capital, i.e., it is capital-poor, if its autarky stock of capital is relatively small and/or its land quota is relatively high and/or if the tax on land-use is relatively low.*

As a simple exercise consider what happens to consumption, output, biodiversity in autarky when it changes its land quota $T_M{}^*$. Since biodiversity is an (imperfect) global good the South is affected by this change as well:

$$dC^* = f_T{}^* dT_M{}^*$$

$$db^* = -b_S s_T^* dT_M{}^*$$

$$\frac{dV^*}{dT_M^*} = u_C f_T^* - \eta^* b_S s_T^*$$

$$\frac{dV}{dT_M^*} = -a\eta b_S s_T^* < 0$$

Production and therefore consumption in the South rise due to the extra input of land in production. Biodiversity declines since habitat area is converted into 'productive land'. Welfare unambiguously declines in the North, because global biodiversity decreases. For the North we find ambiguous welfare effects because utility derived from consumption increases, whereas non-use value from biodiversity declines. The overall effect will depend on the marginal rate of substitution between consumption and biodiversity, u_C^* / η^*, among other things.

<u>Optimal Land Policy (Small Country Case)</u>

In the previous section it was shown that the welfare effects for the country imposing a change in land policy are ambiguous. The question then arises what in this simple context

[1] In case the government uses land-taxes instead, the stock of land used in production is a function of the amount of capital employed.

makes for an optimal land policy, i.e., what is the optimal land tax from a welfare perspective? Differentiating utility with respect to land used in production we get

$$\frac{dV^*}{dT_M{}^*} = u_C^* \frac{dC^*}{dT_M^*} + \eta^* \left[b_S \frac{ds^*}{dT_M{}^*} + b_{S*} \frac{ds}{dT_M} \frac{dT_M}{dT_M^*} \right]$$
$$= U_C{}^* f_T{}^* - \eta^* b_S s_T^*$$

where we have assumed for now that a change in land policy of the South has no effect on policy in the North, $dT_M / dT_M{}^* = 0$. Equating $dV^* / dT_M{}^* = 0$ to zero, rewriting and making use of the fact that $t_M{}^* = f_T{}^*$ and the definition of the species-area curve, the optimal tax on land in autarky becomes:

$$t_M^{*AUT} = \frac{\eta^*}{u_C^*} b_{S*} s_T^* = \frac{\eta^*}{u_C^*} \varphi \kappa T_H{}^{\varphi-1} \tag{10}$$

which is the product of the marginal rate of substitution between consumption and biodiversity and the marginal increase in biodiversity from a marginal change in habitat area. The optimal tax rate on land in autarky takes relates the benefits of more land usage in the form of higher consumption against the damage to biodiversity. Thus, there exists an obvious trade-off in setting the tax between more consumption and biodiversity conservation. To determine how changes in the marginal valuation of biodiversity and ecological carrying capacity affect the optimal land policy (tax or quota), we totally differentiate the first-order condition for optimal land policy with respect to $T_M{}^*$, T_M, κ and η:

$$\left(u_C f_{TT}^* + \eta b_{S*S*} s_T^{*2} + \eta b_{S*} s_{TT}^* \right) dT_M{}^* = b_{S*} s_T^* d\eta + \left(\eta b_S s_{T\kappa}^* + \eta b_{S*S*} s_T^{*2} \right) d\kappa$$

The following comparative statics results can be derived from this equation:

$$\frac{dT_M^*}{d\eta} = \frac{b_{S*} s_T^*}{u_C f_{TT}{}^* + \eta b_{S*S*} s_T^{*2} + \eta b_{S*} s^*{}_{TT}} < 0 \tag{11a}$$

$$\frac{dT_M{}^*}{d\kappa} = \frac{\eta (b_S s_{T\kappa}^* + b_{S*S*} s_T^{*2})}{u_C f_{TT}^* + \eta b_{S*S*} s_T^{*2} + \eta b_{S*} s_{TT}^*} \tag{11b}$$

Countries with a relatively large marginal valuation of biodiversity have a greater incentive to implement a more strict land policy in the from of a high tax or quota. Somewhat more complicated is the effect of a country's carrying capacity on its environmental policy. There are two conflicting forces. First, there is 'positive' effect from carrying capacity on the stock of land used in production. Since the biodiversity index is assumed to be concave, $b_{S*S*} < 0$, the positive effects of increases in carrying capacity eventually 'die out'. Thus, there comes a point where greater carrying capacity needs to be 'traded' for more productive land use (income effect). Second, there is a negative effect from an increase in carrying capacity. A higher carrying capacity increases the returns from 'existing' habitat area ($s^*{}_{T\kappa} > 0$), inducing the country to even increase the stock of land devoted to habitat. We can summarize this in the following proposition.

