Natural Resources, Investment and Long-Term Income

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Summary

We study the negative correlation between natural resource-abundance and long-term income focusing on the savings-investment channel. We first present empirical evidence on this channel and then develop an OverLapping-Generations (OLG) model to study the issue. In this model, savings adjust downwards to income from natural resources, and investment in capital contributes to knowledge creation, a feature based on endogenous growth theory. We analyze the link from resource income future income through savings and investment. Natural resources have two counteracting effects on income. In the short term, resource wealth augments income, but in the long-term, it decreases income through a crowding-out effect on capital and knowledge. We discuss different scenarios under which the resource curse is most likely to take place.

Keywords: Natural resources, Growth, Investment, OLG models

JEL Classification: E22, O13

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1. INTRODUCTION

Over the last three decades a negative correlation between resource-abundance and economic growth has been observed as a general pattern (Gylfason 2000, 2001a, 2001b, Leite and Weidmann 1999, Papyrakis and Gerlagh 2004, Rodriquez and Sachs 1999, Sachs and Warner 1995, 1997, 1999a, 1999b, 2001). Countries rich in minerals, oil, fish banks and agriculture tend to grow at slower pace compared to resource-scarce countries. Despite the potential beneficial role that resource abundance may play in fostering economic development, experience over the last decades reveals that natural resources seem to frustrate rather than promote economic growth. The OPEC countries, rich in natural wealth, experienced on average a negative rate of GDP per capita growth over the last four decades (Gylfason 2001b). Alaska, the richest U.S. state in natural resources with vast fish banks and oil reserves, was the only U.S. state experiencing a negative income growth rate the last two decades. In contrast, resource-scarcity was no obstacle to economic development for countries such as Switzerland, Singapore, Japan and South Korea that surged ahead during the last decades.

Figure 1 illustrates the relation between natural resources and income with a scatter plot of 84 countries. Growth of GDP per capita between 1975-96, adjusted for initial income, has been set out against resource-abundance as measured by the share of natural capital in total capital. The figure also presents the estimated regression line and the adjusted-R^2. Data on GDP per capita and natural capital are provided by the 6.1 Penn World Tables of the Center for International Comparisons at the University of Pennsylvania (CIC), (2002) and the World Bank (1997) respectively.[3] As shown in the figure, there is a significant negative statistical association between the two variables. An increase in the natural capital share by 10% results in a decrease of annual

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[3] Although earlier observations on natural capital would be preferable in order to avoid endogeneity, 1994 is the only year for which data on natural capital are available from the World Bank Database. Gylfason (2001) argues that the share of natural capital is still a good proxy for resource-abundance, since resource-abundance is not a variable varying substantially over time. Indeed, the results in all tables can be reproduced by using alternative measures of resource abundance, such as the Sachs and Warner (2002) measure of the share of primary exports in GDP in 1971 or the share of agricultural production in GDP for the same year.

growth by about 0.8%. The regression line shows that on average, a natural capital share of around 12% implies economic stagnation in terms of growth.

In the literature, the resource curse is often associated with a crowding-out logic (Sachs and Warner 2001). Natural resources are not harmful to growth per se but tend to crowd-out growth-promoting activities. We mention three channels. First, natural resources reduce institutional quality, as they induce rent-seeking behaviour and corruption. Gains from bribing officials and from forming politically powerful interest groups to obtain privileged access to the resource-rents rise (Krueger 1974, Leite and Weidmann 1999, Gray and Kaufmann 1998, Torvik 2002). Second, resource-abundance tends to deteriorate the terms andreduce the degree of openness. A major cause is an overvaluation of the local currency and the resulted loss of competitiveness, as well as the imposition of tariffs and quotas that are supposed to protect domestic producers (Auty 1994, Torvik 2001, Sachs and Warner 1995). Third, natural resources reduce the investment in high-quality education and skilled-labour. Resource booms are often followed by a contraction of the manufacturing sector, for which human capital is an important production factor and the demand and returns to educational quality successively decline as well (Gylfason 2001a, Sachs and Warner 1999b).

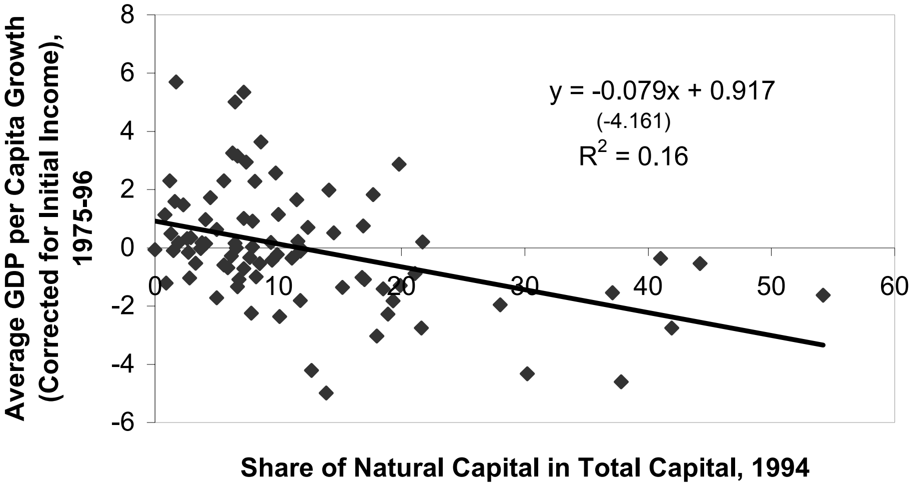

Figure 1. *Resource-Abundance and Economic Growth*

This paper is concerned with a fourth channel, namely the role of resource-abundance in crowding-out investments. Papyrakis and Gerlagh (2004, Table 4) argue that the investment channel is probably the most important channel in terms of its contribution to the resource curse. There are various mechanisms that can explain the crowding out of investments. World prices for primary commodities tend to be very volatile and this creates uncertainty for investors in resource-abundant economies (Sachs and Warner 1999b). Additionally, resource booms reallocate factors of production from the manufacturing sector to the primary sector. Since it is often the manufacturing sector that is characterized by increasing returns to scale and positive externalities, this shift in production factors reduces the productivity and profitability of investments (Sachs and Warner 1995, 1999a, Gillis *et al.*1996). As another mechanism, Atkinson and Hamilton (2003) show that governments often spend resource rents on public consumption. The few countries that use resource rents for public investments are those that have avoided the resource curse.

Our analysis combines the insights from the various studies mentioned above. We develop an overlapping-generations model to demonstrate how public spending of resource rents decreases national savings. Furthermore, we show that the decrease in the level of investment is exacerbated when, in turn, labor productivity (through technology or education) depends on the level of investment. The decline in income may more than offset the increase in resource revenues, when we take account of the decrease in savings and the responsiveness of technology to investment.

The paper is organized as follows. Section 2 provides empirical evidence to the negative correlation between alternative measures of resource-abundance and savings, investment, and growth. Section 3 presents the OLG model, and explains how resource-abundance crowds-out savings and investment. Section 4 compares the steady states of the OLG model under different parameter scenarios and provides numerical examples of the resource curse hypothesis under alternative assumptions. Section 5 concludes.

2. EMPIRICAL EVIDENCE: RESOURCE-ABUNDANCE, SAVINGS, INVESTMENT AND GROWTH

In this section we graphically depict correlations between several measures of resource-abundance, savings, investment and growth in order to establish empirically the relations that we study in our theoretical analysis of section 3**.** Data on GDP per capita, investment and savings are provided by the 6.1 Penn World Tables of the Center of International Comparisons at the University of Pennsylvania (CIC), (2003). Data on natural capital and agricultural production are provided by the World Bank (1997) and the Sachs and Warner dataset at the Center for International Development at Harvard University (CID), (2002). The causal chain linking resource-abundance to economic performance we study here operates in three steps: first, resource-abundance discourages national savings, second, lower national savings frustrate investment, and third, lower investment slows down economic growth.

Figures 2 and 3 depict a scatter plot of the share of net national savings in GDP set out against two measures of resource abundance. Both scatter plots indicate that resource-abundance tends to significantly decrease the level of savings in the economy.[4] Figure 2 points out a significantly negative correlation between national savings and the share of agriculture in GDP. Agricultural production can explain by itself almost half of the overall variation in savings across the sample of 107 countries. It is striking to see that negative net national savings throughout the period 1975-96 characterizes the majority of countries with a share of agricultural production above 35%. Many resource-abundant countries seem to suffer from over-debt problems. Sao Tome and Principe, where agriculture makes up about a quarter of the total economy, has the lowest net savings rate of the sample. Over the last two decades, it had an average current account deficit ratio of almost –40%, and a debt value as a percentage of GDP close to 400% at the end of the 90's.

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[4] The correlation is significant at the 1% level in both scatterplots.

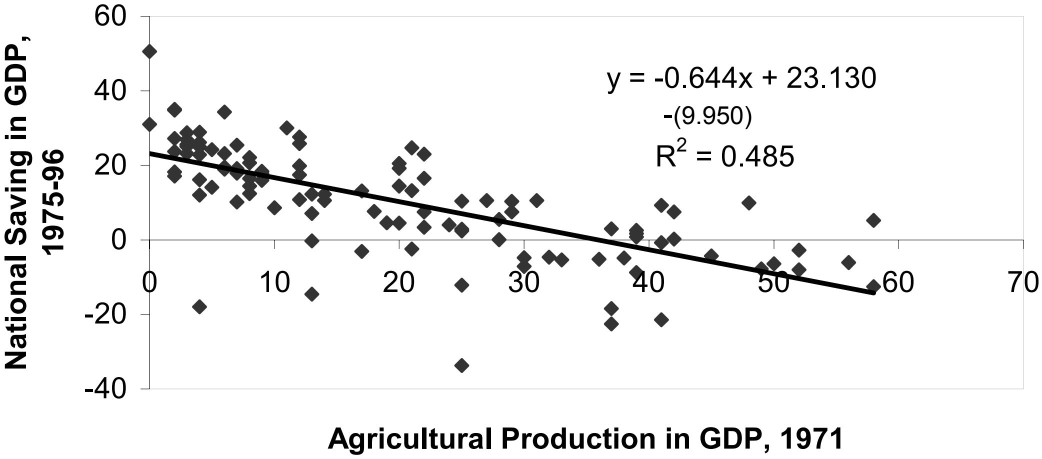

Figure 2. *Savings and Agriculture*

Figure 3 shows a similar scatter plot for 84 countries taking the share of natural capital in total wealth as a proxy of resource-abundance. The results are equally revealing and the negative correlation is highly significant at the 1% level. We notice also that the coefficients for natural wealth are of similar magnitude in both regressions.

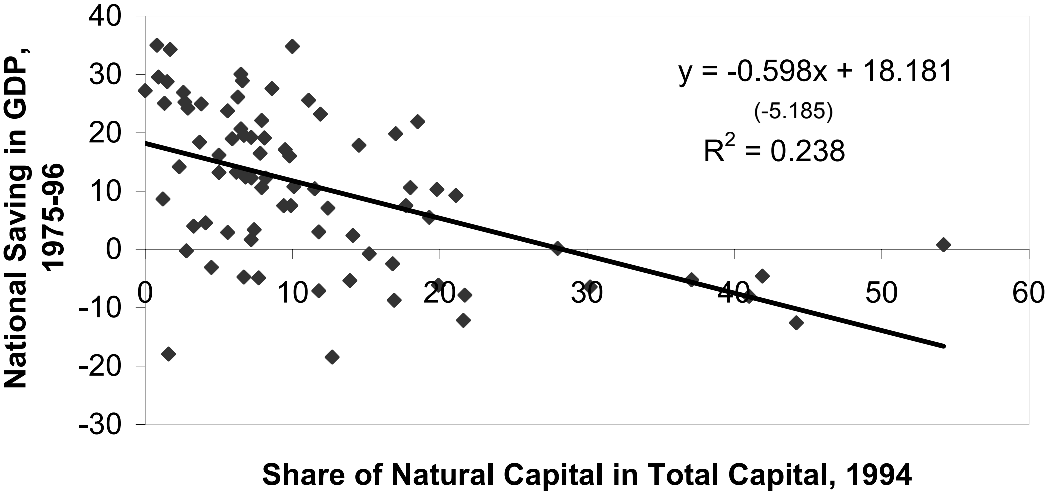

Figure 3. *Savings and Natural Capital*

As a second step, we investigate whether our data support the assumed positive correlation between savings and investment. Figure 4 depicts, for a cross-sectional sample of 113 countries, the relation between net national savings and domestic investment for the 1975-96 period. Indeed, we find a highly significant and positive correlation between the two variables. The correspondence is less than one-to-one, which is not surprising, since foreign investment can compensate for a lack of national savings when an economy offers attractive opportunities. Nonetheless, it is a resource-scarce country, Singapore, which has an agricultural product close to zero, with the highest savings and investment ratio: above 44%.