Proposition 2. *If a country attracts foreign direct investment for other reasons than those concerning endowments, it does so because of relative lax environmental policy. In turn, lax environmental policy itself can be rooted in relatively small preferences for biodiversity and/or a relatively large carrying capacity of its ecosystem. However, a relatively large carrying capacity may actually lead to a more stringent land policy if the biodiversity index is not very concave and/or the existing habitat is relatively large.*

From this we see that a country may chose to set an tax rate on land that induces specialization in nature if the 'substitution effect' of carrying capacity is larger than the 'income effect' from carrying capacity.

<u>Welfare Effects from Increased Mobility of Capital</u>

The welfare effects from increased openness or integration of capital markets depend partially on the environmental policy or land policy that is in place. In the previous section we showed that land policy that is either to protective or too lax could cause sub-optimal outcomes in the face of increased openness. Welfare can even decline if habitat area is excessively converted into productive land area, causing extinction of a large number of local species. If a strict policy, that is, a quota is in place than can be enforced the welfare effects are unambiguously positive:

$$\frac{dV^*}{dI} = u_C^* \frac{dC^*}{dI} = u_C^* \left(f_K^* - r\right) > 0 \quad \Leftrightarrow f_K^* > r$$

A necessary condition for a country with a strict land policy to benefit from increased capital inflows is capital scarcity. A more interesting and probably more realistic case is that of a land tax. Now, the amount of land is not fixed and the inflow of capital increases the productivity of land, which in turn increases the demand for land. In effect, habitat area is converted into land area for production (agriculture, manufacturing etc.) leading to

$$\frac{dV^*}{dI} = u_C(f_K{}^* - r + f_T{}^* \frac{dT_M^*}{dI}) - \eta^*(Ab_S s_T \frac{dT_M}{dI} - b_{S*}s^*{}_T \frac{dT_M{}^*}{dI}) \qquad (12)$$

showing that under a tax-policy the total effect on welfare depends on factor market interactions. Differentiation of the factor market condition for land in North and South we get $dT_M{}^* / dI = -f_{TK}^* / f_{TT}{}^* > 0$ and $dT_M / dI = f_{TK} / f_{TT} < 0$. Substitution of these derivatives into (eq.?) leads again to ambiguous welfare effects in the South under conditions of increased capital mobility.

Proposition 3. *Under a tax-on-land regime increased openness to foreign direct investment leads to an increase in land as a factor of production, an increase in consumption and a decrease (increase) in local (foreign) biodiversity. If the tax on land is relatively small and/or foreign biodiversity is not highly valued (small A) and/or the foreign species-area curve is very concave, then welfare in the capital-poor country may decline.*

Note that with an optimal tax in place, $t_M{}^* = \frac{\eta^*}{u_C^*} n_{S*}s_T^*$, welfare is always increased since now the price of land is set in such a way that at the margin an optimal trade-off between consumption and habitat loss is assured.

Again, in the absence of optimal policies trade in capital is not guaranteed to increase welfare in the capital-poor region. The derivation of the optimal tax was relatively easy, but in practice it requires a high degree of knowledge of the world's ecosystems and the marginal valuation of global biodiversity and consumption. In view of these somewhat unrealistic information requirements one might ask how a country should adjust its policy in response to increased openness since initially an optimal policy might not be in place. A reduction in barriers to capital mobility might lead to economic and environmental changes that, in the long-run, provide for more information on the structure of ecological and economic systems. In time, a country opening its borders might adjust its policy in response to capital inflows. To determine the South's (North's) optimal response to a change in its capital stock recall the first-order conditions for optimal land policy:

$$\frac{dV}{dT_M} = u_C \frac{dC}{dT_M} - \eta \frac{db}{dT_M} = 0, \quad \frac{dV^*}{dT_M{}^*} = u_C^* \frac{dC^*}{dT_M{}^*} - \eta^* \frac{db^*}{dT_M{}^*} = 0, \quad \text{(13a),(13b)}$$