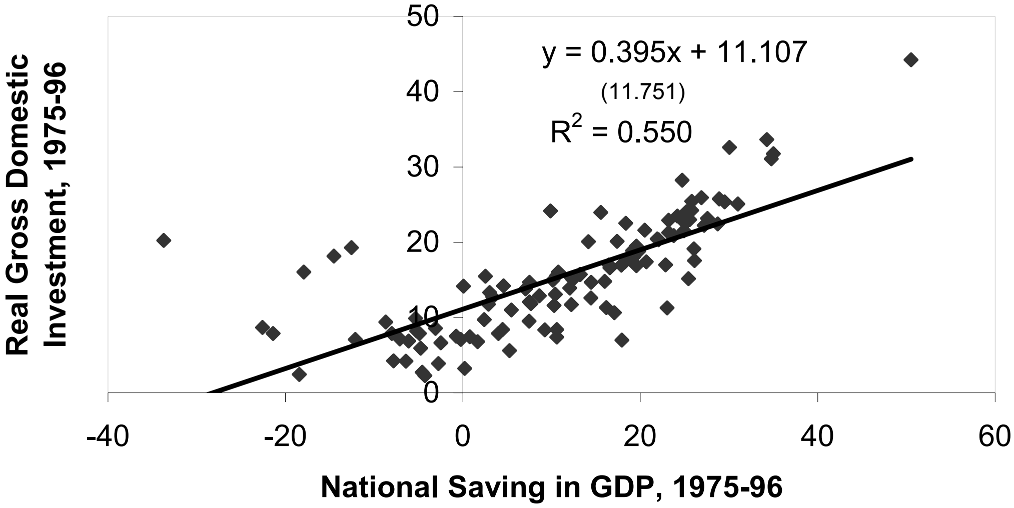

Figure 4. *Investment and Savings*

The sample used for Figure 4 is fairly diverse; the relation between national savings and domestic investments becomes stronger when we focus on a more homogeneous group of countries, such as a sample of 27 OECD countries. Figure 5 is restricted to this group, and shows that savings can explain almost all variation in investment levels, and the estimated coefficient almost doubles. In OECD countries, most of the national savings is converted into investment.

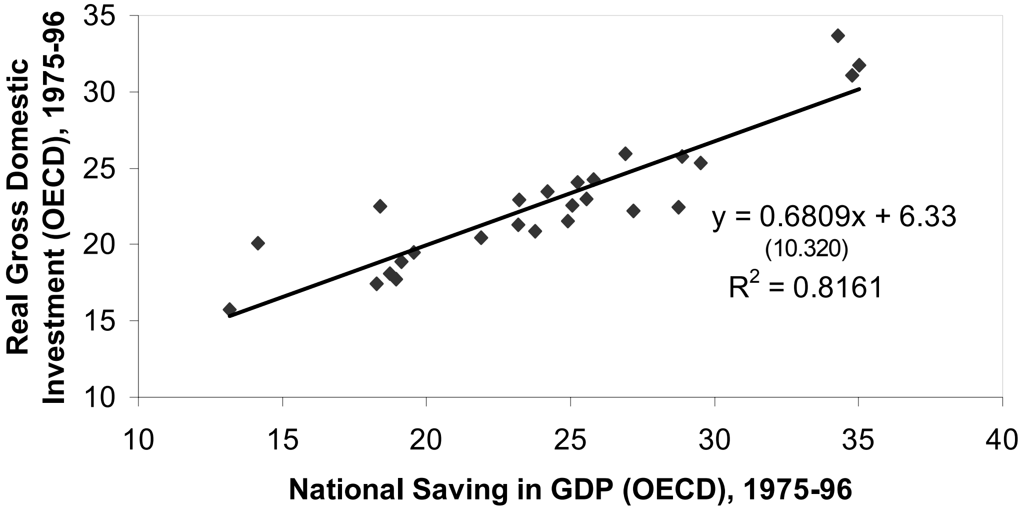

Figure 5. *Investment and Savings (OECD)*

Finally, Figure 6 shows the significant and positive correlation between economic growth and investment for a cross-sectional sample of 113 countries. We corrected economic growth for initial income, so that our data reflect the economic growth rate explained by other factors than convergence. A 10% increase in the investment ratio increases on average the annual economic growth rate by almost 1.4%. To summarize, our data reveal three major relationships: first, resource-abundance varies inversely with savings, second, investment is positively correlated to savings, and third, economic growth depends positively on investment. Together, there seems to be ample statistical evidence that investment is a significant crowding-out channel through which resource-abundance frustrates economic growth.

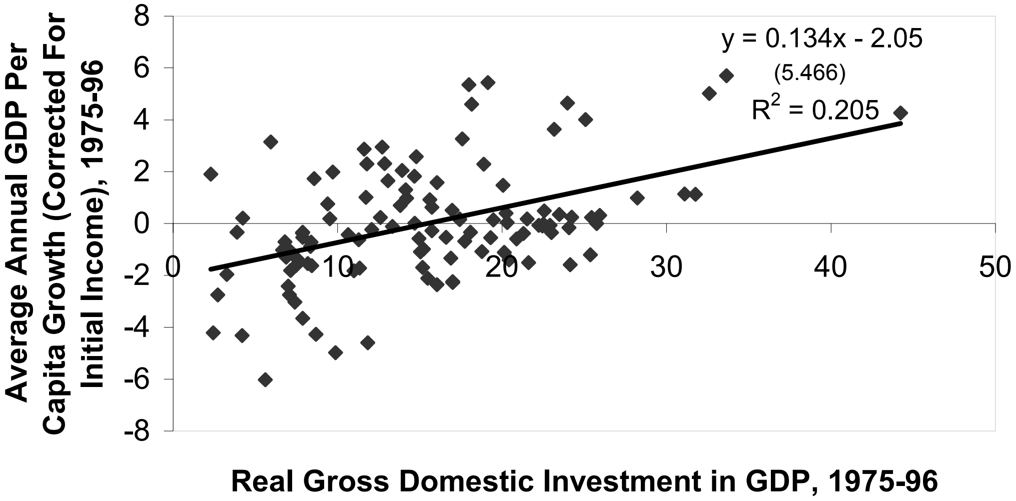

Figure 6. *Investment and Growth*

3. MODEL SPECIFICATION

The model employed in this paper extends the usual OLG models by containing reference to a primary sector that provides the consumers with pure resource rents, and by including a technology spill-over from the capital stock to a labour productivity variable. The model distinguishes discrete time steps, $t \in \mathbf{T}=\{1,\ldots,\infty\}$.

A. Demography

We assume that in every interval two generations live, an old and a young generation. At the beginning of a period, a new generation enters the model and the previously old generation leaves the model, so that there is a turnover in population. Each generation is indexed by their date of entering the model *t* (as a subscript). Each individual's lifetime consists of two periods. The generations work when young and live from savings when old. We thus only examine the adult part of the life-cycle, i.e. from the age of 20 onwards, and each interval consists of a period of about 30 years. Population grows exponentially at a rate n:

$$L_t = (1+\mathrm{n})L_{t-1} \tag{1}$$

where L_t stands for the population size. Each individual provides inelastically one unit of labour during her youth time and retires at the second period of her lifetime. Therefore L_t also measures the supply of labor.

B. Producers

There is a simple production sector for a man-made consumer good Y_t, where physical capital K_t, technology h_t and labour L_t are combined to produce output Y_t. We assume a constant returns to scale Cobb-Douglas production function for the economy:

$$Y_t = K_t^{\alpha} \, (h_t L_t)^{1-\alpha} \ , \ 0<\alpha<1 . \tag{2}$$

Setting $y_t=Y_t/L_t$ and $k_t=K_t/L_t$ we can rewrite the production process in its intensive form:

$$y_t = k_t^{\alpha} h_t^{1-\alpha} \tag{3}$$

We assume a simple form of learning-by-doing based on the endogenous growth models developed by Romer (1990) and Aghion and Howitt (1992), where human capital or technology h_t is a by-product of physical capital production. The rate of knowledge or technological accumulation depends directly on the rate of physical capital accumulation. We assume the following specification for the level of technology or knowledge:

$$h_t = k_t^{\pi}, \ 0<\pi<1 \tag{4}$$

Since each period covers about 30 years, we assume that the capital of the previous period fully depreciates, and we set the capital stock equal to the level of investment of the previous period,

$$k_t = i_{t-1}/(1+n). \tag{5}$$

Markets for labour and capital are competitive so that the interest rate and labour wage per labour unit are given by:

$$r_t = \alpha k_t^{\alpha-1} h_t^{1-\alpha} - 1, \text{ and} \tag{6}$$

$$w_t = (1-\alpha) k_t^{\alpha} h_t^{1-\alpha}, \tag{7}$$

respectively. Taking account of the endogenous channel for human capital (eq.(4)) the output, interest, and wage equations become:

$$y_t = k_t^{\alpha+(1-\alpha)\pi} \tag{8}$$

$$r_t = \alpha k_t^{(\alpha-1)(\pi-1)} - 1, \tag{9}$$

$$w_t = (1-\alpha) k_t^{\alpha+\pi(1-\alpha)}. \tag{10}$$

C. Consumers

Each generation maximises its lifetime utility derived from its two-period consumption scheme. Its utility function $U(c_t^t, c_{t+1}^t(1+n))$ only depends on consumption per capita in the two periods c_t^t and $c_{t+1}^t(1+n)$and is assumed to be logarithmic, which implies a unitary inter-temporal elasticity of consumption. The variable c_{t+1}^t denotes the consumption of the old in period t+1, divided by L_{t+1}, whereas c_t^t is defined as the consumption of the old in period t divided by L_t; the multiplication with (1+n) corrects for this change in unit of measurement.Thus:

$$U_t = \ln c_t^t + [1/(1+\rho)] \ln [c_{t+1}^t(1+n)], \tag{11}$$

where $\rho > -1$ is the pure rate of time preference. Higher values of ρ represent a larger preference for current compared to future consumption. The restriction $\rho > -1$ rules out a negative weight on second-period consumption. Notice that the utility function is differentiable, concave and strictly increasing in its arguments.

Each generation divides its labour income (wages) in the first period between its first period consumption and savings, s_t. These savings are used to finance their second period consumption.

$$c_t^t + s_t = w_t , \tag{12}$$

$$c_{t+1}^t = [(1+r_{t+1})/(1+n)]s_t . \tag{13}$$

where w_t, r_{t+1} , c_t^t and c_{t+1}^t indicate the first-period wage, the interest rate between the first and second-period, and the level of consumption per capita during her two lifetime periods. Notice that when writing variables in intensive form, we should correct for population growth. Over the two periods, the present value of an individual's consumption stream is equal to labour income:

$$c_t^t + c_{t+1}^t (1+n)/(1+r_{t+1}) = w_t , \tag{14}$$

Now, we extend the economy with a natural-resource base (e.g. oil reserves) that generates resource rents G_t, or g_t per person, at period t. For convenience of the analysis, these rents are assumed to be a proportion q of that period's total income Y_t. In the appendix, we show that results do not change much when resource rents are assumed independent of the income level Y_t. The distribution of resource rents over generations will determine its effect on savings. We distinguish two resource policies. First, resources are considered public property and the rents are used to pay for public expenditures such as social security. Second, resources are considered common property and the rents are equally distributed over all consumers. This paper focuses on the first resource policy, when resource rents are used for public expenditures. In the appendix, we briefly analyse the second case.

We assume that the resource rents are used for social security; i.e. in every period, resource rents are paid to the retired generation. The second-period budget constraint becomes:

$$c_{t+1}^t = [(1+r_{t+1})/(1+n)]s_t + qy_{t+1}. \tag{15}$$

The inter-temporal budget constraint adjusts to:

$$c_t^t + c_{t+1}^t (1+n)/(1+r_{t+1}) = w_t + qy_{t+1}(1+n)/(1+r_{t+1}). \tag{16}$$

Each generation maximises utility subject to the budget constraint. The first order conditions with respect to consumption provide us with the Euler equation for the inter-temporal consumption allocation:

$$c^{t}_{t+1} = c^{t}_{t}\ [(1+r_{t+1})/(1+n)(1+\rho)] \tag{17}$$

The distribution of consumption over time does not depend on resource-income or labour income. It only depends on the interest rate, population growth, and the pure rate of time preference.