Totally differentiate these first-order conditions for optimal land-policy with respect to T_M, $T_M{}^*$ and I to obtain the following 'reaction' functions for the North and South:

$$\frac{dT_M{}^*}{dI} = -\frac{u_{CC} f_T{}^* (f_K{}^* - r) + u_C{}^* f_{TK}^* + \eta b_{S*S} s_T^* s_T \dfrac{dT_M}{dI}}{u_C{}^* f_{TT}^* + u_{CC}^* f_T^{*2} + \eta (b_S s_{TT}^* + b_{S*S*} s_T^{*2})} \quad \text{(14a)}$$

$$\frac{dT_M}{dI} = \frac{u_{CC} f_T (f_K - r) + u_C f_{TK} - \eta b_{SS*} s_T^* s_T \dfrac{dT_M{}^*}{dI}}{u_C f_{TT} + u_{CC} f_T^2 + \eta (b_S s_{TT} + b_{SS} s_T^2)} \quad \text{(14b)}$$

these derivatives implicitly contain the reaction functions $R(T_M{}^*)$ and $R^*(T_M)$ for both countries under the small country assumption where no one is able to influence the reward to capital. If we neglect for a moment the other country's reaction to an increase in capital mobility[2], then we observe that for the North the optimal response is to reduce its land quota, that is, tighten its land policy ($dT_M / dI < 0$). This means that the initial positive (negative) effect from capital outflow on local biodiversity (production) is strengthened furthermore. For the South, the optimal response is ambiguous and will depend on the direct ($u_C^* f_{TK}^*$) and indirect effects ($u_{CC} f_T{}^* (f_K{}^* - r)$) of extra capital on the productivity of land. The indirect effect implies that the use of more land in production becomes less useful due to diminishing returns to consumption in utility.

In case countries do recognize the impact of their land policy on the other region the sign of this strategic effect is determined by the sign of B_{S*S}, the cross partial of the global biodiversity index. This derivative considers the effect from an increase in Northern species numbers on the marginal increase in biodiversity from Southern species numbers, and vice versa. We consider two extremes (See Polasky et al.(2004) and Barbier&Rauscher (2007)):

[2] These 'strategic effects' are conjectural variations, implying that each country believes that its choice of land policy will affect the policy selected by the other country. By now, this method of introducing dynamics into a static model is said by some to be theoretically flawed. See Rauscher (1997) and Tirole (1988) on this issue. Here, we only use it to show that these variations become less important when one introduces a high level of redundancy with respect to biodiversity.

- High Species Endemism, $b = s + s^*$

Ecosystems in the North and South may be completely different and give home to a vast amount of species that are all very country specific. In this sense habitat destruction, which is the result of capital-led growth in industrial or agricultural activity, may lead to the extinction of a number of species that are unique to the booming region and for which no 'substitute' exists in other regions. High endemism lowers the probability that an increase in local species numbers make additional specie in the other region redundant. Thus, the cross partial is negative but small in terms of absolute value. For the extreme case of high species endemism, the partial is exactly zero, $b_{S*S} = b_{SS*} = 0$.

- High Redundancy, $b = \max\{s, s^*\}$

At the other side of the spectrum we may find a situation of high redundancy. Both regions may have very similar ecosystems and may contain a set of local species that is found in the other region as well. Taken to the extreme, global biodiversity is just the maximum of species numbers' living in one of the two regions. Habitat destruction in one region does not necessarily lead to global extinction of some species. Here we find that the cross partial is negative and large in absolute value. Under high redundancy an increase in local habitat area and species numbers most probably makes an additional specie in the other region obsolete, $b_{S*S} = b_{SS*} < 0$.

Making use of these various forms of the biodiversity index, we can formulate the following propositions.

Proposition 4. *Without taking into account the other region's change in land policy, a resource-rich country should reduce its land quota in response to increased openness. For the country that is relatively poor in capital the optimal response in land-policy is ambiguous.*

Proposition 5. *If countries act strategically, that is, acknowledging conjectural variations, then the specifics of the global biodiversity index determine the optimal response. Under strict species endemism, the aforementioned strategic effect completely disappears. In case of redundancy, the optimal response of the capital-poor country to a change in the other's regions land policy is negative. For the resource-rich country the optimal response is negative as well.*

This last proposition can be made more clear by analysing the following optimal responses from North (South) to changes in land policy in the South (North) that originate in changes of net foreign direct investment:

$$\frac{dT_M^* / dI}{dT_M / dI} = \frac{-\eta b_{S*S} s_T^* s_T}{u_C^* f_{TT}^* + u_{CC}^* f_T^{*2} + \eta(b_S s_{TT}^* + b_{S*S*} s_T^{*2})} \tag{15a}$$

$$\frac{dT_M / dI}{dT_M^* / dI} = \frac{-\eta b_{SS*} s_T^* s_T}{u_C F_{TT} + u_{CC} f_T^2 + \eta(b_S s_{TT} + b_{SS} s_T^2)} \tag{15b}$$