Substitution of the Euler equation in the budget constraint (eq.(16)) gives consumption c^{t}_{t} as a function of the interest rate, the rate of time preference, population growth, and labour and resource income. Thus:

$$c^{t}_{t} = [(1+\rho)/(2+\rho)][(w_t + qy_{t+1}(1+n)/(1+r_{t+1})] \tag{18}$$

Savings, s_t, will be given by:

$$s_t = w_t - c^{t}_{t} = [1/(2+\rho)]\ w_t - [(1+n)(1+\rho)/(2+\rho)(1+r_{t+1})]\ qy_{t+1}. \tag{19}$$

The savings curve is upwards-sloping with respect to the interest rate. An increase in the interest rate lowers the net present value of the resource revenues and increases the need for savings. When substituting for y_t, r_t and w_t from equations (8), (9), and (10), the savings equation becomes:

$$s_t = [(1-\alpha)/(2+\rho)]\ k_t^{\alpha+\pi(1-\alpha)} - [(1+n)(1+\rho)/(2+\rho)\alpha]\ qk_{t+1} \tag{20}$$

D. Equilibrium

The commodity balance is given by:

$$c^{t-1}_{t} + c^{t}_{t} + i_t = (1+q)y_t, \tag{21}$$

where c^{t-1}_{t}, c^{t}_{t} and i_t stand for total consumption of the older and younger generation and total investment, respectively. Equation (21) indicates that total production inclusive of resource rents can be used for either consumption or investments. The value of consumption of the older generation is equal to the value of capital rents, αy_t, plus resource rents, $q y_t$. Thus, (15) can be restated as:

$$c_t^{t-1} = (\alpha + q) y_t \tag{22}$$

The remainder of the manufactured income $(1-\alpha)y_t$ is used by the younger generation to both consume and save. Thus, equation (12) becomes:

$$c_t^{t} + s_t = (1-\alpha) y_t \tag{23}$$

Equations (21)-(23) combined reveal the saving-investment balance:

$$i_t = s_t. \tag{24}$$

The savings-investment balance, together with the capital identity (5) and the savings equation (20), enables us to write the equilibrium as a recursive dynamic equation for k_t:

$$(1+n)k_{t+1} = [(1-\alpha)/(2+\rho)]\; k_t^{\alpha+\pi(1-\alpha)} - [(1+n)(1+\rho)/(2+\rho)\alpha] q k_{t+1} \tag{25}$$

Rearranging terms provides k_{t+1} as a function of k_t:

$$k_{t+1} = \psi(k_t) = \frac{\alpha(1-\alpha)}{(1+n)\left[(2+\rho)\alpha + (1+\rho)q\right]} k_t^{\alpha+\pi(1-\alpha)} \tag{26},$$

where $\psi' > 0$, $\psi'' < 0$, $\psi(0) = 0$, $\psi'(0) = \infty$, $\psi'(\infty) = 0$. This implies that the sequence k_t is convergent, and there is a unique non-trivial equilibrium level of capital per person denoted by k^*. We set $k_{t+1} = k_t$ in equation (26) in order to calculate the steady-state value of capital per capita. This provides us with:

$$k^* = \left[\frac{\alpha(1-\alpha)}{(2+\rho)(1+n)\alpha + (1+\rho)(1+n)q}\right]^{1/(1-\alpha)(1-\pi)} \tag{27}$$

Similarly, the steady-state value of man-made output per capita is given by:

$$y^{*} = \left[\frac{\alpha(1-\alpha)}{(2+\rho)(1+n)\alpha + (1+\rho)(1+n)q} \right]^{\frac{\alpha+\pi(1-\alpha)}{(1-\alpha)(1-\pi)}} \tag{28}$$

As the parameter q positively enters the denominator and the power coefficients are positive, it follows immediately from these equations that the capital stock and output are decreasing in the resource wealth parameter q, as stated in the next proposition.

Proposition 1. *An increase in the share q of resource rents in income results in a decrease in the steady-state levels of capital and output.*

The responsiveness of output to resource rents depends, to a large part, on the spill-over effects of capital on technology, π. From equation (28), we derive the relative increase of steady-state output y^{*} with respect to the resource share q, that is the semi-elasticity:

$$\frac{dy^{*}}{dq}\frac{1}{y^{*}} = -\frac{\alpha + \pi(1-\alpha)}{(1-\pi)(1-\alpha)} \frac{(1+\rho)}{(2+\rho)\alpha + (1+\rho)q} < 0 \tag{29}$$

In turn, taking the derivative of $(dy^{*}/dq)/y^{*}$ with respect to π, we find,

$$\frac{d\{(dy^{*}/dq)/y^{*}\}}{d\pi} < 0 \tag{30}$$

That is, a larger value for π intensifies the negative effect of resource revenues on the steady state levels of capital and man-made income. This result is stated in the next proposition.

Proposition 2. *A large responsiveness of technology to capital accumulation, as captured by π, enhances the negative impact of resource wealth on the steady-state levels of capital and man-made income per person.*

Furthermore, as we can see from (29), the impact of resource rents on long-term output is independent of population growth.

4. The Resource Curse

For the resource curse to materialize, the decrease in output should exceed the increase in income brought by the resource rents. In order to investigate the effect of resource rents on total income, $(1+q)y^*$, we compare an initial situation, denoted with subscript '0', in which there is a negligible proportion of man-made income $q_0 = 0$, with an alternative situation after a resource boom, denoted with subscript '1', when a resource base is discovered and revenues account for 10% of man-made income, $q_1 = 0.1$. The change in resource income is about one standard deviation of the share of natural capital in GDP used for Figure 1 in the introduction.

We use a set of parameter values to test the dependence of the resource curse thereon. In the baseline, we set the discount factor ρ equal to one, which implies that individuals value their first-period consumption twice as much their second period consumption. In terms of pure time preference, for periods of 30 years, this assumption is equivalent to a pure rate of time preference of 2.3 per cent annually. We assume an annual population growth rate of 1%, which is approximately equivalent to a rate of 35% for a period of thirty years.[5] We consider ranges for both parameters as the analysis proceeds. We allow the capital share α to vary between 0.30 and 0.70. The lower value is a reasonable approximation for a narrow concept of physical capital (see, e.g. Romer 1996 ch.3), while the latter parameter value is reasonable if we interpret capital k_t broadly to consist of human capital as well (e.g. see Mankiw, Romer and Weil 1992 and Romer

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[5] This is the population growth rate for Canada and the U.S. in 1999 (World Bank (WB), 2003).

1996 p.134).[6] In the first case, h_t can be thought of as a measure of both technological and educational improvements induced by capital investments. In the latter case, h_t stands for technological advancement rather than educational quality. Finally, we let the technological parameter π of the endogenous technological channel vary between 0 and 0.9. We evaluate the steady-state values for total income $(1+q)y^*$ before and after the resource boom, assuming the above parameter values. We calculate the steady-state income differential created by the resource exploitation. The resource curse is defined as the negative relative income change,

$$RC = 1 - \frac{y_1^*(1+q_0)}{y_0^*(1+q_1)} \tag{31}$$

The results are depicted in Figure 7. The vertical axis presents the steady-state income differential defined by (31). Positive values imply that resource exploitation results in a lower steady-state income per capita. The legend on the right hand side of the figure divides the figure area according to the magnitude of the resource curse.

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[6] Barro and Sala-I-Martin (1992 p.226) set α equal to 0.80 for an augmented measure of capital.

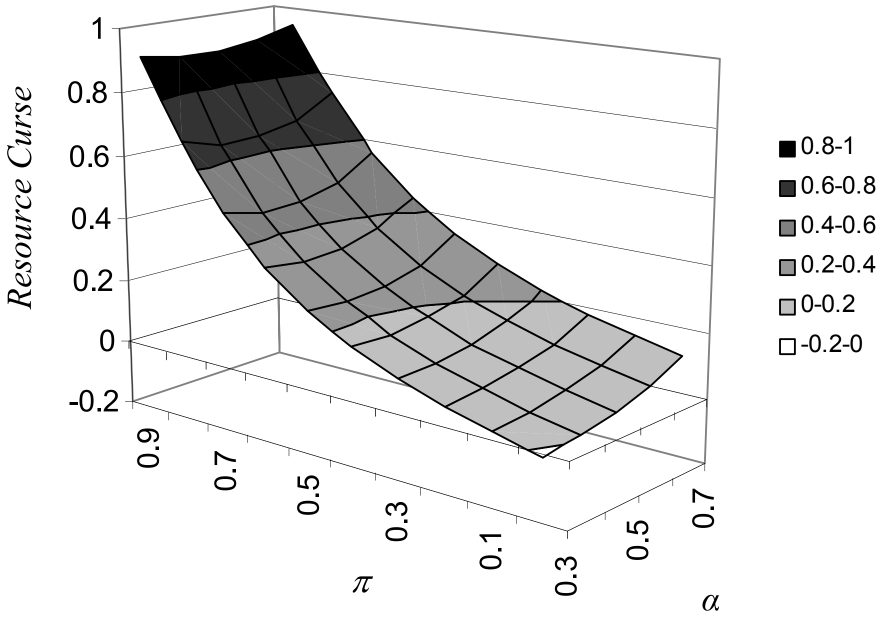

Figure 7. *Decrease in income following a 10% increase in resource revenues, dependence on the technology spillover (π) and the capital share (α).*

As Figure 7 depicts, for almost all parameter values, the steady-state income per capita decreases when resource rents enter the economy. Only for the lowest values of π and α, assuming a narrow concept of capital and the absence of capital spill-over effects, the economy benefits from the resource rents.

As the occurrence of a resource curse depends to a large extent on the value for the technological parameter π, we investigate which is a plausible range of values for it. Linearizing equation (20) around k^* shows that the economy converges to its balanced growth path at a rate $\alpha+\pi(1-\alpha)$:

$$k_{t+1} - k^* \simeq [\alpha+\pi(1-\alpha)](k_t - k^*). \tag{32}$$

Most econometric studies find an annual convergence speed in the range between 0.005 and 0.025, depending on the set of additional variables included and the time span under investigation (e.g. Gylfason 2001a p.856, Barro and Sala-I-Martin 1992 p.242, Kormendi and Meguire 1985 p.149, Mo 2000 p.72, Sachs and Warner 1995 p.24). For a 30-year period, we calculate that the factor $\alpha+\pi(1-\alpha)$ should lie in the range [0.47,0.85]. For α=0.3, this range is consistent with $\pi\in[0.24,0.79]$. For α=0.7, this range is consistent with $\pi\in[0.0,0.46]$. For all possible pairs (α,π) that produce a rate of convergence in the abovementioned range, the resource curse is minimal for the pair α=0.30, π=0.24, when it has the value 0.078. It is maximal for the pair α=0.3, π=0.79, when it has the value 0.657. The numerical calculations confirm the presence of a resource curse for the plausible range of parameters.

As a further check of our results, we also investigate how changes in the discount factor ρ affect the resource curse effect. An increased value of ρ enhances the resource curse, as can be calculated by equation (29):

$$\frac{\mathrm{d}\{(\mathrm{d}\,y^*/\mathrm{d}\,q)(1/y^*)\}}{\mathrm{d}\,\rho}=\frac{\alpha+\pi(1-\alpha)}{(1-\pi)(1-\alpha)}\frac{q\alpha}{(2+\rho)\alpha+(1+\rho)q}<0 \tag{33}$$

Barro and Sala-I-Martin (1992 p.226) assume a rate of pure time preference of 0.05 per year for their calibrations for the U.S. This approximates a parameter value ρ of 3.35 for a period of 30 years. One could claim that for a developing country this parameter value could be even higher, since consumers in the developing world tend to value current consumption more compared to uncertain future consumption. Kotlikoff and Summers (1981) assume a range of (0.02, 0.07) for their yearly discount factor for their calibrations, which implies that the parameter value ρ lies approximately in the (0.8, 6.6) range for a 30-year period. For our robustness check, we set the capital share α and the population growth rate n equal to 0.3 and 0.35, respectively, and let the technological parameter π vary as aforementioned. We allow the discount factor ρ to vary between 1 and 6, so that the values remain in the range adopted by Kotlikoff and Summers (1981). We calculate the resource curse effect and present our results in Figure *8*. For increased values of ρ, the resource curse becomes more acute. For instance, for a π value of 0.5, an increase of the discount rate from 1 to 6 amplifies the resource curse from 0.242 to 0.316.