In response to the North's initial reduction in its land quota, the South has an extra incentive so loosen its land policy even further. First, there is the initial reaction to the inflow of capital inducing South to increase its quota op to the point where the marginal loss of local biodiversity equals the marginal gain in utility from consumption. Second, there is the increase in habitat area in the North that induces the South to loosen its land policy further. This positive externality lies at the root of the further conversion of habitat area in the South; the social gains of habitat protection in the North are larger than the private gains, and the South is willing to 'substitute' some of these gains for extra consumption. The North has a similar incentive, knowing that further habitat destruction will increase the return to its investment and increases habitat area at home to make up for the foreign loses in biodiversity.

It remains to be determined though why the strategic effect becomes unimportant or even disappears completely under high species endemism. One reason might be that the initial increase in habitat area in the North is now a pure gain: there is no overlap in some of the species won with existing species in the South. As a result, the South has no incentive to decrease its habitat area further to get rid of 'redundant' species. Thus, high levels of redundancy increase the strength of the indirect effect and essentially provide a drive towards specialization: one region as a large reserve site, the other dedicated to production (For analysis of this issue in a NEG framework, see Barbier & Rauscher, 2007).

<u>Interjurisdictional Competition (Cooperative Solution)</u>

Up to this point we have assumed that North is relatively well endowed in capital whereas South is relatively abundant in nature, i.e., land. In practice, capital mobility and foreign direct investment might be even more important in the context of similar countries. Likewise, habitat conservation is not necessarily an issue that only comes to play in trade relations between the developed and developing countries. Next we consider symmetric countries. This setting is one that is often chosen in the literature on interjurisdictional competition (tax competition). By starting from full symmetry in terms of factor endowments, ex ante countries might fear the outflow of capital but ex post all countries are left with identical amounts, which is the result of the symmetric Nash equilibrium in tax rates.

Here we will investigate something similar, but this time we will make use of two tax rates, one for land and one for capital. Since both policy instruments are characterized by negative side-effects (outflow of capital, habitat destruction) it is interesting to determine the non-cooperative equilibrium. First, we determine the optimal solution. We maximize the sum of welfare with respect to the allocation of land and investment, subject to a set of consumption and biodiversity conditions:

$$\underset{I,T_M,T_M^*}{\text{Max}} \quad u(C)+u(C^*)+\eta b+\eta^* b^*$$

subject to

$$\begin{aligned}
&b = b(s(T-T_M), As^*(T^*-T_M^*)) \\
&b^* = b(as(T-T_M), s^*(T-T_M^*)) \\
&C = f(K_0-I, L, T_M)+f_K^* I \\
&C^* = f(K_0^*+I, L^*, T_M{}^*)-f_K I \\
&f_K(K_0^*+I, L^*, T_M^*) = f_K(K_0-I, L, T_M) \\
&I \in [-K_0^*, K_0]
\end{aligned}$$

which after substitution of all conditions into the objective function becomes an unconstrained maximization problem with respect to three variables. Note that there is no tax on capital. We get the following set of first-order conditions:

$$\begin{aligned}
&u_C = u_C^* \\
&u_C[f_T + f_{KT} I] = (\eta + a\eta^*) b_S s_T \\
&u_C^*[f_T^* - f_{KT}^* I] = (\eta^* + A\eta) b_S^* s_T^*
\end{aligned} \qquad \text{(16a),(16b),(16c)}$$

net investment should be allocated across regions such that the marginal utility from consumption in each region is equalized. Similarly, the land quota in the North should be set such that the marginal utility from land use equalizes the global marginal benefit from an increase in biodiversity. This holds for the South as well. Thus, in the social optimum both countries recognize the positive spillovers derived from local biodiversity for the other region.