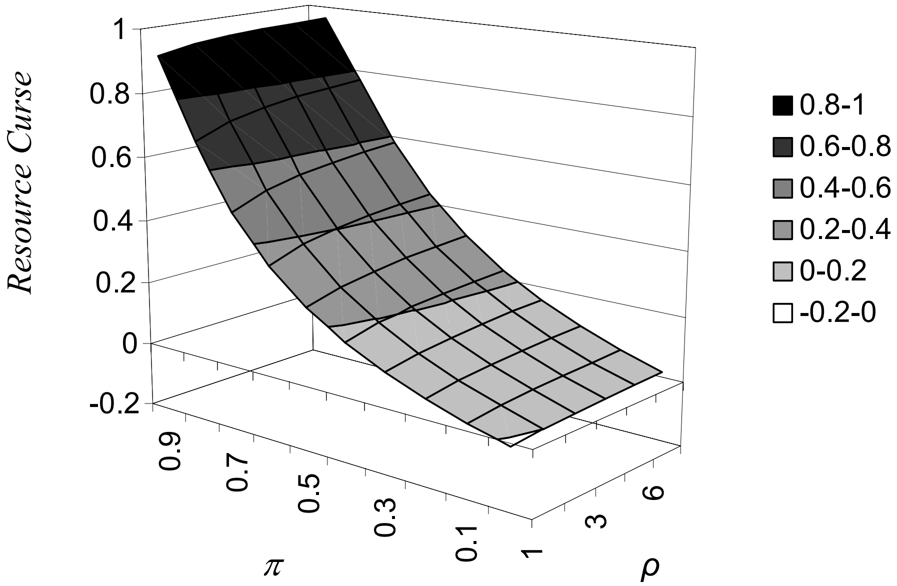

Figure 8. *Decrease in income following a 10% increase in resource on technology spillover (π) and the rate of time preference (ρ).*

Finally, we investigate whether our measurements in Figures 7 and *8* conform with empirical results found in the literature. Papyrakis and Gerlagh (2003) estimate the resource curse effect for revenues from mineral production, for the 1975-96 period, for a sample of 39 countries. They conclude that an increase in resource income of 10% decreases long-term income per capita by 60%, about half of which (30%) is due to a drop in investments in capital and education. The 30% decrease can be reproduced by our model for a set of parameters, e.g. for (α, π, ρ) = (0.3,0.5,4), or (0.5,0.6,1), or (0.7,0.4,1).

5. Conclusions

During the last three decades, a tendency has been observed of resource-abundant countries to grow at a relatively slow pace. In this paper, we have focused on a situation in which resource income decreases the incentive to save and invest. The focus has been motivated by earlier papers and by empirical data analysis.

We have developed a stylized model in which technology (or education) depends endogenously on the level of investment. In this setting, increasing resource rents lead to a decrease in investment that multiply over time, and long-term income substantially diminishes. For most of the reasonable parameter values, the effect of the decline in investment more than offsets the increase in income through resource revenues. Our analysis also reveals that the resource curse worsens with an increasing elasticity of output to capital and with a larger inter-temporal pure rate of time preference.

The mechanism described here provides an explanation to the resource-curse hypothesis that is an alternative to the mechanisms described in earlier literature. From the literature, we know that resource rich countries tend to suffer from currency overvaluations and loss of competitivess (Corden 1984), enhanced corruption and rent-seeking (Krueger 1974, Torvik 2002), bad-decision making (Sachs and Warner 1999b, Auty 2001), political instability (Collier and Hoeffler, 1998) low levels of educational quality (Gylfason 2001a), and low capital investment (Atkinson and Hamilton, 2003). Papyrakis and Gerlagh (2004) claim that the last-mentioned channel is most important in explaining the resource curse phenomenon. In this paper, we describe a mechanism to explain this transmission channel, focusing on the role of resource abundance in crowding-out savings by enhancing future income for which no savings are required. Assuming that labor productivity depends endogenously on the level of investment, the decrease in savings and investment leads to a decline in output that exceeds the increase in resource income, thus producing the resource curse. Such a mechanism can help to understand why resource-abundant countries are characterized by smaller shares of savings and investment in their GDP and lack behind in terms of long-run income.

APPENDIX

A. Exogenous versus endogenous resource rents

The dynamics of our analysis are much simplified by assuming a constant share of resource rents in man-made income over time, $G = qY$, for constant q. It can be the case, though, that resource revenues are an either increasing or decreasing proportion of man-made income y as time evolves. Figure 9 depicts the relationship between the share of primary exports in GDP in 1990 and 2001. Data are compiled from the United Nations (UN, 2003) Database of Human Development Indicators. As the figure shows, the share of primary exports remained fairly stable over a period of eleven years. For instance, the share of primary exports in GDP fell from 30 to 29% for Panama and rose from 42 to 44% for Kuwait.

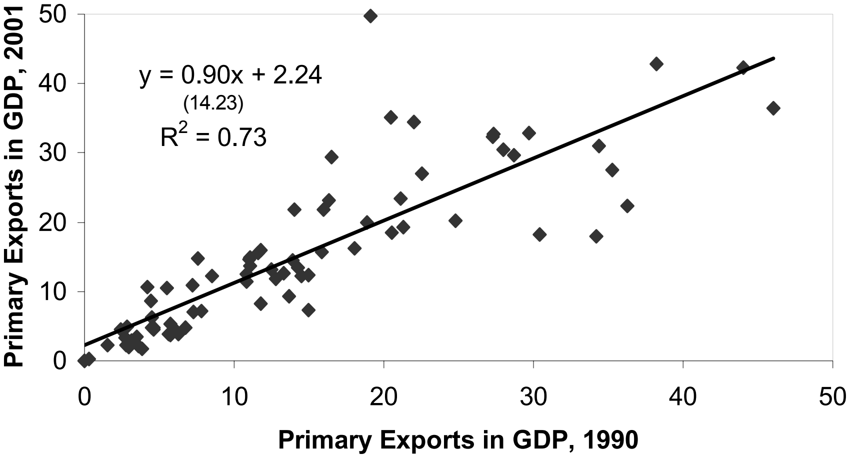

Figure 9. *Share of primary exports in GDP over time*

Still, the objective of this appendix is to show that our steady state model results carry over to an economy where total resource rents R are exogenous with an adjusting share in total income q, instead of the opposed assumption made in the main text. *Figure 10* is helpful in this respect; it depicts the relation between q, y^*, and g. It shows the steady state levels of man-made income y^*, resource income g, and total income $y^* + g = (1+q)y^*$, as functions of q. We adopt the following values for the capital share, α=0.4, the discount factor, ρ=2, the population growth rate, n=1 and the technological externality, π=0.5. The figure shows that, as q increases, the steady-state man-made income y^* decreases (Proposition 1). Furthermore, steady-state income per capita $y^*+g^*=(1+q)y^*$ strictly decreases in q. Resource rents g^* (equal to qy^*) increase initially, and then decrease after a certain value of q, that is, when the decrease in output y^* more than offsets the increase in q.