Rewriting the FOC's furthermore gives the relation between the productivity of land and the marginal utility of habitat conservation,

$$\frac{f_T + f_{KT} I}{f_T^* - f_{KT}^* I} = \frac{\eta + a\eta^*}{\eta^* + A\eta}$$

where we have assumed that $b_S s_T = b_S^* s_T^*$. So if benefits from global biodiversity are derived equally from local and foreign species numbers and if local and foreign ecosystems are equally robust (identical carrying capacities), then in the social optimum the ratio of marginal productivity of land in the North and the South is equal to the ratio of preferences for local and foreign biodiversity in the North and the South. Finally, we can derive the optimal taxes in the North and South which are consistent with the social optimum by rewriting the FOC's:

$$f_T = t_M = \frac{(\eta + a\eta^*) b_s s_T}{u_C} - f_{KT} I \tag{17a}$$

$$f_T = t_M^* = \frac{(\eta^* + A\eta) b_s^* s_T^*}{u_C^*} + f_{KT}^* I \tag{17b}$$

comparing these taxes with those from autarky, $t_M^{AUT} = \frac{\eta}{u_C} b_s s_T$, leads us to conclude that the socially optimal taxes are unambiguously higher than those in autarky if countries are fully symmetric (net investment $I = 0$).

Proposition 6. *In case of identical countries, the socially optimal taxes on land are unambiguously higher than those in autarky. Positive externalities from habitat protection are fully internalised and global biodiversity is maximized. In the optimum, consumption may be lower than in autarky, if factor allocation effects do not outweigh the smaller supply of land for production, which is the result of high taxes.*

The question remains if a possibility exists in which global biodiversity is higher in autarky than under the social optimum? Or, when are the expected gains very small? Using the equations for the tax rate in autarky and in the social optimum we can derive the following condition:

$$f_{KT} I > \frac{a\eta^* b_s s_T}{u_C} \tag{18}$$

This condition states that the increase in total returns to investment from a marginal increase in land should be larger than the ratio of marginal valuation of foreign biodiversity and the marginal utility from consumption. However this does not necessarily mean that global biodiversity declines, since one would still have to determine the tax in the South and the total amount of net investment. Nevertheless, the fact remains that if (1) much is to be gained from factor reallocation ,i.e., countries are not very similar and/or (2) countries do not care about foreign biodiversity (a, A close to zero) then it is possible that the optimum tax is higher in the social optimum and the gains for foreign biodiversity from cooperation may be small.

Interjurisdictional Competition (Non-Cooperative Solution)

Now that we have determined the cooperative solution for land policy it could be interesting to evaluate the non-cooperative solution as well. Up to this point our model has assumed that both regions take the world interest rate as given. This makes sense if the countries are small and when we are interested in unilateral changes in policy. If countries are of significant importance in world markets, then their actions might alter the remuneration to capital. So to be able to consider capital market interactions, the following 'location condition' of capital is assumed:

$$f_K(K_0^* + I, L^*, T_M^*) - t_K^* = f_K(K_0 - I, L, T_M) - t_K \qquad (19)$$

Both countries are able to influence the location of capital by either setting an attractive tax on capital or a loose policy with respect to the land quota or land tax. In what follows next we first determine the non-cooperative solution under the assumptions that both countries take the other's tax policies as given (Nash) and can only change the tax on land. Thus, we consider a non-cooperative game with one instrument. The necessary first-order conditions are:

$$\frac{\partial V}{\partial T_M} = u_C \frac{dC}{dT_M} + \eta \frac{db}{dT_M} = 0 \quad \Leftrightarrow \frac{u_C}{\eta} = -\frac{db/dT_M}{dC/dT_M}$$

$$\frac{\partial V^*}{\partial T_M^*} = u_C^* \frac{dC^*}{dT_M^*} + \eta^* \frac{db^*}{dT_M^*} = 0 \quad \Leftrightarrow \frac{u_C}{\eta^*} = -\frac{db/dT_M^*}{dC/dT_M^*}$$

where the various derivatives can be derived from totally differentiating the consumption and biodiversity equations:

$$\frac{dC^*}{dT_M^*} = (f_T^* - f_{KT}^* I) + (t_K^* - f_{KK}^* I)\frac{dI}{dT_M^*}$$

$$\frac{dC}{dT_M} = (f_T + f_{KT} I) - (t_K + f_{KK} I)\frac{dI}{dT_M}$$

$$C = f(K_0 - I, L, T_M) + f_K^* I$$

$$\frac{db^*}{T_M^*} = -b_S s_T^*$$

$$\frac{db}{dT_M} = -b_S s_T$$

$$\frac{dI}{dT_M^*} = \frac{-f_{KT}^*}{f_{KK}^* + f_{KK}} \quad , \quad \frac{dI}{dT_M} = \frac{f_{KT}}{f_{KK}^* + f_{KK}}$$

Substitution of comparative statics into the FOC for optimal land policy gives:

$$u_C[(f_T^* - f_{KT}^* I) + (f_{KK}^* I - t_K^*)\frac{f_{KT}^*}{f_{KK}^* + f_{KK}}] = \eta^* b_S s_T^*$$

$$u_C[(f_T + f_{KT} I) - (f_{KK} I + t_K)\frac{f_{KT}}{f_{KK}^* + f_{KK}}] = \eta b_S s_T$$

rewriting yields

$$t_M^{*NC} = f_T^* = \frac{(f_{KK} I + t_K^*) f_{KT}^*}{f_{KK}^* + f_{KK}} + \frac{\eta^* b_S s_T^*}{u_C} \tag{20a}$$

$$t_M^{NC} = f_T = \frac{(t_K - f_{KK}^* I) f_{KT}}{f_{KK}^* + f_{KK}} + \frac{\eta b_S s_T}{u_C} \tag{20b}$$

whereas

$$t_M^{*C} = \frac{(\eta^* + A\eta) b_s^* s_T^*}{u_C^*} + \frac{f_{KT}^* I (f_{KK} + f_{KK}^*)}{f_{KK} + f_{KK}^*} \tag{21a}$$

$$= t_M^{*NC} + \frac{A\eta b_s s_T^*}{u_C} + \frac{f_{KT}^* f_{KK}^* I}{f_{KK} + f_{KK}^*} > t_M^{*NC}$$

and

$$t_M^C = \frac{(\eta + a\eta^*)b_s s_T}{u_C} - \frac{f_{KT} I (f_{KK} + f_{KK}^*)}{f_{KK} + f_{KK}^*} \tag{21b}$$

$$= t_M^{NC} + \frac{a\eta^* b_s s_T}{u_C} - \frac{f_{KT} f_{KK} I}{f_{KK} + f_{KK}^*}$$

where we have set the tax on capital in the non-cooperative solution equal to zero ($t_K = t_K^* = 0$). As shown, the cooperative tax is unambiguously higher than the non-cooperative tax in the case of symmetric countries ($I = 0$), that is, $t_M^C > t_M^{NC}$ and $t_M^{*C} > t_M^{*NC}$.

Proposition 7. *Cooperation in land policy is beneficial for global biodiversity in case of countries that are symmetric in terms of endowments and preferences. If differences become larger, net investment in the South increases, and the socially optimal tax in the South (North) diverges (converges) further from the non-cooperative solution. In the end, the effects on global biodiversity may be ambiguous.*

With tax competition, countries do not internalise the positive externalities of a higher tax on land. Local habitat protection benefits the other country as well since both countries value global biodiversity by definition. Only in case of cooperation does the optimal tax 'control' for this externality. However, if countries are asymmetric for any of the reasons mentioned in proposition 1 (preferences, endowments), then there is an extra externality involved. This externality represents the beneficial effects of a better factor allocation for both countries. For the Southern region, this implies that the gap between the non-cooperative and cooperative solutions becomes greater: large net investments in the South induce increasingly larger taxes in the South in the social optimum. The Northern region on the other features an optimal tax that becomes increasingly closer to the non-cooperative tax when net investment increases. The total effect on biodiversity of moving from autarky to capital market integration is ambiguous.

Conclusion

We have analysed the issue of biodiversity and land policy in a simple two-country general equilibrium model with trade in capital. A capital-poor country attracting investment might suffer a loss in welfare, unless an optimal land quota or tax is in place. Local biodiversity declines unless a quota is in place, but global biodiversity might increase. A country's optimal response with respect to land policy when openness is increased is determined partially by biodiversity specifics. In the case of full species endemism the conjectural variation effect , which controls for the other country's reaction to changes in land policy, disappears completely. From this one might infer that strategic interaction of land policy is more important for countries which are similar in terms of ecosystems.

In the social optimum the optimal taxes on land in the North and the South are shown to internalise a factor allocation externality and a positive externality from local biodiversity. In a non-cooperative game these externalities are not internalised and as a result countries set a sub-optimal low tax: habitat protection is sub-optimal for countries that are similar in terms of endowments and preferences. If countries differ substantially however, the non-cooperative tax in the North converges to the cooperative tax, and the difference between cooperation and competition for global biodiversity diminishes.

In this paper we have build a rather simple model with a simple connection between economics and nature. Issues such as irreversibility or joint economic and biological activity on a landscape play no role. Another area for future improvement is the rather static nature of the model. Introducing a truly dynamic element and connecting biodiversity to this element, i.e., species numbers related to a forest, might give the model a more realistic flavour and embed it more within the literature on trade and renewable resources. We leave that as a question for future research.

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