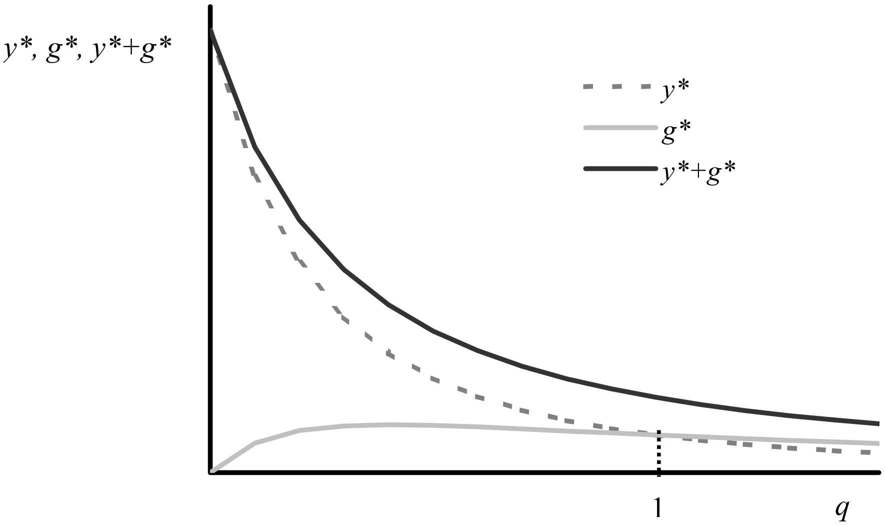

Figure 10. *Resource income g, man-made income y*, and total income y*+g*

Graph based on α=0.4, π=0.5, ρ=2, n=1.

Consider the case that a resource starts to be exploited and revenues R are constant and independent of other income sources y. The steady-state per capita income level y^* decreases due to the resource revenues, and as the economy shifts to the new equilibrium, the share of resource revenues in total income q will gradually increase over time.[7] Consequently, for fixed total resource revenues R, the resource curse will turn out worse when compared to a situation where q is constant.

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[7] We implicitly assume that an economy is initially on a steady-state point. The assumption is inessential to the argument.

B. The case of equal intergenerational distribution of resource rents

As an alternative scenario of distribution of the resource rents G_t, we assume that the rents are equally distributed between the young and the old generation. Since population increase at an exogenous growth rate n, this implies that $(1+n)/(2+n)$ share of the resource rents accrues to the younger generation and the rest $1/(2+n)$ to the older one. The commodity balance for the consumer good is the same as in equation (21). The older generation consumes in period t the resource rents $[1/(2+n)]G_t$ and the savings from period t–1, which is a share α of manufactured income. Thus, equation (22) becomes

$$c_t^{t-1} \;=\; (\alpha+q/(2+n))y_t \tag{34}$$

The remainder of manufactured income $(1–\alpha)y_t$ and resource rents $[(1+n)/(2+n)]G_t$ are used by the younger generation to both consume and save. Thus, equation (23) becomes

$$c_t^{t} + s_t =(1-\alpha+ q(1+n)/(2+n))y_t \tag{35}$$

Equations (21), (34) and (35) combined reveal that the saving-investment balance (24) is maintained. By considering the inter-temporal budget constraint for each generation, as in equation (12)-(19), we can adjust the savings equation (20), and reproduce the recursive dynamic equation for k_t as in (25):

$$\begin{aligned}(1+n)k_{t+1} \;=\; &[(1-\alpha)/(2+\rho)\ ) + (1+n)q/(2+\rho)(2+n)]k_t^{\alpha+\pi(1-\alpha)}\\ &-[(1+n)(1+\rho)/(2+\rho)(2+n)\alpha]qk_{t+1}\end{aligned} \tag{36}$$

We set $k_{t+1} = k_t$ in order to calculate the steady-state value of capital per capita. This provides us with the equivalent of (27):

$$k^* = \left[\frac{(1-\alpha)(2+n)\alpha+(1+n)\alpha q}{(1+n)(2+\rho)\alpha(2+n)+(1+\rho)(1+n)q}\right]^{1/(1-\alpha)(1-\pi)} \tag{37}$$

For $q=0$, the two equations (27) and (37) produce the same steady state capital stock k^*. Under the scenario of equal distribution of resource rents, however, resource revenues have smaller effect on the capital stock, $\mathrm{d}k^*/\mathrm{d}q$ has decreased. Thus, an equal distribution of resource rents is less harmful to investments than the social security scheme.

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(lix) This paper was presented at the ENGIME Workshop on “Mapping Diversity”, Leuven, May 16-17, 2002

(lx) This paper was presented at the EuroConference on “Auctions and Market Design: Theory, Evidence and Applications”, organised by the Fondazione Eni Enrico Mattei, Milan, September 26-28, 2002

(lxi) This paper was presented at the Eighth Meeting of the Coalition Theory Network organised by the GREQAM, Aix-en-Provence, France, January 24-25, 2003

(lxii) This paper was presented at the ENGIME Workshop on “Communication across Cultures in Multicultural Cities”, The Hague, November 7-8, 2002

(lxiii) This paper was presented at the ENGIME Workshop on “Social dynamics and conflicts in multicultural cities”, Milan, March 20-21, 2003

(lxiv) This paper was presented at the International Conference on “Theoretical Topics in Ecological Economics”, organised by the Abdus Salam International Centre for Theoretical Physics - ICTP, the Beijer International Institute of Ecological Economics, and Fondazione Eni Enrico Mattei – FEEM Trieste, February 10-21, 2003

(lxv) This paper was presented at the EuroConference on “Auctions and Market Design: Theory, Evidence and Applications” organised by Fondazione Eni Enrico Mattei and sponsored by the EU, Milan, September 25-27, 2003

(lxvi) This paper has been presented at the 4th BioEcon Workshop on “Economic Analysis of Policies for Biodiversity Conservation” organised on behalf of the BIOECON Network by Fondazione Eni Enrico Mattei, Venice International University (VIU) and University College London (UCL) , Venice, August 28-29, 2003

(lxvii) This paper has been presented at the international conference on “Tourism and Sustainable Economic Development – Macro and Micro Economic Issues” jointly organised by CRENoS (Università di Cagliari e Sassari, Italy) and Fondazione Eni Enrico Mattei, and supported by the World Bank, Sardinia, September 19-20, 2003

(lxviii) This paper was presented at the ENGIME Workshop on “Governance and Policies in Multicultural Cities”, Rome, June 5-6, 2003

(lxix) This paper was presented at the Fourth EEP Plenary Workshop and EEP Conference “The Future of Climate Policy”, Cagliari, Italy, 27-28 March 2003

(lxx) This paper was presented at the 9th Coalition Theory Workshop on "Collective Decisions and Institutional Design" organised by the Universitat Autònoma de Barcelona and held in Barcelona, Spain, January 30-31, 2004

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